THE IMPACT OF MULTICULTURAL PEDAGOGY IN SCIENCE EDUCATION ON THE ACHIEVEMENT, MOTIVATION, AND PERSPECTIVES OF CULTURAL MINORITY STUDENTS.

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PREFACE

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ABSTRACT

This paper explores the interaction between culture and science and the impact of various multicultural science education practices on student attitudes and achievement. The first chapter presents the epistemological arguments underlying support of and opposition to such practices and defines multicultural science education in the context of multicultural education and science education. The second chapter traces brief histories of both of the above mentioned fields and their coming together as multicultural science education within the past twenty five years. The third chapter presents a critical review of the literature that presented five main findings. First, this review corroborated the fact that there is an interaction between culture and science on many levels and that if a student's culture is substantially different from Western science culture a negative attitude toward science may result. Second, this review presented studies which illustrated that incorporation of student worldviews can have a positive impact on student attitudes and achievement in science. Third, a few studies indicated that it is also important to consider other factors in student science outcomes. Fourth, research suggesting the use of particular practices with African American students demonstrated that these strategies are beneficial for all students and may be misinterpreted as cultural preferences. Finally, this review gave examples of the usefulness of culturally specific practices from Haitian students in the science classroom. In conclusion, the research presents an accurate overview of the current work in the field. This work supports a generally positive outlook for multicultural science education practices, but the

research is not substantial enough or stringent enough to exercise these practices without care. There is much room for future research within this field, with particular attention to the selected research populations and to attempting to decipher the complexities of multicultural educational practices.

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CHAPTER ONE: INTRODUCTION

Introduction

This chapter frames the cultural epistemologies specific to the United States about what science is and how it should be taught. These epistemologies determine the degree to which students have equal opportunity in science. The multicultural perspective on education embraces diversity as a valuable resource in the classroom. Utilizing this resource has become increasingly critical as scientists now and in the future are faced with survival related problems that require many and innovative perspectives and ways of knowing to solve. It is important to reexamine our philosophy of science and the pedagogy that results from that philosophy so that students are not daunted by the tasks of the future.

Rationale

The general attitude in American history toward non-dominant cultures has been one of forced submission without inclusion, the dominant culture being that of the Anglo-Protestants. This attitude is present in terms used in cultural anthropology such as “the melting pot”. This term is commonly associated with the United States and suggests a country in which diverse groups shed their original belief systems and cultures to partake of the dominant host culture, at best partially amalgamated. In many ways the development of the school system in this country was consistent with and supportive of this theory of relations; the source of practices historically used to disregard, remove, and destroy the cultures of diverse peoples. Accordingly, Spring (2008) frames the history of

American schools within the concepts of cultural domination and ideological management.

Today the melting pot mentality continues to exist in many ways. A specific example is the educational philosophy behind government policies like *No Child Left Behind* which assumes that all students have the same capacity for, opportunities supporting achievement in, and interest in achieving on standardized tests (Spring, 2008). Such an assimilative perspective assumes that there is one best way to approach doing things and that the needs and interests of all people are the same. Western science, a subdivision of Western culture, connects strongly with this mentality. As such, this sort of outlook has continued to have a strong presence in science education while other disciplines have been more open to exploring and including other ways of viewing the world (Lee, 1999). Reports repeatedly demonstrate a characteristic exclusivity within the study of science through continuing achievement gaps between people in positions that are privileged and those that are not (Rodriguez, 1998). How educators choose to teach science becomes an issue of privilege and equity.

Responses to compounding of environmental issues that will need significant attention within the next century suggest that the utilization of the increasing diversity of students in our schools to increase the diversity of professionals and the variety of ideas in science is critical (AAAS, 1990, p *xiii*). Science reform documents, such as *Science for All Americans*, suggest that having scientists with diverse world views and culturally trained cognitive practices will be necessary for developing solutions to the problems that face the world (AAAS, 1990). As such, it becomes critical to determine just and equitable ways of facilitating the interaction between the culture of Western science and how we teach science in our classrooms to students with "multiple realities mediated by multiple cultural frames" (Hutchison, 2006). Science educators are currently witnessing a critical juncture in the examination of the relationship between science education and multicultural perspectives on learning.

Traditional Focus in Science Education

Science education in the United States teaches students to view science through Eurocentric and androcentric lenses (Barbar, 1995). The exploration scientists in a randomly selected high school biology text will likely demonstrate the history of science as being constructed by Caucasian males emphasizing the androcentric view point. Additionally, science classes emphasize the scientific method which promotes the Eurocentric view of how the natural world should be explored (Barbar, 1995). These perspectives and representations are prevalent internationally because curricula and text books from the United States tend to be well developed and thus are frequently exported (Cobern, 1998). Within science, educators and intellectuals feel particularly entitled to suggest that there is one right way of teaching the curriculum finding support in perspectives ranging from universalism to scientism. The professional and educational spheres regard science as a monolithic culture (Cobern, 1998).

History presents the traditional goals of science education as serving the needs of production and problem solving, with production being the more significant aspect (Hassard, 2005). To support this point one might note that the study of medicine has been an important aspect of science education in the United States since the introduction of the academy and that along with this endeavor came massive profits for pharmaceuticals companies and incomes for doctors while prevention plays a minor role in health care in this country (Adams, 2007). Another example is that the application of science to environmental issues through sustainability has only become prevalent in the American science classroom in the past ten years because it is now unavoidable (Carter, 2007). Past avoidance has been rooted in the fact that it takes money to make money and there has not been enough awareness about sustainability issues to make sustainability industry lucrative until recently. However, Carson's book *Silent Spring* brought concerns over the impact of society on the environment to America's attention in the 1950's. It would follow that the purpose of science education in the United States has often been to ensure enough incoming ranks so that scientists can fulfill largely economic and political purposes (Reiss, 1993).

The Nature of Science

Two general camps explore the nature of science; traditional perspectives which include universalism and objectivism, and progressive perspectives which view science as a cultural endeavor. Universalism claims that the physical world itself determines the nature of scientific practice (Stanley & Brickhouse, 1994). This perspective ignores the mediation of science by people and that fact that these people cannot disconnect from their identities involving their interests, gender, culture, ethnicity, religious association, sex, sexual orientation, and class. It adheres to objectivism, which assumes that following the scientific method allows science to be conducted in a non-biased way (Stanley & Brickhouse, 1994). Essentially, the camp considers the power of reality to be strong enough to overcome the perspectives that limit human insight and interpretation when the proper scientific tools are used.

The universalist position has two specific short comings. First, it does not force scientists to be critical of themselves, rather, just their work, which allows them a “God’s eye view of the world” (Stanley &Brickhouse, 1994, p. 392). Second, this perspective justifies the degradation of other culturally specific scientific practices. One example is the practice of midwifery. Once the White male voice of science dictated that it was safer to have babies under the care of a medical doctor, the practice of midwifery was cast in a negative light, despite research suggesting that midwifery always was the safer of the two choices (Stanley &Brickhouse, 1994).

Critics of the multicultural perspective suggest that the flaws of this view point are that classroom content focuses too much on the peripheries of science like technology, science history, and social studies (Reiss, 1993). Southerland (2000) suggests that multicultural education within science has unexpected down sides, including the limitation of student agency and potential through insufficient preparation for incorporation into our rigorous scientific institutions. Southerland (2000) believes that the power of science is an important characteristic and that the controversy over universalism and multiculturalism is representative of a search for balance between equity and quality.

Perspectives on Learning

Traditional science teaching functions largely on transmission models of teaching including lectures, factual memorization, and recipe based laboratory work (Gallagher, 1993). These models of teaching are consistent with behaviorist perspectives on learning. These perspectives, championed by Skinner (1971), suggest that the student is a blank slate to which information must be given and behavior must be controlled. Science seems a very suitable candidate for transmission based education as it has an extensive fact based body of knowledge, represented in multiple canonical content focused frameworks and benchmarks (Carter, 2007). In addition, exploration of process focused knowledge in science is often limited due to lack of time and funds.

Alternatively, social constructivist models of learning suggest that the student always comes into the learning environment knowing something, prior knowledge accumulated and organized through out their life, and that learning and science are heavily reliant on social interactions (Atwater, 1996). Consistent with this perspective are the philosophies of Piaget, Vygotsky, and Dewey. This model recognizes that students from different backgrounds will likely have different ideas about what is interesting and how things work. In this perspective it is impossible to separate the individual and their identity from the social interactions that help to shape them. Cobern (1998) takes the constructivist perspective and suggested that regardless of the nature of science, humans still learn based on their individual life experiences within the context of a larger culture and so there is no point in connecting debates about the nature of science to any debates about how to teach science. There is much evidence to suggest that our cultures have a rather large impact on how we practice science.

The African continent provides examples of both the influence of science on culture and the impact of culture in science. When the English brought Western scientific practices to some parts of Africa, agricultural practices were included. These practices were more large scale and ecologically damaging than the methodology of African families and villages. After the English left many families no longer knew how to provide for themselves, showing the potential impact of science on culture and that culturally specific scientific practices are in place for a reason and are worth preserving and teaching (Stanley & Brickhouse, 1994). There is also evidence to suggest the importance of a culture's nature in how its people practice science. For example in both Kenya and India, countries that had the Western science tradition transplanted to them by British colonialism, the practice of science took on culturally specific characteristics after emancipation. In Kenya authority, collective responsibility, and involvement in national development characterize the practice of science as opposed to the autonomy, individualism, and the quest for excellence which are more Western attributes. In India the practice of science takes place in highly hierarchically and bureaucratically organized institutions with paternalistic relations between seniors and juniors (Eisemon, 1982). These observations illustrate the major flaw of the universalist perspective, that people practice science and people can never be separated from their cultural background.

Additionally Poole (1998), Irzik (1998), and Ogawa (1998) all suggest that there are culturally relevant driving forces in the reasons why we choose to study science and the questions that we choose to ask. Some Judeo-Christian perspectives view science as important because it can help support the glorification of God (Poole, 1998). From an Islamic perspective science can help support Islamic scientific thought (Irzik, 1998). Some Japanese perspectives frame science as a practice in which the aesthetic and spiritual aspects of life are important in understanding nature (Ogawa, 1998).

Multicultural Science Education

Multicultural education is a complicated field with many perspectives on what multicultural education means and multiple terms representing these meanings. The essential component to any form of multicultural education is that it views diversity as a valuable resource. Grant and Sleeter (1999) described five types of multicultural education which essentially build on each other. The *teaching the exceptional and culturally different* model focuses on the students that are the minority and emphasizes remedial training for such students to the end that they can achieve in school and society. This model views education as an investment and is based on the human capital theory of education and society. Within this model educators can take either a deficit perspective which focuses on the individual or a difference orientation perspective which focuses on society.

The *human relations* model focuses on promoting tolerance and acceptance and feelings of unity in all people by exploring the development of prejudice within individuals and reducing the dissonance between our belief systems and the ways that we act. This model recommends educating about stereotypes, common ground, and contributions by minority groups. It also emphasizes the use of cooperative learning (Grant and Sleeter, 1999)

The *single group studies* model focuses on raising the status of minority groups via promoting structural equality. In this model, educators teach about group culture and social issues and work to promote a willingness for students to participate in change (Grant and Sleeter, 1999)

The *multicultural education* model focuses on promoting strong cultural identities, valuing of diversity, promotion of human rights, acceptance of various life choices, promotion of social justice, and the promotion of equal distribution of power among groups. This model stemmed from the civil rights movement, critical analysis of school texts, desegregation, and questioning of the deficit model. In practice, this model targets everyone, promotes cultural pluralism, includes the perspectives of other groups, promotes critical thinking, builds on student learning styles and adapts to their needs based on skill level, employs cooperative learning, and makes room for multiple cultures and languages. This model moves beyond the choices of assimilation and amalgamation and embraces diversity (Grant and Sleeter, 1999).

The final category of multicultural education is that which is *multicultural and social constructivist*. This model embodies everything that is part of the *multicultural model*. This differs from the model in that it aims to prepare students to work actively to create equality within social structures by organizing content around social issues, involving students in decision making, heavily involving parents, and paying attention to multicultural values promoted in the learning space. This model focuses on the importance of social relationships in the learning process and in the greater society and is consistent with the theories of constructivist philosophers like Piaget, Vygotsky, and Dewey (Grant and Sleeter, 1999).

The NSTA (2001) released a description of multicultural science education which is largely consistent with the *multicultural and social constructivist* model. It describes multicultural science education as embodying a learning environment in which all students feel capable of learning and doing science; a learning environment in which each student feels welcome and that they are functionally important to that community; and a learning environment in which the contributions to scientific knowledge from all cultures is appreciated. It does not explicitly capture the transformative aspect of the *multicultural and social constructivist model*.

This perspective suggests taking an integrative approach to diversity rather than an assimilative approach. It promotes cultural awareness; acceptance and appreciation of diversity; and the act of seeking understanding with ourselves and others. In the classroom the practices used to create this environment can be divided into an additive model which is short term and focuses on integrating cultural diversity into the classroom, and the culturally affirming model which has more long term implications and focuses on culturally syntonic tools, group discovery, eliminating cultural bias, and redefining science itself (Barbar, 1995).

This perspective has recently caught on in the field of science education but is still widely debated because of how ingrained the Western concept of science is in the Eurocentric and androcentric culture that practices it. Many government documents have presented frameworks for creating a science pedagogy equipped to teach all students fairly, however these documents, while wanting to provide equity of opportunity, are still centered on the Western ideal of what it means to do science (AAAS, 1990).

Definition of Terms

In order to proceed in an analysis of the research on the impact of multicultural methods in science education, the definitions of multicultural education, universalism, privilege, marginalized, minority and science must be stated.

Atwater and Riley (1993) define multicultural science education as “a construct, a process, and an educational reform movement with the goal of providing equitable opportunities for culturally diverse student populations to learn quality science in school” (p. 664). The breadth of this definition highlights the complexity of the multicultural education perspective.

Matthew (1994) defines the universalist perspective of science as “an intellectual activity whose truth finding goal is not, in principle, affected by national, class, racial or other differences: science transcends human differences…while aspects of culture do influence science, nevertheless cultural considerations do not determine the truth claims of science" (p. 182). This definition suggests that scientific truth can be found if these truths are based in the natural world, thus disconnecting the truths from the cultures of those practicing science.

Any discussions of privilege within this document are intended to address the issue from a systemic perspective. Privilege is the condition in which a person is likely to receive something of value simply because of the group you belong to while the opposite is true for other groups (Johnson, 2006). Since privilege is a social construct it infiltrates all aspects of our lives, with people favored by privilege often being aware of its implications.

The terms marginalized and minority are used to describe populations in this paper. Marginalized is intended to reflect oppression in which group of people are regarded as less important by a society or group of people. Minority is also used to describe the groups described as marginalized within this work. The authors intended use of minority reflects only to being fewer in numbers rather than presenting a reflection on worth.

Finally, within this paper, science is defined broadly as a way of learning about or modeling the natural world in a way that results in applications based n this knowledge. The words traditional or Western will be attached to science when the term is intended to represent a more linear, universalist, or fact based view of science.

Limitations

As multicultural education is concerned with the education of all diverse peoples, on any plane interacting with education, a limitation of this survey is the wide range of papers I have selected to analyze, which range in both the diversity present and the pedagogical tools used and questions asked. The complexity of this topic is also a limitation in that, despite this review being of a somewhat eclectic nature, there are many other perspectives that are not addressed that would be interesting to investigate. For example, low socioeconomic status is mentioned in a number of the studies presented in chapter three and seems to be a fairly critical factor in educational outcomes, but there is not room within this thesis to address it fully. Another example would be studies focusing on Asians and Asian Americans, who are an ethnic minority in the United States, share some cultural values with groups marginalized by science, but at the same time are stereotyped as being able to navigate the world of Western science education as well or better than Caucasian Americans. In addition, this paper focuses mainly on the students' culture and its incorporation into the science class through a sharing of their worldview or use of familiar practices. There are many other levels that could be addressed, such as the classroom culture, the teachers' culture, and the factors that prevent the implementation of multicultural strategies; none of which are addressed in this review.

Statement of Purpose

At the core of this issue are fundamental human rights. All students should have equal access to an education that prepares them for a life in which their basic needs are met. According to multicultural philosophy this involves but is not limited to- helping them to have opportunities for exploration and choice; getting to know each student as an individual and using that information to help guide pedagogy; learning about a variety of world views to help facilitate clear and productive communication in the classroom; helping students to develop the capacity to communicate effectively with people of any culture in order to become active members of society and to help prevent discrimination; finding ways to motivate students with regards to all aspects of their world; and giving students opportunities for success. It is important to explore whether this perspective does actually increase equity of opportunity when implemented in the science classroom. Therefore, as a concern critical to pedagogy in terms of the opportunities and equal treatment of individuals, and the worsening state of the world, it is important to determine what interactions exist between culture and science and what influence multicultural science education and other culturally sensitive practices have on achievement, motivation, and interests in the science education of culturally diverse students.

Summary

The teaching of science in the United States has historically been consistent with Eurocentric and androcentric perspectives on the nature of science and the history of science. Epistemologies like universalism and scientism have provided the scientific community with reason to be absolved of considering multicultural education. Much evidence suggests that culture is critical to the way that people practice science in terms of their purpose of study, the questions they ask, the methods they use, and the way that they organize their institutions. The science based problems that future generations will face call for new ways of thinking and new innovations and push for the reexamination of our values in terms of what we think science is and how we think it should be taught. The critical issue in exploring the issue of multicultural science education is the determination of whether or not incorporating multicultural perspectives and practices will make science more accessible and equitable to all students. In answering this question it is important to consider the historical context, including the evolution of ideas in science education, the evolution of the multicultural movement, and the nature of the intersection of these two paths. Chapter two will now explore these historical aspects.

CHAPTER TWO: A SHORT HISTORY OF RELEVANT FIELDS

Introduction

Chapter one presented a rationale for this review of the research in multicultural science education. The chapter introduced the epistemological roots of the argument around multicultural science education, specifically having to do with the nature of science as being either universal or a cultural construct. Chapter one also introduced suggested benefits of enriching the diversity within the scientific professional community. Multicultural science education was described in the context of multicultural education. Finally, limitations for this composition were discussed and the purpose of the paper described. The purpose of this work is to address how culture interacts with science and also to explore the impact of multicultural science practices on science achievement and attitudes for marginalized groups.

Chapter two will begin with an introduction to science as a cultural phenomena as supported by the scientific traditions of various cultures and the development of the idea of Western scientific methodology presenting a universal science. Following this introduction chapter two will discuss, as relevant to the educational system in the United States, short and interspersed histories of multicultural education and science education, and will conclude with a description of the surfacing of multicultural science education. These histories will discuss the roots, goals, and reforms within these fields.

Scientific Traditions around the World

Given the definition of science presented in chapter one, it becomes important to introduce a brief chronologically comparative history of scientific developments across various cultures. Particularly, a few African and Native American developments will be described here, though there are many other examples from other cultural heritages.

Though not the only African country to make discoveries and develop practices worth noting, Egypt stands out from other African countries in terms of its scientific history (Selin, 1993). An obvious example of their mathematical and astronomical knowledge is the construction of the pyramids, which are intricately designed and situated. Not so obvious are the Egyptian practices in medicine. Contraceptive practices date back to 1900 B.C. in Egypt, as evidenced by ancient papyrus records. Almost 4000 years later, materials used by the Egyptians for this purpose, such as acacia gum, have been validated as spermicidal. Additionally, Egyptians were one of the first cultures to practice surgery, specifically circumcision, dating back to approximately 2500 B.C. In addition to these technical advances, these people developed an ethical code for doctors and collected a wealth of knowledge related to astrology and the development of calendars. The history of their development of a calendar highlights their abilities at scientific processes such as careful observation and creative problem solving. The end result was a calendar of 12 thirty day months with 5 intercalary days each year to help account for the extra 5 hours in Earth's period of orbit around the sun. This calendar predated the Aztec calendar by

3000 years. They were also aware of the correlation between various astrological markers and the flooding of the Nile (Selin, 1993).

Notable Native American achievements are more interesting from biological and sustainable perspectives. One example is the construction of Anasazi buildings to make optimal use of solar energy. These buildings were semi-circular and faced the south, this way the sun would heat the inside of the dwellings while their closed side would provide protection against winds from the north. From an agricultural perspective, the Native Americans were aware of the relationship between organism characteristics and selection through breeding because they employed this knowledge to cultivate corn, beans, potatoes, and chocolate among other plants. Additionally they developed the technique of hilling, which was adopted by farmers of European ancestry in the colonial period and was used until the 1930s. Finally, intercropping was a common practice among tribes, a practice which is quite sustainable, productive, and more authentic (Selin, 1993).

Despite these accomplishments Westerners have considered Western science the only real science for a very long time. This perspective is rooted inductivist and empiricist ideologies that developed during the Enlightenment period. Such well known scientists as Bacon, Boyle, and Newton were supporters and developers of these ideologies. Additionally, the belief in the superiority of Western science is rooted in positivism which emerged later, an ideology developed by Auguste Comte in the mid nineteenth century (DeBoer, 1991). These perspectives have long allowed people from Western cultures to adopt and take credit from other cultures scientific pursuits (Selin, 1993).

Science Education before the Emergence of Multicultural Education

Hassard (2005) divided the history of science education in the United States into seven phases. These phases are: the roots of modern science education from pre-1900 to 1930; progressive education and science from 1930 to 1950; the golden age of science education from 1950 to 1970; text book controversies and back to basics from 1977 to 1983; a nation at risk during the 1980's; reform efforts in contrast with the golden age during the 1990's; and science for all and the new millennium. The first two of these phases will be discussed in this section. Following this section will be a brief survey of *The Emergence of Multicultural Education*, followed by a section on science education after this emergence which will include the third and fourth phases of science education history. The last three will be discussed under the subsection entitled *Multicultural Science Education*.

The Roots of Modern Science Education from Pre-1900 to 1930

One prominent theme in the history of science education is the use of said education for the oppression, discrimination, or misuse of minority groups. Science made its way into the curriculum of American schools around the turn of the 17th century with the formation of academies. The shift from traditional colonial educational ideology was made possible by the influx of ideas from Europe emerging from the scientific revolution (Spring, 2008). In these earlier years, figures such as Francis Bacon wrote many novels speaking praise of the study and methodology of science (Spring, 2008). When the idea that inquiry was a healthy past time quit being dangerous to enough people, science was introduced into schools though a specific focus on inquiry was not incorporated into science education until the mid 1900s. At the turn of the 18^{th} century science education was being employed conspicuously for the purposes of assimilation and gain. An example of this was when Thomas Jefferson issued an order to educate Native Americans in animal husbandry and agriculture. The logic was that if they were able to be civilized, or to master these skills, that they would require less land and that the land would then be available to Anglo Americans (Spring, 2008).

Around the turn of the 19^{th} century women found a particular use for science through the founding of home economics courses. The field of home economics was developed by women so that women could be liberated from their time consuming household obligations and could become consumers and have an opportunity for education instead (Spring, 2008). In some ways this was one of the first accepted pluralistic practices of science education in the United States, though it also served to re-enforce gender roles which later hindered the entrance and achievement of women in science. During the same time period, Americans found another way to get science into the classroom and that was through scientifically based intelligence testing, which perpetuated the acceptance of the Anglo and masculine standards for science education by “confirming” the inferiority of other races (Spring, 2008). Once again, the belief in science as an entity separate from humans led to the discrimination and oppression of various groups of people.

With regard to the history of the pedagogical aspects of science education during the roots period, the early functions of science education were largely to teach discipline, to teach facts and principles, to prepare students for college, and to gain access to science methodology. As scientists and educators began to think critically about science education around the turn of the century these goals began to expand, though these early goals in science education have remained highly influential to this day (Hassard, 2005). The National Education Association developed the first committee, comprised of scientists and teachers, to make recommendations for the organization and content of science education in 1895. After four years this committee recommended nature study for elementary students, and four lessons per week of science in grades nine through twelve, progressing from physical science to biology to physics to chemistry. The recommendations of this committee were consistent with the goals of science education mentioned above (Hassard, 2005).

At the time of these recommendations, two approaches to science education existed at the elementary level (Hassard, 2005). One, as recommended by the committee was nature study, which involved hands on exploration of nature intended to develop a sense of respect within the student. The practice of nature study peaked prior to 1910. The other was the elementary science movement lead by Jerrold Craig. This movement broadened the scope of science education at the elementary level to include physical science and also was responsible for the production of science text books, reducing the authentic nature of science learning and resulting in a more abstract science curriculum (Hassard, 2005). Over time secondary science changed very little with regard to the goals of science education, rather most changes at the secondary level involved content. At the turn of the century students had the option of taking astronomy, geology, botany, and zoology in addition to chemistry, physics, and biology. These courses were eventually removed from most school offerings and the organization of science education has not changed dramatically since. The creation of the junior high school did require accommodation, which was the shifting of general science from high school level to the junior high level.

Most of the early innovations in science teaching in the United States existed at the university level. Benjamin Silliman, Louis Agassiz, and Asa Gray are three examples of such innovators among university level scientists in the 1800s (Hassard, 2005). Silliman was a proponent of using visual aids and also developed Yale’s first chemistry lab. Agassiz employed Pestalozzi’s object lessons, discovery learning, and active involvement in teaching science. Gray encouraged his students to perceive science in a holistic manner and worked to reduce conflict between science and social values. At this point in time, the presence of inquiry in science education was completely dependent on the perspective of the teacher.

Progressive Education and Science from 1930 to 1950

Through the popularization of Dewey’s theories and practice and the Progressive Education Movement, school science moved from being a discipline and factually oriented process to acknowledging the importance of the scientific method, conceptual thinking, critical thinking, and project based learning (Hassard, 2005). *A Program for Teaching Science* published by the National Society for the Study of Education in 1932 was the first document to support the teaching of science methodology and the application of it in the classroom. The Progressive Education Association published *Science in General Education* in 1938 and it laid a heavy emphasis on the role of science in helping students to become critical thinkers. Throughout the 1930s and 1940s the importance of science education increased for its understood usefulness to the extent that the 1947 report by the Harvard Committee on General Education entitled *Science Education in American Schools* recommended that all students be required to take science subjects (Hassard, 2005). This period was characterized by the emergences of practices in science teaching that are consistent with multicultural science education, however at this point in time the cultural nature of the student was not a consideration in science education.

The Emergence of Multicultural Education

Historical Treatment of Ethnically Underrepresented Peoples

Multicultural Education has very different developmental histories across Westernized nations, and these histories are closely related to the way in which such nations became diverse. Early in American history, education primarily served the purpose of an Anglo protestant population in teaching reading so that citizens could obey the law and obey God. America has always been a mixed community, first of Native Americans, English, French, and Spanish. As the educational system developed and became more complex, America- the land of opportunity- simultaneously became subject to an influx of immigrants. America is characterized as an immigrant nation; however, as far as its race relations are concerned it can be characterized as a colonizing nation. This is with regards to the African slaves that were brought over not long after its inception, the Asian Americans in forced labor and concentration camps, and the Native Americans who were robbed before they knew it possible (Pusch, 1979). Given the diversity, debates arose about what the nature of the school system should be. In these early years of the American public school system figures like Noah Webster and Horace Mann promoted the school as a means of creating a new nationality and as such the Anglo-protestant roots of the school system remained (Spring, 2008). Into the early 1900s programs such as kindergarten, social centers, and playgrounds were developed in order to continue with the assimilation of ethnicities deemed acceptable (Spring, 2008, p. 232). Concerns about a national identity have been the root of much opposition to multicultural education through the 1900s.

The colonizing and subordinating nature of America's race relations has been engaged in an interaction with the concern over national solidarity for years and has resulted in two major waves of integration followed by segregation (Banks, 1993). In the first wave, during the colonial period, integration had mainly to do with various European nationalities. However, if Africans were educated they could be educated in integrated institutions. The Native American population was generally educated separately with the hopes of an attitudinal shift that would allow for them to be exploited or converted. Toward the 1800s a fear of mixing blood through social contact with people of African descent led to their segregation into separate schools and the three century long overt disregard of their educational needs (Spring, 2008). Similar practices of deculturalization, segregation, and exploitation occurred towards people of Mexican, Asian, and Puerto Ricans heritage as they came into the picture (Spring, 2008, p. 232-246).

The Intergroup and Ethnic Studies Educational Movements

In America, the treatment of African Americans specifically is directly linked to the arrival of multicultural education. Segregation of schools in the 1800s left students in under funded and under supplied schools that had a hard time maintaining teachers (Banks, 1993). African Americans suffered this treatment until the mid 1900s. The intergroup education movement was a first attempt at increasing the multicultural nature of schooling. The movement arose as a result of World War II in that there was a national shift in job opportunities to the north and west which resulted in the relocation of rural ethnic minorities and Whites. The result of this relocation was racial tension and some incidents that prompted the intergroup education movement (Banks, 1993). This movement was characterized by leadership from White scholars with the goal of reducing prejudice by creating cross cultural understanding. Unfortunately this movement was ineffective in creating a supportive school environment for oppressed peoples.

There is a rich history of scholarly literature from the African American community that supported this movement and the one that eventually seeded the field of multicultural education. Some of the influential authors included Alain Lock, Allison Davis, Woodson, and W.E.B DuBois. Additionally, during the intergroup education movement, a great deal of research was conducted which supported the use of democratic and multicultural practices to the end of helping students develop more accepting attitudes (Banks, 1993).

Along with the civil rights movement in the 1960s came the ethnic studies movement which existed throughout the 1960s and 1970s. The ethnic studies movement pushed for the teaching of black history and culture in schools (Banks, 1993). The goal of the movement was to support the development of a sense of empowerment; and of a pride for and connection with ones roots. This movement was characterized by leadership by people of color. Toward the late sixties various educational institutions began to oblige the wishes of the movement and created courses that focused on ethnic content. As other oppressed ethnic groups witnessed these developments they also requested the emergence of courses relevant to their histories and cultures; these groups included Mexican Americans, Native Americans, Asian Americans, and Puerto Ricans. As a result a vast amount of writing was done in the 1960s and 1970s related to the emergence of these studies, along with the reprinting of books from authors such as W.E.B. DuBois earlier in the 1900s. It was not until the 1980s and 1990s that there was a request for integration of such studies into general curricula as opposed to being treated as separate content.

The ethnic studies movement is considered the first phase in the development of multicultural education. Eventually it became apparent that while important, ethnic studies alone could not create the necessary change and the second phase in the development of multicultural education occurred. This phase was known as multiethnic education and it sought to increase educational equality in a structural way within schools. As other oppressed peoples witnessed these advances, they requested incorporation of content on their groups. This was the third phase in the development and is particularly relevant to women, people with disabilities, and people living in poverty. The final and current stage in the development is multifaceted and is attempting to address the interconnection between race, class, and gender characteristics through theory, research, and practice. Key players in these developments in multicultural education include Baker, Banks, Gay, and Grant. In addition, scholars that specialize in the history and culture of oppressed ethnic groups have also been pivotally important.

Science Education after the Emergence of Multicultural Education

The Golden Age of Science Education from 1950 to 1977

At the same time that struggles for multicultural perspectives in education began, science education took on a very new meaning. It was during the golden age of science education that the government took responsibility for the funding and restructuring of science curriculum. After World War II, as the country entered the cold war, and as it sought to annihilate communism, science became an incredibly important aspect of educational debates. There was a new recognition of the war faring power that could be found in science, an awareness of the scientific manpower necessary to be the most technologically advanced country in the world, and an awareness of the increasing rate of scientific discovery (Spring, 2008). The National Science Foundation (NSF) was created in 1950 primarily to deal with increasing the workforce available to scientific endeavor but also to deal with fears that science courses and science teachers were ineffective toward relieving science related concerns (Hassard, 2005). In the early years of the NSF, these problems were addressed through a series of institutes available to college and high school teachers. After seven years funding these institutes, the NSF considered cutbacks as a response to public scrutiny but never instigated them because the Soviets launched Sputnik I in late 1957.

Hassard (2005) asserted that the launch of Sputnik I was the historical event to have the most impact on the direction of science education in this country. As a response, over 117 million dollars was funneled into science education improvement projects over the next twenty years. The nature of these improvement projects significantly altered science education. The curricula were reformed by scientists, the design of the reform was based on the needs of the various scientific disciplines rather than the needs of the students, and the goals of science education became more distanced from social problems and more focused on content and how science is done.

Textbook Controversies and Back to Basics from 1977 to 1983

Changes in science education functioned under the impact of the Sputnik I launch until the mid seventies. At this point in time two controversies emerged. The first involved a rather large upheaval with regard to the presentation of evolution. A discussion of this aspect of the history of science education will be avoided here, though it continues till present time and is culturally relevant. The other controversy had to do with what is now known as the *Back to Basics* movement. This movement was related to the evolution issue is that was also a liberal versus conservative based conflict. In particular, one project from the NSF called *Man- A Course of Study*, came under intense scrutiny by John Conlan, a congressman from Arizona. Accusations against the material had to do with it promoting an elitist science that supported cultural relativism and imposed the liberal values of the scientific community onto the public (Hassard, 2005). Specifically, the material presented cultural practices of a particular group of people, such as cannibalism and abandonment of the elderly, as survival based actions in order to develop critical thinking skills about culture through comparison with animal behavior and other human cultural behaviors. As a result of this attack, the NSF's educational program was suspended and put under review. To reassert itself, the NSF conducted a number of studies supporting the positive impact on science acquisition resulting from their projects. These studies were refuted by Ronald Reagan and as a result most NSF funding was allocated to university research for a number of years (Hassard, 2005).

Multicultural Science Education: 1980s to Present Day

A Nation at Risk: the 1980s

In the United States, multicultural science education surfaced on the radar of science educators and researchers in the 1980s amidst many other science reform perspectives. These ideologies emerged as a result of two main factors:

first, Americans were scoring poorly, in comparison, to other nations on science performance tests. This related very strongly to a historical sense of science as functioning for the economic and military protection of the country. America's fear of being technologically surpassed by Japan in the 1980's was similar to America's dread at being surpassed by Russia in 1957. The second reason involved the scientific community's developing awareness of the global problems that science would play a key role in addressing in the near future, including environmental damage and limitations, though these issues would become more important after the turn of the millennium (Hassard, 2005).

The result of these two factors, what many perceived as a crisis, was an examination of the goals of science education and curricula, which had not changed dramatically since the 1960s (Hassard, 2005). The immediate impact was a movement to increase the number of science classes and lab time in that was required for graduation. These recommendations were a part of the *Five New Basics* curriculum which advocated the learning of science with regards to concepts, methodology, applications and relevance, and social and environmental implications. Another report released at the same time, *Educating Americans for the 21st Century*, put more emphasis on scientific skills and knowledge, pushing for a curriculum similar to that following *Sputnik I*. Various organizations, both public and private, produced over 300 reports and proposals addressing this perceived crisis during the 1980s (Hassard, 2005).

A Contrast with the Golden Age: the 1990s

In 1990, Oakes released a seminal study on the performance of girls and ethnic minorities in science. This work is a very comprehensive survey of the information that was available at the time. Krugly-Smolska (2007) suggested that this article brought the achievement gap issue to the forefront such that scholars supporting Western science as universal or supporting deficit models could no longer dismiss it. Three of the most important reports thus far, in terms of investigating these issues and reforming science curriculum, have been *Project 2061* released by the American Association for the Advancement of Science (www.project2061.org); *Scope, Sequence, and Coordination Project* released by the National Science Teachers Association (www.nsta.org); and the *National Science Education Standards* released by the National Research Council (www.nap.edu/readingroom/books/nses/html/). These documents all emphasized the importance of science education in social responsibility and literacy, and were all structured with support of constructivist theory, which is considered generally consistent with multicultural educational practices. These documents, in particular *Project 2061*, present the first clear emphasis on science reform that incorporates multicultural perspective in both its attitude toward students and its attitude toward teaching science. The presence of these perspectives in reform documents may also be a product of work done by Glen Aikenhead, a prominent scholar in the field of multicultural science education. In 1993 Aikenhead served as editor for an issue of *Science Education* which focused solely on the multicultural issue from a variety of perspectives. The invention of the internet in the 1990s has also supported science and science education in becoming more cross cultural endeavors (Hassard, 2005).

Science for All and the New Millennium

Of particular importance in *Project 2061*, is the emphasis on equity. *Blueprints for Reform*, a *Project 2061* release, stressed that equity is one of the largest problems for science reform and calls for an analysis of the American educational system to determine which characteristics are the largest barrier to equal opportunity for all students in science. It also called for a determination of how science classes can accomplish the teaching of a set of standards while making room to honor diversity. Additionally, it aims to explore whether this is possible given unequal distribution of resources. As mentioned earlier, global problems, particularly with regard to environmental issues have come front and center in reform structuring, pushing toward a position of multiculturalism in science education (Hassard, 2005).

Chapter Summary

Chapter two, presented brief histories of scientific traditions in other cultures, science education in the United States before the emergence of multicultural education, the emergence of multicultural education in the United States, science education after that emergence, and the development of multicultural science education. Despite the presence of ancient scientific traditions in many cultures around the globe, the Western scientific tradition has been the only one recognized as valid for over a century in the United States. This Western tradition emerged during the Scientific Revolution of the seventeenth and eighteenth centuries, with ideas such as positivism and empiricism. Science education in the United States was described in chapter two as originally being incorporated into the educational systems as a result of a belief in its ability to support mental discipline, though also serving as a tool for the oppression of marginalized peoples, from its earliest days to the present. Chapter two described that the emergence of multicultural education resulted primarily from the treatment of African Americans in this country, their prolonged segregation and lack of equity in educational opportunity. It also described major changes in science education as being a result of mainly political and economic needs, and briefly traced the emergence of multicultural science education in the past twenty years.

CHAPTER THREE: CRITICAL REVIEW OF CURRENT RESEARCH

Introduction

The previous chapter outlined the historical developments related to multicultural science education. The chapter surveyed scientific traditions from African and Native American cultures that preceded similar developments in Western nations. The chapter then proceeded to depict the history of science education in the Untied States, particularly with reference to its goals for mental discipline and economic and political issues; and its interactions with marginalized groups as an oppressive force. A brief presentation of the roots of multicultural education as directly emerging from the ethnic studies movement was included, and the discussion of science education after its rise to prominence continued. Chapter two finished with a discussion of multicultural science education, particularly in terms of important figures in the field and current reform documents.

Chapter three presents a critical review of the current body of research that explores the effects of culture on science education and the impact of multicultural education practices on these interactions. The interactions that exist between culture and science education are complicated and can be explored through numerous lenses. Themes focused on in chapter three will be presented in the following order a) the impact of culture on science education in structural and environmentally based ways and the impact of culture on science education in student based ways, b) the impact of multicultural practices related to ways of knowing, worldviews, and prior knowledge and other perspectives on this issue, and c) the impact of multicultural practices related to styles of learning and skills in urban primarily African American populations and with Haitian students and other examples.

Impact of Culture on Science Learning

The following group of studies addresses the ways in which culture and science interact with regard to learning science. These studies present a variety of routes through which culture can impact science learning. In the first subsection, the first two studies introduce the issue in terms of large cross national work demonstrating that there are significant differences in the aspects of science that we find important and the ways in which we are taught to learn science between cultures. The third and fourth studies provide examples of how culture in the classroom that is external to the student can impact the attitudes and achievement in science. The findings offered here are relevant to the implementation of multicultural science education on many levels. This chapter includes these four articles to indicate the scope of the interaction between culture and science.

Presence of Interactions between Culture and Science Education on Many Levels

Cogan, Wang, and Schmidt (2001) performed a quantitative study analyzing survey data about curricula collected in conjunction with the 1996 Third International Mathematics and Science Study (TIMSS). The research group sought to determine what culturally or nationally specific patterns arose in the data in terms of how science curriculum was organized. Forty one countries participated in the TIMSS, which focused on eighth grade students. Only thirty six of these countries provided complete information for the data discussed here. Teachers of these eighth graders provided the curricular information collected with the study.

Data collected which are considered in the study of Cogan, Wang, and Schmidt (2001) included information about content standards, textbooks, and classroom instruction. The teachers participated in a training on how to code their content standards and textbooks, and also completed a teacher questionnaire about their practices. The TIMSS framework addressed 79 science topics within earth, life, and physical science. Data for the study was organized in charts comparing these science topics across countries showing either percentage values or dichotomous values. The researchers addressed the content standards dichotomously as either including a topic (one) or not (zero). The researchers organized textbook data with regard to the portion of the textbook devoted to each of the 79 topics. Other data addressed which proportion of teachers in each country covered each topic in their classroom. The researchers examined all of the data by comparing values across countries, by comparing values across topics, and by closely examining irregularities.

The findings of this study inferred that differences in the presence of various topics across countries is potentially representative in cultural differences in how different populations address science education. The two topics that were consistently emphasized across nations were human biology and energy. Countries ranged from covering eight of the 79 framework topics in their content standards in Korea to covering all 79 in the United States and New Zealand. Textbook coverage ranged from nine topics in Denmark to 78 in the United States. Human biology and energy information constituted anywhere from zero percent to approximately 40 percent of the space in textbooks across nations. Extreme examples of variation included Japan, which devoted the most space per topic to all topics in its books, and Denmark, which on average devoted 97 percent of its text book space to one topic with a standard deviation of 31. The researchers conducted a median polish analysis which determined that there were at least 80 country by topic interactions evident with in the textbook data.

Classroom instruction data found that most teachers across countries intended to cover all topics arranged into 22 categories, however reported coverage by teachers indicated much more variability in what was actually taught. The greatest percent of teachers covered environmental issues, though this percentage was only 60 percent. Topic coverage time ranged from zero percent in one country to 60 percent in another for human biology. In the United States, high numbers of teachers covered each topic and high percentages of teaching of the least taught topic suggesting superficial coverage of curriculum.

This study is a survey and as such it is descriptive and presents no actual proof of the role of culture in the structuring of science education. The evidence that there are differences across countries is quite real; however surmising that culture is the responsible factor may be too large of an assumption. One strength of this research is the large sample size of the TIMS study which is documented in other publications. This survey contained two particular weaknesses, one of which the researchers pointed out. The first weakness involved the issue of how science courses are divided. Cogan, Wang, and Schmidt (2001) suggested that this is a caveat of the work in that particular teachers or particular countries may teach either earth, life, or physical science in the eighth grade year which would cause a great deal of variability that is not accounted for. The second weakness is the lack of statistical analysis. The paper clearly illustrated that there are differences but does not explore the root of those differences or whether those differences are significant. This descriptive study offered little information on the testing processes, instrumentation, selection, or mortality involved in the process.

Another cross national study suggested that culture may impact science education in terms of the learning strategies employed in the classroom. Chiu, Chow, and Mcbride-Chang (2007) presented a quantitative case study that examined correlations in the relationship between students' science achievement and their learning strategies, specifically memorization, elaboration, and metacognition, across 34 countries. This research also explored correlations between strategy use and cultural characteristics.

The research population included 88,401 15 year old students from 34 countries. To create a valid questionnaire the Organization for Economic Cooperation and Development (OECD) collected this population via stratified sampling, first at the school level, then at the student. OECD employed stratified sampling with the intent of amassing research populations representative of each national population. The researchers based stratification on socioeconomic and demographic data. The group that contributed to the development of the questionnaire included 35 students from each of 150 schools. The actual study involved 4500 students from each of the 34 countries.

The OECD assessed the 15 year old students' science literacy through a two hour exam format, and had them fill out 30 minute questionnaires in 2000. Educational experts at OECD created this assessment with pilot testing involving reliability and validity testing. The researchers also referred to OECD socioeconomic data and cultural value data collected by Hofstede in 2003. The researchers considered past achievement and other student belief and family related variables in their analysis. Chiu, Chow, and Mcbride-Chang (2007) took a number of precautions in their methodology, including using a testing format that avoided student fatigue by reducing the amount of work each student did and then using a Rasch model for analysis. The assessment included both multiple choice and written answer questions. The researchers analyzed the data using a hierarchical linear model and required that all statistical tests had an alpha level of .05.

Chiu, Chow, and Mcbride-Chang (2007) found that students' self reported learning strategies varied widely across countries; memorization ranged from 25 percent in Hungary to 81 percent in Italy, elaboration ranged from 41 percent in Iceland to 72 percent in Macedonia, and metacognition ranged from 38 percent in Norway to 67 percent in Macedonia. Approximately a quarter of the variance in the students' scores on the assessment occurred at the country level, however researchers did not link achievement to cultural values such as individualism or collectivism. Researchers reported that familial factors and self belief factors had similar linkages to achievement across countries; interestingly they found that learning strategy usage across countries differed in culturally relevant ways. The researchers found that students' self reported metacognition was positively linked to achievement scores in individualistic countries; while students' peer reported use of metacognition was positively linked to achievement scores in a number of collectivist oriented countries. These results were significant to $p < .05$ or less.

Chiu, Chow, and Mcbride-Chang (2007) presented a respectable study with a large sample size. The researchers presented a careful consideration of their methodology, instrument development, and statistical analysis. The researchers also attempted to control for past performance and gave attention to a large number of potential factors in student achievement in their hierarchical analysis. However, the study omitted information that would have been pertinent; for example, selection was discussed in terms of the population used to create and pilot questionnaires, but was not described for the research population. Additionally, this analysis considered no maturation issues as it explores data taken at one time point. The scope of the research presented difficulties as well with regard to the intent of this review, in that the research dealt with a large body of data. The researchers failed to describe specific statistical data for findings pertinent to this work, rather these findings seemed only noteworthy to the researchers.

Brok, Fisher, Rickards, and Bull (2006) examined California students perceptions of their classroom environment through hierarchical analysis of variance conducted on data collected from a questionnaire and demographic data. Data from this analysis suggested that a number of ethnicity specific cultural perceptions exist at the group level in the classroom.

The sample studied consisted of 655 eighth grade students from 26 science classrooms. The researchers selected the schools due to time constraints. Teachers at 11 of 18 invited schools indicated willingness to participate in the study. Participating teachers selected only one of their classes to be included in the study. The participating students represented a heterogeneous make up that is significantly different from the population of California in that it included fewer Hispanic students and more African American students. The study population included 20.7 percent Latino students, 15.9 percent African American, 0.9 percent Native American, 14.2 percent Asian American, 35 percent Caucasian American, and 13.4 percent ‘other’ students. The percentage of students that received lunch at these schools ranged from 20 to 80 percent. Class size averaged to 25.8.

Brok, Fisher, Rickards, and Bull (2006) employed the What is Happening in the Class (WIHIC) questionnaire. The questionnaire included 56 5-point Likert type items which relate to seven scales: student cohesiveness, teacher support, involvement, investigation, task orientation, cooperation, and equity. Data analysis involved multilevel analysis, specifically hierarchical analysis of variance using MLN for Windows. The researchers determined variance at the student, class, and school level in the analysis. The researchers performed analysis in two steps for each of the seven scales, first by calculating the variance at all three levels in an empty model and second by entering data for explanatory variables into the model. These variables included: gender, ethnic background, class size, percentage boys, percentage various ethnicities, socioeconomic background, and racial diversity at the school level. Researchers only reported significant values.

Brok, Fisher, Rickards, and Bull (2006) resolved that most of the variance in the findings existed at the student level. Gender was linked to four of the seven scales. Ethnicity analysis revealed interesting results in that ethnicity at the student level was not linked to any of the scales in itself, but class make up with regard to ethnicity was linked to various scales. For example the percentage of Latin American students in the class correlated negatively with the perceived cooperation as demonstrated by a regression coefficient of -1.07 and an effect size of $r = -.229$. The percentage of African American students related negatively with perceived cooperation and involvement as demonstrated by regression coefficients of -2.51 and -1.32 and effect sizes of -.212 and -.103 and respectively. The percentage of Native American students in the class correlated positively to perceptions of student cohesiveness as demonstrated by a regression coefficient of 2.46 and an r of .096. An additional finding showed that an increase in the number of ethnicities in the classroom significantly increased student perceptions of cohesiveness with a coefficient of .09 and an r of .096.

Strengths of this work included the moderate sample size, the attention paid to instrument validation and reliability, and the use of multilevel analysis to help account for non-random sampling. As with many other studies presented here, the researchers collected data at only one time point so issues around history, maturation, or mortality do not exist. Previously, no studies employed the WIHIC in California so the researchers deemed it necessary to perform a number of analyses on the instrument prior to use. The researchers calculated reliability coefficients determined to be sufficiently high for all scales used. One weakness, despite the use of multilevel analysis to evaluate the data, was the use of voluntary selection practices. This caveat decreased the generalizability of this work.

Khine and Fisher (2004) specifically addressed the culture of the teacher as an aspect of the learning environment that can impact science education in a quantitative comparative survey based study. The results of this study, which took place in Brunei, suggested that students in secondary science classes respond more positively to cultural characteristics of Western teachers than Asian teachers and that this is correlated with their attitudes in the classroom.

The participants of this study included 543 male and 645 female students from 54 science classes in ten secondary schools. All participating students attended grade eleven during the study and had an average age of 17.1. Forty seven teachers participated in this work, 24 of which were Asian and 23 of which were Caucasian. Classes averaged 27 students in size. The researchers selected Brunei as the location of their study because a continual shortage of science teachers resulted in a high presence of expatriated teachers from foreign countries, namely from the UK, Australia, and New Zealand.

Participating students completed the Questionnaire on Teacher Interaction (QTI) and the Test of Science Related Attitudes (TOSRA). Researchers also collected information on the cultural background of the teachers. Five part Likert type items on the QTI measured eight scales including leadership, helping/friendly, understanding, student responsibility/freedom, uncertain, dissatisfied, admonishing, and strict. Past research validated the QTI across various cultural contexts. Researchers provided no other information about the methodology of the study.

The findings from the study significant differences in students' perceptions of the teachers' interpersonal behavior correlated with the teachers' culture. Students perceived Western teachers as demonstrating more leadership (mean difference = -0.40, t-value = 10.76, $p < .001$), understanding (-0.47, 12.14, $p < .001$), and helping/friendly behaviors (-0.55, 13.16, $p < .001$). Students perceived Asian teachers as demonstrating more uncertainty (0.42, 10.76, $p < .001$), admonishing (0.42, 10.72, $p < .001$), and dissatisfied behaviors (0.41, 9.87, $p < .001$). Additionally, the researchers analyzed the TOSRA to find that students proclaimed to enjoy science classes with Western teachers more than with Asian teachers (-0.15, 4.06, $p < .001$). Students appeared not to have differences in their attitude toward science in classes with Asian versus Western teachers.

The lack of information presented on the instrumentation is the largest caveat with this paper. Additionally demographic data about the students is completely absent. Data collection is not discussed, however the presentation of the statistical analysis is clear enough to compensate. No history, maturation, selection practices, mortality information, testing information, or regression information is presented here. The study does work with a large sample size and also holds its statistical analysis to a high level of stringency. The data appear to support the results, but certainly much discussion could and should occur about the study itself and the reasons behind the findings.

Summary

The studies in this section suggested the scope of the interaction between culture and science education. Cogan, Wang, and Schmidt (2001) conducted a cross national study which suggested that science curricula are organized differently across cultures. Chiu, Chow, and Mcbride-Chang (2007) conducted a similar cross national study, however they focused on the use of learning strategies in science and found differences across countries potentially suggesting culturally relevant preferences. Brok, Fisher, Rickards, and Bull (2006) explored how the cultural climate of the classroom seemed to change in response to the classroom characteristics and found that varying presence by different ethnic groups was correlated with perceptions of classroom cooperation. Khine and Fisher (2004) investigated student responses to the cultural attitudes of their science teachers and proposed from their findings that the students preferred more Western characteristics such as being more helpful or understanding. Standing alone these studies failed to prove a particular interaction between culture and structural components of science education, and the work done by Cogan, Wang, and Schmidt (2001) contained critical caveats.

Student Based Interactions Between Culture and Science Education

The following seven studies, which focus on the impact of the students' culture on their attitude and achievement in science, are more critical to the intent of this review. Many of these studies are correlational, but they represent a broad range of cultural contexts. In the first study, James (2006) performed a correlational, survey-based quantitative study which examined how the self reported cultural identities of Native American students affected their attitudes toward science. The students in this study attended tribal college, urban high schools, or reservation high schools in Colorado, South Dakota, or Washington. A total of 196 Native American students participated in this work.

Each participant completed three inventories; the Oetting-Beauvis Cultural Identity Inventory (CII) which assigned each participant Anglo and Indian identity scores; the Kluckhohn Inventory which evaluated cultural values related to nature involving human nature, group structuring, the role of humans with regard to nature, and time orientation; and a Cognitions and Beliefs about Technology and Science Inventory (CABATS) which explored potential perspectives that one could maintain about science. A literature survey identified eight categories for the CABATS, though only four showed significant correlations in the results. These four categories included perceived social damage, perceived environmental damage, technology as spiritually and intellectually positive, and technology as heroic. The analysis of respondents' inventories involved examination of the bivariate correlations between the three instruments.

The research findings suggested that having a strong Native American identity is correlated with having negative perceptions about science and technology. Analysis accepted all values as significant at the $p < .05$ level and all correlations mentioned here were found to be significant. Strong Anglo identity was positively correlated with future time orientation and individualism. The researcher found a negative correlation between a strong sense of individualism and perceived social and environmental damage. Participants with a strong Indian identity demonstrated a positive correlation with a positive view of human nature and negative correlations with a sense of individualism and mastery over nature. Again, Indian identified participants correlated negatively with individualism which correlated negatively with perceived social and environmental damage. Indian identified participants correlated negatively with a sense of mastery which correlated positively with seeing technology as heroic, therefore suggesting that Indian identifiers are significantly less likely to see technology as heroic. Finally, Indian identification linked in a significant positive way with a positive view of human nature which was negatively linked with seeing technology as mentally or spiritually positive, demonstrating that these participants were unlikely to see science as positive in these ways.

The correlational data present in this study is statistically significant. The researcher presented information about the instruments in such a way to support their validity and managed to accumulate a research population of medium size. This research, interestingly, presented the cultural identification of Native American students on a spectrum. Research conducted in the future will need to compare Anglo identifying Native American correlations with data from Anglo identifying Caucasian students. Like many of the previous studies, James (2006) collected data at one time point and this work did not move to explore the interaction between the development of their identities and science. James described the research population but provided no information on selection or history with regard to this population.

In a similar fashion, Kesamang (2002) explored the correlations between socio-cultural background and science achievement and attitude in Botswana schools via the implementation of a one shot case study quantitative design. The researcher randomly selected eleven junior secondary schools within about 60 miles of the Botswana capital. The researcher employed a stratified random sampling technique to ensure that the sample represented urban and rural populations. The research sample consisted of 395 randomly selected 14 year old students, 179 males and 216 females.

Study participants completed three instruments: one for Setswana socio-cultural beliefs, one for attitudinal data, and one for science achievement. The socio-cultural instrument consisted of 20 Likert-type scale items. The researcher created the attitudinal instrument specifically to address the students likes and dislikes of science and their attitudes toward its relevance which also contained 20 Likert-type scale items. The Botswana primary school science syllabus provided the framework for the science achievement instrument. Science officers at the Ministry of Education helped to validate the instrument along with pilot testing which focused on the difficulty level of the questions. The final instrument consisted of 20 questions, five related to biological science and 15 related to physical science. The researcher administered the instruments in booklet form in the beginning of the school year to reduce the effects of schooling in science and also employed a previously developed change binomial model to help determine if achievement scores were better than guess-work scores. The researcher accumulated both quantitative and qualitative data from these instruments, involving the use of item analysis techniques, product-moment correlational analysis, and t-test analysis.

Kesamang (2002) determined that Setswana belief systems were likely to have a considerable impact on the students' worldviews. On the socio-cultural instrument, student responses ranged from 13.7 percent to 80 percent agreement with items supporting taboos or omens such as the idea that a widow should not walk through a herd of cattle to avoid aborting unborn calves. Responses also included neutral and negative answers from students. For 13 of the 20 items more students affirmed the statement than were neutral or disagreed. Kesamang compiled overwhelming evidence that these students have a positive view of science; all of the 12 'likes science' items on the science attitudes were supported by a majority of students ranging from 59 to 95 percent. Upon conducting Pearson's correctional analysis, the researcher determined a negative correlation between socio-cultural background and attitude toward science evidenced by a correlation coefficient of – .144. The researcher conducted t-test analysis of this value and found it to be significant at the $p < .05$ level. Kesamang conducted the same analysis to determine the correlation between socio-cultural background and science achievement and found a correlation coefficient of – .117 which was also significant at the $p < .05$ level.

Further, the researcher performed similar analysis to demonstrate a positive relationship between attitude and achievement, and also compared the attitudes and achievement of students with high socio-cultural background with those with low socio-cultural background. With regard to attitude the researcher determined a significant difference between the groups based on mean scores of 72.51 and 76.37 for the high and low groups, respectively. These values produced a t-score of 2.26 which was significant at $p < .05$. Students produced mean achievement scores of 9.44 and 8.44 for the low and high groups respectively, which resulted in a t-score of 2.42, significant to $p < .05$.

This research obtained a moderately sized participant body. Additionally, Kesamang (2002) reported clearly on the development and validation of the instrumentation, and on the testing and selection practices for the research group. The researcher structured the study a single event case study with analysis allowing for group comparison. The researcher did not account for history and could not consider issues of maturation. The study provided clear results with a thorough analysis of the data suggesting that while there is a general positive attitude toward science for these students in Botswana, having a stronger tie to cultural heritage of the Setswana people is negatively and significantly correlated to attitudes and achievement in science.

Medina-Jerez (2007, 2008) published two case studies. The first study involved an exploration of the conceptions held by middle and high school students in Colombia about nature.

For the first study Medina-Jerez (2007) worked only with 18 middle and high school students from a provincial school in Northeastern Colombia. Students' ages ranged from 13 to 17 and all students attended either chemistry or biology classes. Previous research suggested that this sample size was sufficient for the emergence of themes. The researcher interviewed each of the 18 students, using one focusing event and two elicitation devices to steer the conversation. The researcher practiced the interview material to ensure the best elicitation, and also gathered demographic data about the students through their schools and teachers. The focusing event and elicitation devices included a series of six images representing different aspects of nature combined with the question “how do you define nature or the natural world”, a series of preselected words the researcher asked the student to group into nature is and nature is not categories, and a series of statements about nature the students agreed or disagreed with.

The interview process revealed that the students were inclined to describe nature in ways that relate to their own world before relating nature to Western science. A number of students validated science as being able to describe nature; however, most students described nature in terms of its holiness, purity, or origin in God. Students presented a range of perspectives on nature from aesthetical, to environmental, to religious, to personal, to holistic. The research findings supported the significance of prior knowledge and the idea that these conceptions should be addressed in someway in the science classroom.

The researcher explained his considerations in development of the interview questions. However there is no evidence to suggest that student responses were in no way influenced by the design of these questions. The group of research participants satisfied the researchers’ needs in terms of sample size but is a very small group and the sampling conditions for these 18 individuals was not discussed. The researcher did not mention member checking or triangulation of the data collected through this work, though it may have occurred and did in the following study. The findings are dependable to the extent that the following study, conducted by the same researcher, corroborated them. Transferability and confirmability are not precisely supported within the context of this chapter.

The second study by Medina-Jerez (2008) involved an exploration of how students from different types of schools in Colombia perceived their home life, peers, and worldviews to interact with the Western science taught at school through a case study interpretive design.

Student participants in this study consisted of 250 students in middle and high school ranging from 11 to 17 with a majority of these students in grades eight, nine, and ten. The group included 74 females and 176 males. 57 students enrolled in chemistry and 193 in biology at the time of the study. Participants emerged from three different schools, two urban and one provincial. The researcher selected these schools based on the networks he had developed living in the area. The researcher characterized the urban schools as one religious school and one military school that exist within the country's capital and are divergent in every other way. The researcher noted the social climate in this urban center as being prone to violence and a difficult place for making a living. He characterized the provincial school as a Catholic school run by nuns.

Data collection involved the use of an Attitudes Toward School Science instrument (ATSS). It also involved having students answer two questionnaires and interviews with students for clarification of their questionnaires. The ATSS included 30 items that had an overall reliability coefficient of .75. The researcher recorded all interviews for codification and analysis in Spanish before translation. Participants reviewed interviews with the researcher. The questionnaires asked students to share opinions about evolution and creationism using excerpts from articles on the matter as elicitation devices. The researcher conducted interviews with students that mentioned the words scientist, nature, and science. The interviews reviewed student responses, asked a clarifying question, and confronted the students' claims in an increasingly specific pattern. Medina-Jerez (2008) executed narrative analysis of all data collected.

The findings from this study suggested that students at all three schools addressed science as a passage point but not generally related to their future, rather as something compartmentalized from their worlds. The researcher inferred that part of the problem may be in the teaching practices. Students at all schools described their science classes as very procedurally oriented and teacher centered. Teachers shared concerns about increasing scores on a national standardized test. In addressing the students' attitudes toward science, a majority of students indicated that they like their science classes, that they are concerned about the environment, shared a personal experience about nature, and made comments with regards to aesthetic aspects of nature on the questionnaire. Around 30 percent of the students reported negatively on science classes, commented on nature in an epistemological way, or referred to a relationship between religion and nature on their questionnaires. 15 to 30 percent of students indicated that science might play a role in their future. A few students indicated excitement about having taken up science in some way at home.

This second study conducted by Medina-Jerez (2008) is more structurally sound than the previous. He took a number of steps to ensure the credibility of the results which included a larger sample size and he employed member checking, referred to similar past work for structural advice, and performed reliability measures on his instruments. On the negative side, the number of boys skewed the study population in a way that quite probably had an impact on the results. For example, in the first study presented from Medina-Jerez, all of the girl respondents mentioned religion in their description of nature while not all boys did. The unequal number of girls within this sample may have altered conceptual presentations reported in this study. Additionally, the researchers sampling methods do not necessarily lend to the credibility of the work and other work within this chapter does not lend to the confirmability or transferability of the study.

Catsambis (1995), in exploring gender differences in science attitudes and achievement through a correlational survey based study, revealed interactions related to the students' ethnic background. Catsambis worked with data from a national survey called the National Educational Longitudinal Study 1988 (NELS-88). This sample consisted of 24,500 eighth grade students from 1052 schools. However, Catsambis focused only on public school students in the analysis, reducing the sample size to 19,000 students. Sample selection involved a two stage stratified sampling method that selected for a group representative of national averages. Study data also included surveys completed by the parents and teachers of these students in the same year.

Catsambis (1995) collected data from only one year of the NELS-88 to use in this analysis, so this work is not longitudinal. Students answered survey questions regarding demographic data, perceptions of self, educational experiences, and aspirations. Parents answered survey questions about the way and degree that the parents supported the students' educational efforts. Teachers answered questions with regard to teacher perception of student performance, information about their pedagogical practices, and information about their background. In conducting this analysis Catsambis focused on science achievement, science interests and attitudes, social background characteristics, and teacher perception of performance as variables. Analysis consisted of looking for statistical significance in the difference between mean scores of subgroups.

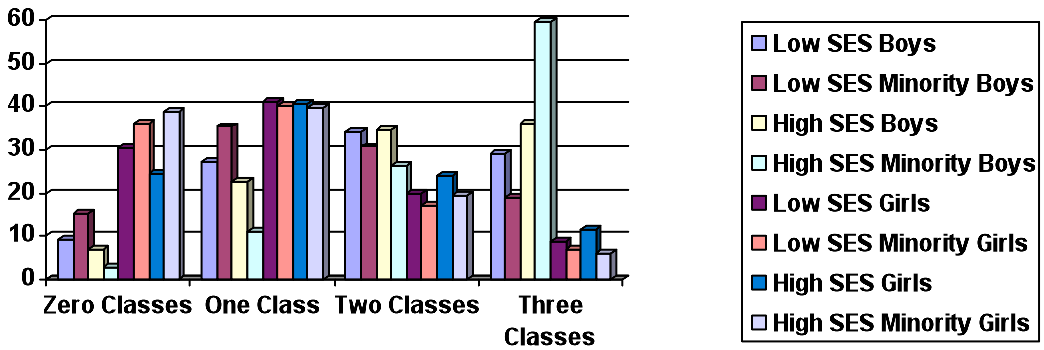
With regard to science achievement, this work demonstrated that African American and Latino students received lower grades and scored lower on tests than Caucasian students. African American and Latino students looked forward to science classes more than their Caucasian counterparts, with percentages of 71.4 and 66 for African American males and females and 71 and 62 for Latino males and females compared to 63.7 and 55.7 for their Caucasian classmates. However, with the exception of the African American females, the Caucasian students were less afraid to ask questions in science class as demonstrated by 12.4 and 14.9 percent agreement for males and females compared to 17.8 and 14.5 respectively, for African American students and 21.1 and 21.5 respectively, for Latino students. African American and Latino students also aspired less for careers in science as illustrated by 8.5 and 3.4 percent aspiring among Caucasian males and females respectively, compared to 5.3 and 2.4 percent for African American students and 6.3 and 2.5 percent for Latino students.

Similar to other studies in this section, Catsambis (1995) arranged this work as a comparison of data from one point in time, and as stated before the experimental setup is not particularly strong. The large sample size constituted the one strength of this study. Assuming that the researcher pulled random samples from each subgroup in the stratified sampling, this process may also be a strength, especially considering the sample size. Otherwise, Catsambis included little information about the instruments, the testing procedures, the history of participants, the data analysis, and the sampling procedures. The researcher neglected to carry out statistical analysis between ethnic groups. Statistical significance was determined for differences between gender groups and in comparison it seems possible that the differences between ethnic groups could be significant. Catsambis also neglected to analyze and discuss the impact of socioeconomic status though she suggested its importance and collected data on it. It is also important to note that this work is quite old, with the survey data being collected in 1988.

In a large-scale longitudinal quantitative study on the interactions between gender, social class, and ethnicity in stratification and school success, Dekkers, Bosker, and Driessen (2000) displayed that interaction between social background characteristics is not always negatively related to school success. Also the researchers illustrated that disparities in science choice patterns are not fully developed by the age of 12.

The research body investigated in this study consisted of roughly ten percent of the secondary students in the Netherlands at the time or 18,391 students from 381 schools. Researchers conducted a two stage sampling process to collect this research body. The researchers analyzed data for the VOCL study that started with the participants in 1989 and collected data on attainment with regard to number of science classes chosen in the participants 1995 school year. For students that left the study researchers estimated attainment based on past achievement scores. The study determined achievement based on the results from a series of IQ tests and CITO tests. The analysis used gender, socioeconomic status, and ethnic status as variables for organizing patterns of inequality.

The research results suggested that choice of taking science classes was influenced in complex ways by socioeconomic status, sex, and ethnicity. For example, ethnic minority girls professed taking fewer science classes than any other group, regardless of high or low socioeconomic status. Ethnic minority boys, on the other hand, demonstrated a strong susceptibility to decreased success due to low socioeconomic status. Low socioeconomic status ethnic minority boys had the lowest enrollment of all boys, though not as low as ethnic minority girls, while high socioeconomic boys had the highest enrollment of all groupings. Overall, the strongest patters can be seen across gender. The patterns found in this data are illustrated by percentage participation in the following graph:



This study is different from other studies explored in this section in that it does not directly address student attitude toward science. This study obtained a large sample size and did thorough analyses of the data. However, the structure of the research design weakened the evidence because of its descriptive nature. The research suggested, as evidenced by percentages of students enrolling in science courses and supported by other research in this section, that culturally relevant factors such as poverty or ethnicity can impact the students' interest in science. The researchers presented no statistical analysis of the results. As with other studies in this section, the researchers accounted for few important experimental factors that would support credibility due to the set up of the design.

The last research article included in this sub-section is similar to the previous but presented quite different findings. Research conducted in the Netherlands by Langen, Rekers-Mombarg, and Dekkers (2006) addressed whether or not group differences exist in selection of math and science courses. The research group addressed this question via quantitative analysis of data collected throughout the high school careers of the research participants.

Participants in this study included students that began high school in 1993 and completed their exams for senior secondary general education or preuniversity education no later than 2000. In total this included 1299 students from 63 schools pursuing a senior secondary general education and 987 students from 55 schools pursuing a preuniversity education (total N = 2285). Forty five percent of the potential sample failed to complete the required math test in time, so the research analyzed the research group in comparison with the group that left the study for similarity and found the research group to be different in that it included slightly more non-minorities and scored one point higher on IQ tests.

The methodology included annual collection of school type and year in school information. The first and third years involved math, language, and IQ testing and completion of questionnaires by students, parents, and principals. In the fifth year, researchers initiated data collection with regard to subject choice and achievement data. After data collection, Langen, Rekers-Mombarg, and Dekkers (2006) selected variables that would be considered in the analysis. The researchers identified 40 potential explanatory variables from the questionnaires collected in the first and third years of the study, and organized the variables into the following categories: group characteristics; capacities and achievement; other student characteristics; family characteristics; school context and organization;

and school characteristics with respect to subject choice. The researchers analyzed the data for the senior secondary and preuniversity students separately as preuniversity students attend an extra year. Multi-level statistical analysis of the data involved Spearman correlation analysis and Chi-square tests. The researchers also attempted to take past achievement into account in their analysis.

Research findings suggested that ethnicity is significantly related to number of science courses taken for the preuniversity sample ($p < .05$), and the findings presented no data for ethnicity in the senior secondary population. More specifically, the researchers explored the interaction between sex, ethnicity, and level of parental education and found that for boys there were no noticeable differences between the percentages that chose science classes for any category. Girls however, demonstrated a distinctive pattern where minority girls with low parental education chose to take substantially more science classes compared to non minority girl (47.1 , 15.8, 18.9, and 18.2 percent for ethnic minorities in zero, one, two or three courses respectively compared to 83.8, 7.0, 5.5, and 3.7 percent for non-minorities). Additionally, non-minority girls with high parental education took more science classes than ethnic minorities with high parental education (37.6, 15.8, 21.9, and 24.8 percent for non-minorities taking zero, one, two, or three courses respectively compared to 64.0, 13.2, 12.8, and 10.0 percent). This work also indicated a number of other important variables in student decision making in science such as parental level of aspiration, sex, and urbanization. Chapter four of this text will include a discussion on the presence of such variables in these studies.

This work inferred that group specific choices do existent and appear to be related to educational disadvantage within the study population. On the positive side, the research worked with a large sample size, was longitudinal in scope, and attempted to account for history in the analysis of its data. However, the researchers presented a number of aspects of the study in an unclear fashion, perhaps because it was previously released in other places but this is never clearly stated. Langen, Rekers-Mombarg, and Dekkers (2006) employed multiple means of statistical analysis and presented values without specifically stating what the values represented or where they came from. Additionally, the researchers presentation of the instrumentation, testing, and selection were virtually absent, as was a thorough description of the research population. These insufficiencies prevented the complete interpretation of the results and undermine the validity of the work though it is quite comprehensive.

Summary

The majority of the studies in this section illustrated in diverse populations, that the culture of the student can interact with their attitude and achievement in science, particularly in a negative way if the student’s culture is different from the culture of Western science. Almost all of the studies presented were correlational, and unfortunately a number of them do not compare between groups that are marginalized in science education and groups that are not, rather they look at a spectrum of cultural perspectives within a marginalized group, such as was done in the work of James (2006) with a native American population and Kesamang (2002) with a Setswana population. Medina-Jerez (2007, 2008) demonstrated a prevalent connection between religious perspectives and nature in student in Colombia. Catsambis (1995) conducted a large survey in the United States which suggested cultural differences in science attitudes among girls. In the Netherlands, Dekkers, Bosker, and Driessen (2000) proposed complex interactions between sex, culture, and socioeconomic status and science achievement. In another study in the Netherlands, Langen, Rekers-Mombarg, and Dekkers (2006) suggested complex interactions between ethnicity, sex, and socioeconomic status in relation to the choice to take science courses. All studies in this section supported that culture may be a relevant factor in the formation of attitudes about science and achievement in science. Unfortunately the correlational nature of these works does not suggest a mechanism for the interaction and does not act as proof.

Impact of Multicultural Science Education Practices on Achievement and Attitude

The first six papers in this section report on the impact of multicultural practices that include the incorporation of indigenous knowledge or allowance for students' prior culture related conceptions on achievement and attitudes in science education.

Impact with Regard to Practices Involving Worldviews, Ways of Knowing, and Prior Knowledge

An early study, by Jegede and Okebukola (1991), collaborators that produced an abundance of work with concern to the worldview of African students and their science experiences, involved a pretest/posttest experiment aimed to answer whether discussion of socio-cultural topics related to science topics improved students' attitudes toward learning science.

This research recruited 600 grade ten students from 15 secondary schools in Nigeria. The sample included 442 boys and 158 girls. Within each of the 15 schools, the researchers selected two classrooms by random sampling and assigned the class to experimental or control status. Altogether the researchers sorted 300 participants to each experimental group.

The design of this experiment involved assignment of classes to control and experimental groups followed by the incorporation of socio-cultural issues into science lessons for the experimental groups. Teachers of classrooms that participated in this work spent two weeks with the researchers becoming familiar with the instruments, learning the theoretical framework of the study, and practicing lessons. Study consisted of mammalian reproduction during this six week period. For students in the experimental group this included discussion of topics such as circumcision of the mother, mating in the daytime producing albinos, and habits of the pregnant woman such as not sweeping at night. In addition to the testing discussed below, the researchers conducted interviews with 18 students that aimed at eliciting information about attitude change with regard to the instruction in their science class.

This pretest/posttest design employed the Socio-Cultural Environment Scale (SCES) and the Biology Achievement Test (BAT) for data collection. The researchers developed the SCES and had it validated with the help of a number of science educators, anthropologists, and teachers. The instrument contained 30 three point answering system items related to five scales: authoritarianism, goal structure, African worldview, societal expectations, and sacredness of science. This instrument produced a reliability coefficient of 0.88. The BAT consisted of 50 multiple choice items and had a reliability coefficient of 0.79. The researchers administered posttest six weeks after the conclusion of the treatment. Testing time took approximately 30 minutes for each instrument.

The research findings demonstrated that the experimental student group had significantly greater positive views of their experience than the control group did represented by mean score values of 45.72 and 34.34, a t-value of 9.25, and $p < .001$. Additionally the experimental group achieved significantly higher science scores than the control group with mean scores of 29 and 23.0, a t-value of 7, and $p < .001$. Findings from the interview process presented that students felt more freedom to give their opinions, felt a large degree of enjoyment of the lesson, felt assured in their understanding, and felt that the discussions connected to what they learned at home from their parents.

Jegede and Okebukola (1991) used an experimentally sound research design, a pretest/posttest design with a control group, for this work. This structure supported the validity of the results. In addition, the researchers took care in providing all cooperating teachers with specific training since the research involved the implementation of lessons. The selection processes employed in this work was questionable as it was a mixture of random and volunteer methodology and produced a student sample highly skewed toward the experience of boys. A more thorough presentation on the instrumentation is wanting. Additionally, the researchers produced this work a long time ago, but it is included as it is one of the first of its kind in the field of multicultural science education.

In a second study, Herbert (2004) explored answers students would give on a teacher made test after participating in a unit involving the incorporation of traditional beliefs with Western science. This work occurred in Trinidad and Tobago and is a qualitative work, specifically two case studies.

Participants in this study arose from two different schools, Parkview Secondary and Seablast Secondary. The first school maintained an entirely female student body, all between the ages of 12 and 16. The researcher characterized these students as being typical of those entering Parkview Secondary in that they placed with in the top twenty percent of students taking entrance exams that year, were of various socioeconomic groupings, and exhibited varying but positive interest in science. The second case study was with students that attended Seablast Secondary, a rural school, with student ages ranging from 13 to 17. The researcher did not characterize this school as co-ed or single sex. The researcher suggested that entrance exam scores for these students were below those of the Parkview students.

In this case, the researcher used the case at Parkview to inform her work at Seablast. At Parkview the participants attended seven lessons about the common cold that incorporated culturally accepted explanations, like a change in temperature causing the cold, as comparisons for germ theory. Students completed a summative test at the end of this case, in which assessment items included personalized or scientific cues, for example ‘you’ or ‘operational definition’ might be included into the questions. The tests were coded and categorized such that they could be adapted for the second case at Seablast. For the case at Seablast the researcher reduced the number of lessons to five, and simplified the language of the assessment instrument. Additionally the cues presented in the items on this instrument were made more deliberate and the instrument was administered as a pretest as well.

The findings from the first case at Parkview exposed a pattern of responses consistent with the pattern of cues in the assessment items, that is, the students were less likely to use Western science terminology when asked a question in a colloquial manner, and were likely to use this terminology when such terminology was included in the question. For example, in one set of questions with the first part using scientific language and the second not using it, 57 percent of students used similar language in response to the first question, while only 32 percent used scientific terminology in response to the second. In another example the percentage of students that used scientific terminology in response to a question with such cues rose to 90 percent. Additionally, the researcher noted that students’ scientific explanations were at varying levels of congruence with accepted scientific explanations. The researcher suggested that this pattern of response was indicative of parallel collateral learning. The findings from Seablast corroborated the findings from Parkview and explored more in-depth the processes of collateral learning that happened through student responses. In some cases students maintained misconceptions and complicated them with new information, in others students maintained prior knowledge but presented answers in a new frame of reference, for example the pretest described the properties of an item and on the posttest described the properties in terms of a relationship.

From a Piagetian perspective, the findings of this research are quite logical. However, Herbert (2004) failed to present a number of relevant pieces of information that would be necessary for proving confirmability. The researcher neglected to describe the sample sizes, the characterization of the population at the second school, the nature of the lessons and the way in which the cultural comparison was presented to the class, the process of selection, the coding strategy that was developed, and the themes that emerged. The author did not mention the use of member-checking or triangulation in the analysis of the results. As such, while seemingly quite logical, this study is not necessarily trustworthy and it appears that the characteristics of the questions on the tests were directive for the students in a way that is worth considering as a potential caveat.

In an action research study, Gibson and Puniwai (2006) developed and assessed a program incorporating native Hawaiian knowledge into an Earth science program. The researchers sought to determine if this program was successful in terms of students' perspectives on their development of skills, their learning, and their feelings with regard to the inclusion of indigenous knowledge. Student responses to the program were generally positive.

The course participants included twelve students of native Hawaiian ancestry, ranging ages 13 to 15. This group contained 8 girls and 4 boys, all without experience in earth sciences. The students embodied a wide range of experience with regard to native Hawaiian knowledge, with two students attending schools that focus on incorporating the indigenous knowledge into their curriculum and others knowing nothing.

The researchers designed this course to last two weeks and focus on earth systems science through the use of Hawaiian indigenous knowledge and the incorporation of geospatial technology such as global positioning systems. The integration of indigenous knowledge involved cooperation with a native caretaker of the land. This caretaker served to guide students during field based learning experiences and also taught the students Hawaiian chants; information about Hawaiian culture and traditional resource usage; and information about ecological topics. Throughout the course students considered how the information provided by the caretaker is connected to geoscience topics, creating a more holistic perspective. The course also included a service learning portion.

At the end of the program, students completed questionnaires asking how well they felt about their abilities related to the technology introduced in the course, if they learned about Hawaiian traditional knowledge, and if they felt good about the course at the end of the experience. Gibson and Puniwai (2006) also provided room for student comments and surveyed the students' coursework to look for learning and improvement in skills.

In response to the first assessment questions, the researchers found that 40 percent of the students considered themselves to have learned “a lot” with regard to their geoscience related abilities. In response to the second question, 80 percent of the students reflected that they had learned “some” or “a lot” about Hawaiian native knowledge within the realm of science. With regard to the students’ feelings about the experience, all rated the course in a positive way, with 80 percent rating it as “excellent” or “good”. Students contributed a number of comments on these questionnaires, including statements about how they liked the hands on aspects of the course, and that they were interested in learning more about science, geoscience, and the interaction between technology and culture.

While interesting and credible, on its own this study is not powerful. In terms of its strengths, this study accomplished its purposes from the researchers’ perspective which was to pilot a new course that integrated native Hawaiian knowledge with geoscience practices and determine student reaction in order to reflect on the nature and continuation of the course. Gibson and Puniwai (2006) applied pedagogical practices that are very consistent with what multicultural science education can be on a number of levels, particularly in terms of having an authentic incorporation through the use of a native guide and hands on practices that are relevant to the real world and to the students cultural history and sense of place. In addition, the researchers provide a clear description of the course and also of the instrumentation used for assessment.

While the results of the study suggested that the students learned, enjoyed, and were motivated by the experience, the study does not provide a comparison to suggest that any of the results are directly related to the incorporation of indigenous knowledge or to the use of constructivist practices. Based on their needs the researchers organized this action research project as a one shot case study, which provides no information about history of the participants or maturation during the study. The sample size in this study was relatively small, and selection for the course was by choice which may have predisposed the students to more positive perspectives. In addition, the researchers used instrumentation and testing that were simple and were not explored for significance. This study is credible, but is not substantial. Through conjunction with other studies, this study may be more dependable.

In another study involving Hawaiian indigenous knowledge, Feinstein (2004) explored student experiences in an undergraduate immersion class in Hawaiian traditional ecological knowledge, using action research with qualitative case study methodology. One critical difference between the studies involved the participants. In Gibson and Puniwai's (2006) work all participants considered themselves Native Hawaiians.

The participant body in Feinstein's (2004) work included students from a variety of places that identified with a variety of cultural and ancestral backgrounds. The group included 12 participants comprised of five boys and seven girls. Participant ages ranged from 19 to 27. Participants joined the study from California, Washington, New Jersey, Florida, Hawaii, Indiana, and Japan.

Four of the participants identified as part Native American or Hawaiian, and four considered themselves Natives of Hawaii, not all of which identified ancestrally. The research group included students at all levels of their undergraduate career.

Students in this study participated in an in-depth semester long course on traditional ecological knowledge in Hawaii, in which the researcher hoped to temporarily supplant participants' Western perspectives. Instructional methodology for the course included service learning, expert presenters, experiential learning, and critical multiculturalism. Feinstein (2004) collected data for analysis via student artifacts, observation, and interviews with the students. Student artifacts included questionnaires, journals, and projects. Journal entries included reflections on the experiences in the course and how they related to each students sense of identity. Much of the course included instruction by Native Hawaiian experts which allowed the researcher to take field notes during sessions. A total of three interviews were conducted with each student, two during the course and one a month after the course finished. The interviews lasted thirty minutes and centered around revealing aspects of the course that allowed the participants to explore their identities. The researcher analyzed all data immediately after the course and final interviews and coded the information in terms of Hawaiian cultural knowledge, student environmental knowledge, and student identity.

The findings revolved around the three mentioned coding themes. First, the questionnaire responses indicated that all students learned a great deal about Hawaiian culture. Additionally, the interviews suggested that many of the students appreciated Hawaiian customs and give credit to Hawaiians for the important roll these customs play. It is also noted that the students constructed much of this knowledge on their own through hands on learning experiences. The students produced a more sound understanding of TEK and general environmental knowledge through the course work. Students revealed being able to relate information from the course to systems level issues in their own worlds, for example seeing the many uses of one plant prompted curiosity about where things come from at home. Feinstein (2004) also interpreted evidence to support that the students all began to take interest in who they are through the identity aspects of the course. Some students professed interest in learning who they were while others professed that their identity had shifted through the course to become environmental advocates.

The researcher shared in depth about one student's identity transformation through this study. Jasmine, a Native Hawaiian, had previously not accessed her Hawaiian heritage. The researcher explained that this lack of access resulted from being adopted by Caucasian parents. Jasmine felt unable to complete writing exercises revolving around identity early in the course, and in her words this led her to search for that identity during the course. Throughout the course Jasmine reported strong feelings of respect, humility and awe, at the customs of Hawaiian tradition and at Hawaii itself. One experience in the course involved visiting a Hawaiian healer. This experience prompted Jasmine to realize what path she wanted to follow in her life- to help people become in touch with the land as the healer did. She followed this experience by transferring to the

University of Hawaii and changing her major from premedicine to Hawaiian studies.

As a qualitative study the selection process is a point of critique in that participants were voluntary. Additionally the sample size is quite small. The researcher clearly described his background and theoretical framework for the study and the work is credible, particularly in terms of such results being the result of a program that is so involved. This work is dependable and transferable to the extent that many of the studies incorporating indigenous knowledge into course work produced finding supporting an increase in enjoyment and appreciation of the work, however, it should be noted that the demographics of the sample in this study were quite different from other studies in this chapter. The researcher presented minimal information on the course, instrument, and design such that confirmability would be dependent on contacting the researcher.

Klos (2006) conducted an action research project in South Africa that produced both qualitative and quantitative data. In this study she explored whether the inclusion of indigenous knowledge in a science support program could be linked to mastery of science related literacy skills. She found that students demonstrated successful understanding, motivation in the course, positive perspective of the course, and positive self concept through analysis of the results. Klos (2006) also determined that students performed better on formative and summative assessment questions that included indigenous knowledge as opposed to Western scientific knowledge.

The study involved the participation of 80 students enrolled in the Science and Health Sciences Foundation at the Nelson Mandela Metropolitan University. The researcher reported a majority of the participants' cultural background as being based in indigenous belief systems.

The action research involved the incorporation of indigenous knowledge in a language support program within the science program. Students experienced this incorporation through assignments involving reading, writing, or presenting; and also through lectures and audiovisual media. The research required that students create an expository essay on any of a given list of science topics. The teacher conducted preparatory lessons that primarily employed the use of everyday language in the exploration of indigenous knowledge resources and supported the practice of paraphrasing, defining, explaining new concepts, and holding conceptual discussions. In addition, students practiced skills at recording notes and composing from notes in these lessons. Klos (2006) collected data via unstructured interviews, observations, and case studies. In addition, Klos obtained quantitative data through formative and summative class assessments. Through this data the researcher examined students' skills at taking notes and deriving understanding from academic scientific texts, writing academic scientific texts, and giving academic scientific presentations. The researcher stated that they analyzed the qualitative data for emerging themes and triangulated this data with past research.

The researchers found that four main themes emerged from the qualitative data. Students made comments suggesting that familiarity with indigenous knowledge supported their understanding of scientific information, that the indigenous knowledge presented was considered relevant to the students in a way that was motivating, that students enjoyed the incorporation, and that students developed positive concepts of themselves as learners.

The quantitative findings illustrated that students performed better when asked to perform tasks based on indigenous knowledge rather than Western science knowledge. Researchers presented a graph showing four rounds of assessment, each of which contains five tasks, one of which per round incorporated indigenous knowledge. Klos (2006) concluded that the incorporation of indigenous knowledge helped students to access subject specific knowledge and enjoy learning in this context.

This action research study seems to have two strengths, that the data is triangulated and that the qualitative data presented is very to the point and convincing of the study's conclusion. However, although the author presented convincing statements made by participants she neglected to describe the portion of students within the sample size that made such comments, lessening the validity of the researcher's conclusion. This study provides too little information to be reproducible. The skill building practices used in the preparatory lessons are not considered within this study and could be responsible for students' scientific literacy improvement. In addition, the researcher failed to provide any statistical analysis of the quantitative data and failed to provide a clear description of what exactly is represented by this data.

There is also no description of the instruments or assignments that produced the qualitative data.

Barton (1998), working from a social constructivist perspective, produced an ethnography that addressed the issue of the usefulness of a science education that is culturally relevant. Specifically this study questioned what a science curriculum would look like created from the vantage point of homeless children. Barton (1998) found that different life situations have a large impact on how students think about science. The researcher also determined that the borders of science had to be less definite or traditional in creating a science curriculum with these children.

This study included three girls living at the Carla Voster homeless shelter located in a depressed urban center in the north east part of the United States. Signs of community impoverishment included condemned dwellings, closed businesses, and evacuated car lots. This shelter, built in the early 1900s, housed nine single mother families with a total of 22 children at the time of the study. All families shared a single bathroom.

One girl that participated in the study is Gilma, a 13 year old Latina sixth grader. The researcher characterized her as having three younger siblings and as the oldest sibling having child care responsibilities and translation responsibilities for her family which had recently emigrated from Mexico. Barton characterized the other two participants as a pair of African American sisters named K’neesha and Patrice. She described them as having to continually move and live in shelters due to their father’s substance abuse problems, which created a number of educational difficulties for the girls. K'neesha described herself as stupid as a result of being labeled as learning disabled and being held back in the seventh grade. Barton (1998) described her as having given up on school related efforts. Barton (1998) described Patrice as being a smart sixth grader and being aware of her intelligence and the problems created by her home life to the extent that she had anxiety over school.

Barton (1998) carried out this study via action research and interpretive design from a social constructivist perspective. The researcher collected data from 1995-1996 as a part of a larger three year study on the needs and interests of homeless children. The researcher visited the children involved in the study two times a week for two years for the purpose of teaching them science at the shelter and collecting data. Data sources included field notes; a teaching journal; video and audio tapes of the science classes; videos produced by the participants; interviews with the participants and their parents; and written work from the students. Barton (1998) interviewed the participants, their parents, and their teachers three times each over the course of the two years. The researcher collected multiple modes of data for the purpose of triangulation. Transcribed data were coded around several themes, but particularly in terms of the themes of identity and representation. The study included member checks, periodically used to check intentionality and re-interpret and analyze the data.

Barton (1998) developed a science curriculum with these three students by first working with the girls to formalize complaints about the area in which they lived, and using these negative reactions as a driving force to motivate the students. The students took initiative to conduct interviews and do research at the library about pollution in the area. The structuring of the science curriculum in this way resulted in the girls creating long term plans for picking up trash, planting gardens, developing recycling programs, and continuing study. The researcher suggested that the students experienced science in a way that merged emotion, reason, mind, and body, and that their science experience included data collection, analysis, and incorporation of values. For example, the girls investigated cooking within their science class and naturally moved into a position of discussing the unfairness of the food policy at the shelter through this work.

Barton (1998) suggested that the critical aspects of this work were the de-centering of science and the direction gained via the life experience of the participants. She determined that this exploratory process provided space for unique perspectives that the process of making their experiences suit a predetermined curriculum would not have allowed. Barton (1998) concluded that it is important for the students to examine their lived experience through science because their experience will inevitable determine how they interact with science.

Strengths of this study include its thoroughness and the presence of triangulation and member-checking to validate the work. The research also specifically described the derivation of coding categories. The research is credible in considering social constructivist philosophy, though it does not exclude that participants from a different cultural background would select the same issues and pursue them in a similar fashion. The particular weakness of this study is the small sample size. The study is convincing but there is no data to support any transferability or confirmability.

Other Perspectives Regarding the Impact of Worldviews and Ways of Knowing on Science Education

Three studies are presented in this subsection. These studies take relatively conflicting view points about the importance of cultural background in the determination of science attitudes. The first study attempted to present an oppositional view point, which was largely rooted in the researcher's theoretical understanding of multicultural practices as being racist. Zhao (2007) presented a case study of Asian American scientists exploring the question of whether or not culturally appropriate pedagogy is necessary in science for this group. The interviewees in this study were all Chinese, had all lived in the united states for 8 to 25 years, ranged from 30 to 50 years of age, and all completed their first degree in China and their second in the United States. Of the ten participants only two were female. All participants immigrated to the United States by 20 years of age. All participants obtained a Ph.D. in chemistry, math, biology, or engineering. This sample accumulated through friendship and networking.

The interviewees each participated in conversations with the researcher that lasted an hour to an hour and a half, and all follow up conversations were conducted with some participants via phone interview. The researcher questioned how the participants could explain the success of Asians in math and science from a cultural perspective, how their culture relates to their careers, and how they mediate this relationship. The researcher recorded the interviews on tape, transcribed the interviews, and reviewed them repeatedly for emerging themes.

The research findings revealed that the interviewees disagreed that their cultural heritage interfered with their science experiences. Instead they argued that the holistic thought patterns in East Asian thinking supported their pursuit of scientific understanding, as did an appreciation of the artistic aspects of science. However, the scientists acknowledged the lack of a systemic scientific approach such as exists in Western science, and therefore this dominant tradition becomes a necessity. These scientists generally supported exposure to both practices.

The structural aspects of this study failed to satisfy recommendations for structural integrity, and reduce the credibility of the work. In particular the researchers sampling methods are not sound in terms of selection based on friendship which may have predisposed the researcher and subjects to similar perspectives and previous interactions relative to the material. Additionally, Zhao (2007) does not describe triangulation or member checking processes involved in this work. The dependability, transferability, and confirmability of this work are not supported here as this article is presented as an oppositional view point. Interestingly, Zhao inadvertently advocated what this survey considers consistent with multicultural practices, that is, the incorporation of multiple ways of knowing. This article will be discussed further in chapter four.

The following two studies presented critical caveats to the multicultural work presented in this section, namely in terms of the complexity of the situation. While all of the previous studies recommended incorporation of indigenous knowledge, Dzama and Osborne (1999) sought to determine the extent to which traditional beliefs impact student performance and what other variables are in effect. Dzama and Osborne conducted this work as a correlational one shot case study. The participant body in this study included 160 students from five schools in Malawi, specifically 120 boys and 40 girls ranging in age from 17 to 25. The large age range resulted from the practice of allowing students to repeat the final year of their primary education as many times as needed to advance to secondary school. The schools varied dramatically but were not specifically described in the paper.

This research involved the completion of a test focused on principles of electricity, a rational thinking task, and a traditional beliefs questionnaire. The subject of electricity was selected as it posed no conflicts to traditional knowledge in the area. The test on electricity included items from a previous test that were reworded to be open ended, requiring students to explain their answer. For each question students also indicated their confidence at correctness on a five point scale. The electricity test instrument was validated by a panel of four physics experts, and was found to have a reliability coefficient of 0.8. The rational thinking task involved a 14 item test regarding a pendulum, on which items were graded as right or wrong. The rational thinking instrument had previously been used successfully in other African nations. The researchers designed the traditional beliefs questionnaire, which was intended to measure the students' degree of belief in pieces of traditional knowledge. The instrument contained 26 items, all of which were validated by a panel of experts on Malawi culture. The instrument produced a test re-test coefficient of correlation of 0.9. All analyses were done by a computer program for statistical analysis.

The findings demonstrated a number of correlations between the available data. Most relevant to the question of culture, the data suggested a significant negative correlation between traditional attitudes and beliefs and performance on the electricity test (-.42 and $p < .001$). Additionally, they suggested a significant negative correlation between traditional attitudes and beliefs and confidence on the electricity test (-.28 and $p < .05$). Similar significant values emerged between the traditional attitudes and beliefs and the reasoning task. All other negative correlations that emerged were between the tasks and age, which suggested that students that repeated the last year of primary school more times we less capable at reasoning skills. The researchers further analyzed the data and revealed that traditional beliefs and attitudes can only account for 11 to 20 percent of the total variance in scores, where as ability accounted for almost 40 percent and around 50 percent of the variance is not accounted for within the variables explored.

Again, this sort of experimental design is not particularly valid. The design excluded history, maturation, and mortality. The researchers described the instrumentation and testing in a minimalistic manner, and the selection practices were questionable. While this work demonstrated a similar correlation between cultural beliefs and science achievement as many papers in section one presented, this analysis went a step further to determine the source of variance within the data which suggested that the role of cultural beliefs is minimal, however the design is not sound and this work should only be considered as trustworthy as any of the work in section one. The presentation of confidence in this work hinted at a mechanism for low performance in a way that no other studies had done so far, this will be discussed further in chapter four.

In a similar project in terms of purpose, Nielsen and Nashon (2007) explored the reasons that students do not have as much access to science in rural British Columbian towns that are not linked to student culture. Their work involved a qualitative case study with interpretive data analysis. The researchers referred to information from the B.C. Ministry of Education to suggest a significant First Nations presence in these schools although the ethnic demographic was never specifically addressed. The research group included 12 schools selected for their size and rural nature. Students, teachers, and principals all participated in completing questionnaires. School size ranged from 25 to 600 students and all communities were characterized as having substandard access to civic services such as hospitals, police stations, and human services. All participating schools accepted an invitation to join the study.

The researcher profiled the schools involved in terms of demographics and achievement via data available from the Ministry of Education. Data analysis included all 55 schools in B.C. that matched the participation criterion met by the 12 schools involved in the qualitative aspects of this research. The researchers compared data from these schools to all schools in B.C. that did not match the criterion. The qualitative aspects of this work, supported by the profiling of the rural schools, included an analysis of structural and cultural issues impacting student experiences in science at these schools. Students (n = 45), teachers (n = 28), and principals (n = 11) all completed questionnaires. The researchers conducted follow up interviews for clarification. These interviews lasted approximately one hour and occurred with three principals, six teachers, and five students. Nielsen and Nashon (2007) analyzed the data interpretively, grouping, coding, and summarizing the results thematically in a process that was repeated multiple times.

The profiling of rural schools compared to the average provincial school revealed that fewer students took physics, chemistry, and math in small rural schools, and also that students scored lower on provincial exams for biology, physics, chemistry, and math in small rural schools. The largest differences existed with physics courses with a participation rate of 7.6 percent for rural schools compared to 18.1 percent and a mean score of 25.7 on the provincial exam compared to 51.0. The slightest difference existed in biology where participation rates were 30.8 for rural schools compared to 29.1 and mean scores were 32.2 for rural schools and 38.4. The analysis of the qualitative data determined that a number of barriers existed in terms of reducing student access to science courses. These barriers included lack of staffing, lack of specialized teachers, poor teacher-student relationships, and the culture of the school. Principals and teachers revealed that a common root of many of these issues is high teacher turnover that resulted from less compensation, the task of adjusting to a new environment, and a lack of anonymity within the small community. Principals stated that it was not only hard to recruit teachers, particularly specialized ones, but it was also hard to keep them. This had an impact on data reported from students and teacher which suggested that the high turnover does not allow time for the student and teacher to develop a trusting relationship. In addition participants suggested that often the school culture in these contexts is not competitive as a means of supporting student success.

Nielsen and Nashon (2007) did not provide enough information for this study to be confirmable and also neglected to mention practices such as triangulation and member checking in their work. However, with regard to the research by Dzame and Osborne (1999) the findings appeared some what transferable and dependable in that they highlighted aspects aside from cultural background as being responsible for lower achievement and engagement with science in diverse populations. This research is somewhat credible although it did not conduct statistical analysis of the data, and was based on a moderate sample size.

Summary

In this section, *Impact with Regard to Practices Involving World Views, Ways of Knowing, and Prior Knowledge*, studies suggested that the incorporation of indigenous knowledge and the allowance of students prior knowledge or ways of knowing into science curriculum seems to increase the students' positive attitude toward their experience and sometimes is motivational. Many of the studies in this section were of the action research format. Jegede and Okebukola (1991), Herbert (2004), and Klos (2006) conducted studies in African nations which suggested that achievement can be improved through such incorporation, potentially through processes of collateral learning. Gibson and Puniwai (2006) and Feinstein (2004) both completed work with Hawaiian traditional ecological knowledge, suggesting that the experience was enjoyable for the students, even to the extent of being transformative for one participant. Barton (1998) conducted an interesting study working with homeless children in which she let them determine the course of their science curriculum based on their interests and the students became very involved with the work. Although these studies were in agreement across cultural contexts and in different formats, it is important to note that the projects implemented for this research were quite complicated. Perspectives in conflict with the suggested usefulness of incorporating the ways of knowing from students marginalized from science emerged from Zhao (2007), Dzama and Osborne (1999), and Nielsen and Nashon (2007). Zhao's interviews with Asian scientists reflected that they felt their cultural heritage was not an impediment to studying science. The other two works suggested that while culture is part of the picture, it will not be a panacea as there are also a number of other factors that should be considered in students' science experiences.

Impact with Regard to Practices Involving Cultural Practices and Skills

Examples from Primarily Urban and African American Settings

The next nine studies focus primarily on methods considered consistent with the NSTA's definition of multicultural science education in the context of urban schools with high attendance from African American students. While all of these studies suggest that practices such as incorporating movement into class, use of cooperative learning, multiple presentation options, and inquiry based hands on learning are beneficial for marginalized students, they also suggest that the employment of these practices are not enough to close the achievement gap. This leads to the question of whether supposedly cultural characteristics of African American students, as discussed in the following studies, are really cultural, and additionally, what then are the critical factors in giving these students opportunities for equal achievement. Following these nine articles, another case will be presented which points to the allowance of culturally preferred practices in the science classroom for Haitian and Hispanic students.

In the first study in this section, Parsons, Travis, and Simpson (2005) conducted a quantitative and qualitative study in a multiple case study approach that explored what the learning preferences are for eighth grade students and what the impact is when these learning preferences are actualized. Specifically, the research group framed these preferences in terms of the Black Cultural Ethos (BCE) including practices that involve movement, verve, and communalism. The study group included forty students, approximately half of which were African American and half of which were Caucasian. Three teachers were involved in this work. Selection of the school used was determined by the superintendent of the school district, the teachers volunteered, and the students were selected randomly. The school involved was urban and had a high percentage of low socioeconomic standing families. The researchers examined only one school because only one of them was onsite.

The researchers organized the study (N = 3) so that one teacher experienced at using BCE served as a control, and the other two teachers participated in an intervention that added BCE to their teaching style. Both taught two physics topics lasting approximately 10 days each and both applied BCE to one of these two physics topics. The second of the two physics topics was taught in the teachers usual fashion. Intervention for the teachers consisted of a reading on practices consistent with BCE and consultation on lessons. Data collection included video recording for each case two days a week, in addition to field notes. Data collection also included completion of an instructional preferences survey and pre and post content tests taken by students. Questions for the content test were taken from the TIMSS test. The researchers administered the preferences survey at the very beginning of the study along with the pretest and administered the posttest approximately 45 days after the completion of the physics units. Additionally, the researchers selected four students to participate in interviews six months after the completion of the physics units. In these interviews the researcher requested that students respond to two lessons, one with BCE and one without. Data analysis included both qualitative and quantitative methods.

The findings from this work demonstrated that students with a strong congruence with BCE practices improved on their post test scores. Forty six percent of students with a high congruence in the BCE intervention group made average to good improvement on their posttest as compared to zero percent that made average to good improvement in the nonintervention group and 100 percent that made no to poor improvement in this group. The same pattern existed with low congruence groups, though to a lesser degree. In the BCE intervention sample, only 33 percent of low congruence students made average to good improvement while 67 percent made no to poor improvement. For low congruence students in the no intervention sample, 17 percent made average to good improvement and 83 percent made no to poor improvement. No differences were found in the pattern of preferences among African American and European American students and no differences were found in between achievement in the two groups in relation to their preferences.

The structure of this study makes it quite credible. The researchers structured a pretest/posttest control group design that controlled for more than just the BCE treatment. It also tried to control for teacher ethnicity. Additionally the researchers analyzed the data on multiple levels, and took care in determining the validity of their instruments through multiple sets of feedback from the students. The researchers also triangulated data and used member checks. The one particular weakness of this work is the low sample size, and while the results are believable, statistical analysis would have helped to highlight the degree of differences.

Elmsky (2005) conducted a qualitative case study in the form of action research. This case study was part of a larger ethnographic work by the researcher involving five African American youth from economically disadvantaged backgrounds in Philadelphia. The researcher hired all five students as interns, and their roles involved the science project discussed in this study, in addition to being research aids for Elmsky's ethnographic work.
The freshman level participants included two girls and three boys.

For this part of the study, the students created a 40 minute video entitled *Sound in the City* during their 10 week summer break. The study provided students with materials and tools, and allowed for freedom in designing and implementing the project. The researcher focused particularly on issues on resource utilization in her data collection. Elmsky (2005) collected data through student artifacts, narratives, interviews, and her own field notes. Analysis tried to determine how the students' cultural background supported them in the work they did with *Sound in the City*.

Elmsky (2005) described the students initial wanderings in the creation of the movie as being very Western science oriented, involving the defining of sound related concepts. Eventually the students related the information to their worlds, particularly, they related many of the sound concepts to rap music. In the creation of the movie, the students also employed the skills they had at rap, dance, speaking, and the creation of visual aides. The researcher noted that as students progressed in relating the physics material to their own experiences, they facilitated group learning through realizations related to making the project their own. In addition the researcher referred to energy, movement, verve, and orality, characteristics correlated with African American culture in previous works by other authors, as being present in the project.

The researcher also suggested the benefits of this project as a result of its character being empowering and accepting of the students' background. Elmsky (2005) noted that some of the students became conscious of the scientific relevance of their everyday lives. Also, after the completion of the project, developments occurred that suggested its importance to the participating students in terms of empowerment, in that students incorporated this work into later experiences in science and high school, allowing the students to express pride in their work and receive commendations from peers.

There are a number of weaknesses with this study around the way in which the participants were selected. First of all, the researcher never explicitly states how these students were selected. While they may have been African American and of low socioeconomic status, there is no indication of their academic histories, and they may have been students inclined to science in the first place. Additionally, the students were paid for their work, which may have had an impact on the process and product. As mentioned above the students also served as research assistants through this project which may have in itself heightened their awareness and pride in the completion of the project, though it seems that this science project occurred early in their internship. Another key caveat with this work is the interpretive analysis suggesting the projects cultural conduciveness, when some of the results could also be interpreted as multiple intelligences. This will be discussed more in chapter four. The results of this study seem logical, though this composition does not address their transferability or dependability, with the exception of seeing similar patterns of student empowerment and apparent achievement in articles such as the upcoming Hudicourt-Barnes (2003) study that allow for the students world and practices to enter the learning environment. This work is somewhat trustworthy, though it is complicated by the selection practices and nature of the project.

Moore (2007) discussed three teachers' coping strategies in low performing school districts as being inline with multicultural educational practices in science. The researcher organized this work as three case studies based on interviews and working from a critical social theory perspective.

The researcher conducted this work in a small rural county in the southeastern United States. This study included two public schools, Carver high school and Parks high school. Student bodies at each school included 98 percent African American and two percent Caucasian and Hispanic students. Both schools are labeled critically low performing because they failed to meet minimal state requirements on six norm-referenced tests. This state assigned letter grades to each school based on state test scores, progress, and students participating in testing. Carver received a D in 2000 and an F in 2001. Parks received a D for the same two years. The researcher spent one to three days per week at these two schools for over a year.

Moore (2007) collected data via interviewing, participant observation, and reflective journaling. Each teacher participated in five interviews with the researcher. These interviews lasted 30-90 minutes during the teachers planning period or lunch and took place monthly starting half way through the research period. The topics of the interviews included: discussion of their teaching practices, constraints on their teaching, and overcoming these constraints; discussion of teaching an African American student body and their perceptions of self and the students; discussion of their views on science and science teaching; discussion of their view of relationships with students, colleagues, administration, and families; and discussion for the purpose of clarification. This process involved member checking. The researcher audio taped, transcribed, and coded all interviews to determine themes. The themes eventually categorized into six competing issues all revolving around constraints including: economic, historical, social, academic, institutional, and structural factors. The researcher's reflective journal served two roles, to record comments and informal conversations with the teachers, and as an ongoing test for understanding the teachers, their practice, and the context.

These three teachers shared information about the district that provided insights into their work ask teachers, the backgrounds of the students and the changes that have taken place in that district. This information also highlighted three factors that the teachers dealt with in this county, for example, Caucasian students left the schools over time and when they left funding decreased; the publics' and students' perceptions of the schools as being poor quality and of themselves as being inferior; and poor leadership and a lack of development opportunities. The teachers employed various pedagogical and communication strategies in line with multicultural science education to help their students overcome negative perceptions of themselves and to value science education. Mr. O'Neal helped the students to over come the negative perception they had of themselves by entering them into an engineering contest. The students worked hard and doubted themselves along the way, but ended up winning multiple prizes and being featured on the news. Mr. O'Neal stated that this gave the students pride and lifted their spirits.

While Mrs. Martin and Mrs. Nelson did not specifically make statements regarding the impact of their strategies on student interest and achievement it is suggested by their presentation that their coping strategies are effective practices. Mrs. Martin exposed her students to resources, information and opportunities in science. She theorized that by offering resources and experiences to students the students may be able to make more informed decisions and take more responsibility in their science education. Mrs. Nelson was interested in forming strong student teacher bonds. She also exerted a degree of effort to help students to see how science impacted their lives and how their actions impact everything. It is interesting to note that cultural issues are not suggested as being issues in the achievement of these students.

The researcher adequately described her coding categories and did a thorough job of describing her methodology in general. Member checking was practiced and the researcher triangulated data from multiple sources. With this in mind, this research can be considered relatively credible. The work is also transferable in that all research included in this section supports student centered practices. However, Moore (2007) worked with an incredibly small sample size. The researcher neglected to mention their selection process or how access was gained to the school district. The researcher unfortunately did not focus on the impact of these practices on student achievement or attitude though the participating teachers briefly mention these issues. The researcher presented surprisingly little data given the length of their interaction with these teachers.

The dependability and confirmability of this research is not addressed by other studies in this chapter.

The next study is a quantitative comparative study by Kahle, Meece, and Scantlebury (2000) which explored whether standards based teaching practices, such as a community orientation, inquiry based teaching, and multiple modes of presentation, make a difference in terms of achievement for diverse students in urban environments. Some of the standards based practices are inline with what has been described as Black Cultural Ethos, a cultural way of being for African American students that involves movement, orality, communalism, among others.

The researchers selected a random sample of 126 schools in Ohio at the middle and high school levels, which had teachers present that had participated in professional development training for standards based teaching (SSI). Principals and teachers at these schools completed a questionnaire which the researchers used to narrow their group of participants. Eventually the researchers selected eight schools based on the presence of an SSI teacher and at least 30 percent minority enrollment. From this sample nine SSI and nine non-SSI teachers were selected randomly to participate. This study analyzed data only for African American students. The specific sample size is not given. For the students, grade levels ranged from six to nine, ethnic minorities made up 26 to 86 percent of the school populations, and free/reduced lunch ranged from 14 to 85 percent. 52 percent of these students participated in SSI led classes and 48 percent participated in classes where the teacher had no professional development for standards based teaching.

Students completed a questionnaire about their Attitudes Toward Science (ATS). A panel of expert science educators validated the questionnaire and it was tested in schools not involved in this work. The questionnaire included four subscales: standards based teaching practices, peer participation, home support, and attitudes toward science. The researchers measured science achievement with the Discovery Inquiry Test, created by university scientists in the mid 1990s. The test included 29 items covering life, physical, earth, and space science.

Kahle, Meece, and Scantlebury (2000) findings, through multiple analyses, supported that the students performed better with SSI teachers. The MANOVA revealed this pattern as supported by $F = 17.05$ and $p < .01$. It also supported a significant difference between SSI and non-SSI teachers in terms of their standards based teaching practices with an $F = 28.45$ and $p < .001$. Correlational analysis revealed a strong positive correlation between perceived peer participation and standards based practices with $t = 3.61$ and $p < .01$. The results of the Hierarchical Linear Modeling analysis for science achievement also indicated that students performed better with SSI teachers with at $t = 2.70$ and $p < .017$.

As a static group comparison, this work supported validity in terms of the history of the teachers and regression. The reliability values for the instruments used are sufficient, particularly for preliminary work. The researchers explained selection practices explicitly, however more information could have been provided in other areas. Lack of info on the student sample size and little info on the nature of the instruments are two particular shortcomings. This work is trustworthy, but would be much more substantial with a cross comparison to students of other ethnic heritages.

The Lynch, Kuipers, Pyke, and Szesze (2005) research group investigated a similar question about the impact of standards based instruction via a highly rated science curriculum, on the achievement and engagement of diverse students in an urban setting. The researchers conducted this work, which was part of a planning grant, as a quasi-experimental pretest/posttest delayed posttest design.

The research participants included 2259 eighth grade students from five middle schools in Washington, DC. The researchers examined ten schools for demographic data and selected schools with higher levels of cultural and socioeconomic diversity. The researchers divided the student sample into two equally diverse research groups, one serving as a control and the other for treatment. The study included approximately equal numbers of boys and girls; and of European American and African American students. The article also provided data for other ethnic groups, proportions of students receiving free and reduced lunch, and English language learning student. Additionally the study involved an ethnographic component in which four students were videotaped in one classroom. This group of four included an Asian American ‘gifted’ girl, a European American ‘gifted’ boy, a Latino boy that had recently been mainstreamed from ESL classes, and an African American girl characterized as being very socially oriented. The teachers involved in this research were used to pilot testing new reform based practices.

The researchers paired the ten schools into similar sets and randomly assigned intervention to one school in each set. The intervention group received 18 lessons from *Chemistry That Applies* (CTA), a curriculum developed by the NSA and designed in accordance with *Project 2061*. The unit is student centered, hands on, and involves similar aspects to the previously presented study by Kahle, Meece, and Scantlebury (2000), such as a focus on group work. Student participants completed questionnaires with Likert type scale items about motivation and engagement, and completed a science content test at three points during the research. The questionnaire for engagement is entitled *the Basic and Advanced Learning Engagement scales*. Determination of motivation involved the use of the *Patterns of Adaptive Learning Scales*. The content exam included four scenarios that students explored through open ended questions designed to be accessible to diverse students.

No significant differences emerged in comparing the pretest scores of the treatment and control groups. Lynch, Kuipers, Pyke, and Szesze (2005) found significant difference for achievement with the CTA curriculum ($F=59.80$ and $p < .05$ and $F=72.16$ and $p < .05$ for the delayed posttest), and on some aspects of engagement and motivation significant relationships emerged with the CTA curriculum ($F=9.8$ and $p < .05$). When the researchers divided by subgroups for between group ANCOVA analysis they found that pretest scores represented stereotypical findings with Caucasian and Asian students scoring higher than African American and Hispanic students. They also found that all groups improved with the CTA treatment, but that the groups improved to similar extents, only the Asian group closed a small gap with the Caucasian students. The researchers presented the corresponding data in tabular and graphical format. The researchers also revealed a relationship between the application of the CTA curriculum and motivation and engagement with lower socioeconomic status students.

Interestingly, dynamics from the ethnographic aspects of this research, showed that the Caucasian male in the group of four students functioned as the authority in the group, partially as a result of using more scientific language, despite misconceptions that he presented. The students interacted with the material in ways suggested to be stereotypical, the Asian American girl seeking the most support, the African American girl being involved physically more than the other students, and the Hispanic boy being focused on process and procedure, potentially as a result of still learning the English language.

As a pretest/posttest control group design, this study is experimentally sound. The researchers used instruments that were valid and reliable and used a sufficient sample size and logical sampling methods. It would have been interesting had the researchers asked participating students to describe what they liked about the curriculum, or why they thought they did better with it, to try to reveal any culturally relevant aspects of the practice. Like much of the other work here, this study shows improvements but no closing of the achievement gap. In terms of the ethnographic part of the study, the sample size was small and the researchers collected over 45 hours of tape which translated into over 1000 pages of dialogue. However, the researchers only presented one conversation from all of this data. This conversation seems in line with stereotypical and oppressive power dynamics, but cannot be considered as representative or credible as it was the only information presented.

Odom, Stoddard, and LaNasa (2007) conducted an investigation involving both pretest/posttest and correlational survey based methods. This inquiry addressed what the relationship was between particular student centered instructional practices and diverse students attitudes and achievement in science. Student centered practices examined in this study included group experimentation, learning from classmates, an emphasis on talking in problem solving, and evidence based communication practices. Teacher centered practices included the use of handout notes, taking notes, teacher demos, and homework.

The sample involved in this work included 394 students from two urban school districts and 227 students from two suburban school districts for a total of 611 students. All students participated in grades seven or eight at the time of the study and represented 13 teachers from nine schools. Demographic data for the research group illustrated composition ranges of 13 to 88 percent free or reduced lunch, seven to 98 percent African American, zero to 20 percent Asian American, four to 25 percent Hispanic, and one to 95 percent Caucasian students.

One content test and one survey were constructed and used for this work. The content tests included 12 multiple choice items and four open ended responses. Participating teachers constructed these tests with relation to physics content. The researchers created the survey to measure students' attitudes to science, home related factors, and determine classroom practice characteristics. The researchers compiled questions from the survey from two previous surveys and the new instrument was entitled the Science Achievement Influences Survey (SAIS). It consisted of 31 Likert scale type items. The researchers stated that the reliability for the SAIS was favorable but did not present a value. The reliability coefficient for the content test was 0.85. Students completed the SAIS online. Odom, Stoddard, and LaNasa (2007) collected all data during three weeks in fall quarter.

Analysis of the data followed five steps. The first two involved determining the reliability for the overall instruments and their components. The third involved multiple regression analysis for all of the factors on the SAIS. The fourth involved item analysis for various teaching practices and student attitudes. The fifth step included determining the relationship between various teaching practices and student attitudes. The researchers administered content exams before and after survey completion to control for past content knowledge in their analysis.

Not surprisingly, within this diverse population, the data suggested that student centered practices had a significant and positive correlation with both student achievement and attitude. Through their multiple regression analysis the researchers found a significant positive relationship between posttest scores and both pretest scores and student centered practice. They also found a significant negative relationship between posttest scores and teacher centered practices. All relationships were significant to $p < .001$. Odom, Stoddard, and LaNasa (2007) also found that the significant positive relationship with all student centered practices and achievement and attitude got stronger the more frequently the practices were experienced. One finding from this work, different from those presented in many other studies, suggested that family support and peer factors were not significant in relation to achievement or attitude. This may be a result of the diversity in the group.

There are many things that this study didn't address which would have enriched it. Analyzing the survey data by subgroup for the impact of particular teaching practices would have been interesting. The researchers also did not differentiate between population characteristics in classrooms with more teacher centered practices versus student centered practices. The research worked with a decently sized sample, and the researchers provided detailed information about the instruments and their validity. The researchers also tried to control for science achievement history through a content pretest and posttest. Once again, selection practices were not discussed. This study can be considered somewhat trust worthy, and indicates that across diversity student centered practices are important in creating positive attitudes and achievement in science, however, this study is hugely minimalistic and therefore offers many fewer insights than it potentially could.

Although not specifically carried out in a similar context to the previous studies, the next work presented has similar implications in terms of particular practices being beneficial for all students, rather than a single marginalized group. Cardona, Spiegel, Alves, Ducommun, Henriques-Pons, and Araujo-Jorge (2007) conducted an action research study with qualitative analysis to determine the cross national applicability of a biology game created in Brazil. Specifically they wished to evaluate the acceptance of the game in terms of motivation. This comparative study was carried out in Switzerland with 18 tenth grade students from Lycee Jean Piaget. This group included ten boys and eight girls. A second research group included 32 teachers from a teaching university. The researchers divided these teachers into two groups for analysis of their students' responses to the game, the first included 22 in their first year of teacher education characterized as 13 men, nine women, age range of 26 to 46, 12 biology specialists, five physics specialists, and five mathematics specialists. The second group included ten teachers in their second year of teacher education, characterized as one woman and nine men, with an age range of 24 to 39.

The researchers employed the use of a Brazilian board game called *Discovering the Cell*. The game structure included the use of inquiry, problem based, and cooperative learning strategies to teach molecular biology concepts through the solving of a mystery. The research took place during one fifty minute class period and involved an introduction and signature of consent for the completion of questionnaires by students. Each group of students involved read the rules for the game before beginning. They then proceeded through the game, interpreting and discussing the game clues. At the end of the game participants completed the questionnaire developed by the researchers. This questionnaire explored participants' sense of issue comprehension and their level of empathy with the game. The researchers subjected the resulting questionnaires to qualitative analysis and quantitative descriptions. The researchers also collected data through group observation during the sessions, participated in discussions with the participants at the end of each session, and participated in focal group dynamics with the teacher groups.

The results from researcher observation indicated that the groups were slow to start the game, were quite focused in beginning the game, and quickly began to derive pleasure from the experience. Through the questionnaire the researchers found that about 65 percent of students felt that they had learned something new from the game and a few students said that they reinforced prior knowledge. It is interesting to note that 97 percent of the teachers involved thought students would learn something new from the game. Students and teachers found the game difficult but understandable. To determine acceptance and enjoyment, the researchers asked how time passed during game play and if they would like to have more lessons like this. Most students, 13 out of 18, said they felt little time go by, and 85 percent of all groups said that they would like to have more lessons like this. For the student research group this preference was represented by 16 out of 18 participants. Finally, while researchers did not present the data in this paper, they asserted that the findings with the game in a similar study in Brazil were quite similar. No statistical analysis is included to support this assertion.

In terms of its qualitative findings, it seems that this work is dependable and transferable. It also seems that it would be quite easy to confirm the findings after acquiring a copy of the game. However, without a description of the research populations in Brazil and Switzerland in terms of economic status and other descriptors it is hard to tell how culturally different the two groups were. With regard to the quantitative aspects, unlike most of the other studies presented in this chapter, this research did control for history by selecting students with no prior experience with the topic matter involved in the game. In addition, they did triangulate, collecting data from a number of sources. Their discussion with the class may be considered a minor form of member checking since the researchers were somewhat aware of the results through helping mediate the use of the game. This study is particularly weak in its sample sizes. A discussion of the selection process is also absent, which makes this study only somewhat trustworthy.

One of the most interesting things about this study is the direct comparison of a particular pedagogical technique across two cultural groups. It is unfortunate the researchers did not publish this work in one study and was not more descriptive about the characteristics of the study population.

Russel and Atwater (2005) examined the factors African American science majors attribute to their pursuit of science. This work stemmed from a phenomenologied research perspective and produced qualitative information through interviews. The researchers employed purposeful sampling to select relevant participants, which included eight African American females and three African American males. All planned on majoring in biology, would obtain a Bachelor of Science degree, were seniors, and ranged in age from 18 to 25. The researchers selected the students from a list of 30 provided by the Minority

Services Office at their university. Of these thirty students, eleven volunteered to participate.

All participants completed a demographic questionnaire prior to being interviewed that presented questions about race, gender, citizenship, school information for both college and high school, home community, course level placement in high school, and home life. The researcher analyzed these questionnaires to determine each students' precollege experience with science. The researcher then interviewed each participant for one to two hours to discuss what they thought determined their participation in science, their course taking patterns, and strategies for persistence in science. The researcher taped and transcribed each interview and analyzed the data for themes common to each participant. Member checks and peer review were used to ensure validity and reliability.

Four themes emerged: parental influence, teacher influence, precollege experiences in science, and college pipeline experience. The students shared that it was understood within their families that they would attend college. Students shared feelings of needing to make their families proud or to respond appropriately to sacrifices made by parents. Multiple students suggested that their science teachers in high school were critical to their path determination. Many cited a sense that their teacher genuinely cared for their progress, pushed them into extra science experiences, and tried to make science interesting. In terms of their precollege experiences with science, many of the students participated in AP math and science courses or participated in other hands on science projects, such as research in a university setting, having surgery, volunteer work with the medical community, and science fairs. In addition to citing factors that supported their efforts in science, the students also suggested that racism was something that they dealt with in this pursuit. One student suggested that she felt more comfortable in her identity as a scientist because she attended an all black high school. Others mentioned experiences with racism in grading as a motivating force.

While the sample size for this work is small, the sampling procedures were appropriate for the intentions of the study. The researchers took steps to ensure the validity of their work. They did not however triangulate these data. The findings of this work, suggesting resources as a particular factor in promoting or suppressing the science experiences of African American youth, is dependable and consistent with other papers, which suggest the role of family as being important in students science experiences. This work would be confirmable by an outside party. This work is trustworthy however, it is important to note that there may have been other predisposing factors not explored or mentioned in this study such as socioeconomic status.

Hanson (2007) explored the critical factors in the science experiences of young women of color through a series of surveys producing qualitative and quantitative data. The participants in this investigation included 281 African American women between the ages of 13 and 30 and a control group of 781 European American women between the ages of 13 and 28. The researcher selected these women randomly via a web based survey panel called *Knowledge*

Network. This network randomly sampled households in the United States and invited them to join the panel via a phone call. In exchange for participation, the network offered volunteers free Internet connection, free hardware, and free installation. Panel members answered questions voluntarily through a password protected account. Of the members that were invited to join this survey, 37 percent accepted and of that percentage only 53.7 percent completed the survey.

The survey applied in this work included a comprehensive range of factors spanning family variables and science experience variables. For example, some variables included level of parental education, closeness with parents, parents' outcomes in science, participants' outcomes in science, high school grades, and household income. The survey contained both Likert-type questions used for gathering quantitative data and open ended questions used for gathering qualitative data. The researcher analyzed the data using bivariate analysis to compare the data from the African American group to the European American group. Additionally the researcher employed multivariate analysis and logistic regression in exploring the interaction between factors for African American women in their science experiences. Hanson explored the qualitative data for further insights, but did not specify an analytical perspective.

The bivariate analysis revealed significant differences between the African American and European American respondents for many of the variables. For example, White women perceived being closer to their parents and reported their parents having more involvement in science and higher educational attainment ($p < .05$). Interestingly the African American sample reported having significantly higher expectations and hopes of their involvement in science, but considered themselves significantly worse at it and less welcome in it ($p < .05$). The multivariate analysis revealed that there are significant family factors related to each science outcome for African American women. The researcher reported family encouragement as the most important factor because it had a significant positive relationship with all of the science outcomes, including perception of being good at science, liking science, expectation of a science occupation, hope of a science occupation, and feels welcome in science (all $p < .05$). It is important to note that another factor, attitudes about work, also had a significant positive relationship with four of the science outcomes.

The qualitative data revealed that approximately half of the African American sample did not articulate perceived family support as being important in their science experience. When asked how family contributed to their experience in science, many of the African American girls made statements reflecting a strong personal nature to their likes and choices, which was not as present in the European American sample. Other themes emerged such as a greater awareness of the mothers support than the fathers, a perspective of science as a way to gain employment, and an awareness of the lack of support for African American women in science.

The selection practices, although weighting adjustments are applied, are questionable. Hanson (2007) suggested that there are significant differences between the study group before and after attrition, and it is safe to assume a significant difference between panel members that accepted participation and those that didn't. However, Hanson also suggested that the findings from this work are similar to the findings from the National Center for Educational Statistics from 2002, suggesting dependability. Regardless, this survey is interesting in that it points to factors other than those related to culture and pedagogy with regard to the success of this group in science.

Summary

This section focused on practices considered by some to be consistent with potentially cultural African American learning preferences. Elmsky (2005) and Moore (2007) both presented case studies that advocated the use of student centered, hands on, cooperative and relevant science instruction for African American students and presented its impact in creating pride and motivation in the students. In looking at the studies by Parsons, Travis, and Simpson (2005), Kahle, Meece, and Scantlebury (2000), Lynch, Kuipers, Pyke, and Szesze (2005), and Odom, Stoddard, and LaNasa (2007) all recommended student centered and standards based teaching practices for marginalized students in science classes to promote achievement. However, the Parsons and Kahle studies noted that the use of these practices supported all students rather than a particular marginalized group, the Lynch study looked only at the African American population, and the Odom study did not differentiate between populations. Cardona, Spiegel, Alves, Ducommun, Henriques-Pons, and Araujo-Jorge (2007) also demonstrated cross cultural acceptance of a pedagogical tool that is similar to those that are consistent with the descriptors in other studies in this section. Russel and Atwater (2005) and Hanson (2007) both explored the self perceived science experiences of African Americans, and in both cases the study participants suggested a number of factors as being important to their pursuit, including family factors, having access to science experiences related to the real world, and having caring teachers. While the science experiences mentioned by students in these studies are consistent with the practices cited as being useful in the rest of the studies here, they took place out of the school setting and required resources that many urban students and schools may not have access to.

Examples from Haitian and Other Settings

The following three studies focus on more obvious cultural practices that proved useful within the science classrooms of Haitian and Hispanic students. The final study presented in this chapter presents a culturally appropriate pedagogy, another option for teaching practices that may be conducive to equal opportunity science experiences for marginalized students. Lee and Fradd (1995) produced a one shot case study that explored the science knowledge and cognitive strategy differences between Caucasian, African American, Hispanic, and Haitian students in fourth grade classrooms. Although old, this study is included here briefly because the following study by Hudicourt-Barnes directly addresses some of the observations and conclusions from this earlier work. If that were not the case, this study would have been included in the first section of this chapter with the research by Chiu, Chow, and Mcbride-Chang (2007) because it approaches a similar issue.

Participants in this study included 32 students organized into 16 dyads. These dyads included four Caucasian monolingual English, four African American, four bilingual Hispanic, and four bilingual Haitian and of the four dyads of each ethnolinguistic category, two were girls and two were boys. These students enrolled in the fourth grade in the south east of the United States while in this study. The researchers selected these students from the classes of eight teachers based on their diversity, parental permission, and literacy skills at grade level.

Participating students took part in three 50 minute activity sessions. The teachers participated in preparation courses for using the elicitation devices created by the researchers. These devices explored three different science topics; hurricanes, levers, and buoyancy. The researchers chose topics that they thought would have the most relevance across the diversity present in the study. The researchers arranged the topics into tasks designed to engage the student on multiple levels including the prompting of manipulation and generalizations, and completion of a literacy activity. The researchers used audio and video tape to record the completion of these tasks, and translated and analyzed the information for evidence of science knowledge and use of cognitive strategies. Member checking was employed, via a teacher review of the final report and students perceived strategy usage.

Lee and Fradd (1995) found that the students demonstrating the most science knowledge were the monolingual English students, followed by the African American students, the Hispanic students, and the Haitian students. It is important to note that not all of the students had the same amount of experience with the American school system. In terms of cognitive strategies employed the researchers found that the Caucasian, African American, and Hispanic students had similar frequencies of strategy usage while the Haitian students demonstrated strategies three times less. They characterized the Caucasian students as referring to metacognition in their science explorations the most, the African America students as using analogies the most, and the Hispanic students as using collaboration the most. They characterized the Haitian students as infrequently using cognitive strategies saying "they used more incipient strategies, such as observation and imitation" (Lee and Fradd, 1995, p. 808), devaluing the behaviors of these students and ignoring skills demonstrated by these students in the following paper.

The full detail of this research is not described here. However, the researchers were careful in the design of their work. The provided complete information on the instruments, selection, and task procedures. The work is dependable in that it reflects similar findings as the Chiu, Chow, and Mcbride-Chang (2007) study; that different strategies are used in learning across cultures, but also has the huge caveat of students having unequal experience within the same educational system. While culture may impact students science achievement, strategy, and attitudes, the next researcher, Hudicourt-Barnes (2003) considered it inappropriate for Lee and Fradd (1995) to make statements that suggest a diminished capacity for Haitian students in participating in science.

Hudicourt-Barnes (2003) in concert with the Cheche Konnen research group presented qualitative data for a series of case studies which asked whether Haitian children are capable of actively engaging in science classrooms through the description of the use of a culturally relevant argumentative technique. Her narrative presented three examples from three classes with three different teachers from two different schools. All teachers participated in research projects and professional development with Cheche Konnen. The students ranged from grades five to eight and ages ten to 14. All moved to the United States within three years prior to their participation in these case studies, had various levels of experience with the American school system, and all were learning English.

The research group observed in three classrooms and videotaped discussions that took place. The group transcribed interesting segments and discussed them with participating teachers in a reflective manner. The conversations took place in Haitian Creole, were transcribed into Creole and were then translated into English. As a technicality it is interesting to note that while the participating teachers received support from the Cheche Konnen center, they did not have text books in Creole to support their teaching. Hudicourt-Barnes (2003) conducted interpretive analysis of these discussions. The researcher describes the argumentative technique studied as *bay odyans*, a type of public argumentation that Haitians engage in regularly, and is similar to the dialogue in the scientific community in that it involves the presentation of ideas, analysis of those ideas, and presentation of reasoning and proof, while also providing opportunities for entertainment through comical participation.

In the first case described by the researcher, the researcher acted as the teacher in the discussion and the discussion followed a typical question-answer-evaluation format. It took place in a grade seven and eight bilingual classroom. The discussion was not planned, and involved learning about aspects of sound through interests in drumming. The discussion started when the researcher asked the students to describe what was on a computer screen showing a sound wave. The researcher described the conversation having a natural feel, despite the more traditional stance taken by the teacher. Two students emerged in this conversation as key players, one taking a more theoretical approach to the conversation, and the other responding theatrically to the first student's musings. This conversation demonstrated the students' capacity to be interactive in their science classes. The second case takes place in a similar environment though the topic of discussion is snail reproductive rates. A student initiated this discussion by making an assertion, which was repeated and challenged by another student. In this conversation the teacher played only a supportive role and the students did most of the talking. After the initiation another student took up the conversation, challenging the initiator and pushing them to reconsider their reasoning. Again the students were engaged with the content and made progress in their thinking during the discussion. The third case presented was similar in its characteristics, students initiated and challenged in attempting to form science related conclusions while the teacher encouraged the conversation.

This research is believable, but open to interpretation. The research sample is quite small, and it seems that the work would be confirmable given sufficient background on the topic. However, the dependability is questionable since much of the research with this particular cultural group comes from the same set of researchers. Again the transferability of this work, as with some others in this section, is existent but very general in the sense that it revolves around positive science experiences resulting from the allowance of the students' world to enter the classroom.

Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001) presented two qualitative case studies documenting successful use of strategies suggested to be culturally specific in the science experiences of Haitian and Hispanic students. They addressed the question of what sense making strategies these students used in science activities. The participants in this study included two boys, Jean-Charles, a bilingual Haitian sixth grader that received a learning disabilities tutor to help with his language development, and Emilio, a fifth grade bilingual Hispanic student. Data collection for this work involved observation, interviews using open ended tasks for elicitation, and narrative ethnographic analysis.

In the case of Jean-Charles the researchers described the following case. The students in Jean-Charles participated in a discussion of whether or why humans do or don't change in the same way as an insect does through metamorphosis. The researchers witnessed a lively discussion in which the students essentially struggled with whether or not they needed more than one type of change to describe the differences or similarities. Jean-Charles presented his ideas in this discussion from a developmental perspective, using the word change in its broadest sense. Students in this discussion referred to everyday examples to support their perspectives, such as taking on an off clothing, playing basket ball and losing skin when you wash your hands afterward, and in Jean-Charles case the evidence that babies change from when they are in their mother's womb till when they grow up. In follow up interviews, Jean-Charles demonstrated a creative use of language, in both Haitian Creole and English, in trying to more accurately formulate his ideas around change and development. The researchers suggested that the usage of everyday language in the science classroom led to a greater awareness of the language on the part of Jean-Charles.

In the case of Emilio, the researchers described the students in his class using imagined assumptions as factual knowledge in their study of ant behavior. While this may seem inappropriate of a science classroom, the researchers found that it was quite useful in an interview with Emilio and two other students in which they asked the students about the ants' preference for light or dark and asked how they would prove their beliefs. Through a process of repeatedly imagining the situation from the ants perspective, Emilio created a number of experimental designs controlling for a variety of experimental factors. Thus this process of imagination in the classroom was an asset for him in terms of experimental design.

Selection processes for this work were not described. I expect that this is because these were two cases that emerged as particularly interesting from a larger body of work by researchers associated with the Cheche Konnan research group. The researcher did clearly describe their theoretical positioning and gave very in-depth accounts of the classroom situations. Little information was provided about the experimental design, making it hard to confirm, and it is not clear whether triangulation or member checking were used. These results seem dependable in terms of other work done, by the same research group, with other Haitian students, though it is not transferable to other context within the work presented in this chapter.

Rodriguez, Jones, Pang, and Park (2004), conducted a pretest/posttest and ethnographic study in which qualitative and quantitative data were collected to answer how university outreach programs can promote academic achievement and identity development among culturally diverse tenth grade students. The study's quantitative findings demonstrated that the students' academic competency improved significantly each year that the program was held. The qualitative data suggested that the students appreciated the culturally responsive practices used as a social framework for the program.

This San Diego State University outreach program selected participants based on recruitment through a network of teachers, school counselors, and outreach program counselors. Selection also required that participants be either the first person from their family to attend a four year college or be from a low income family. The program required students to submit a written application for review as well, with the acceptance of 50 students per year. This study analyzed four programs worth of data involving 193 participants, 53.5 percent of which were female and 46.5 percent of which were male. All students attending the program were in the 10^{th} grade. Most participants originated from California, Arizona, Nevada, New Mexico, Hawaii, and American Samoa. Ethnic composition of the participants over the four years was 45.75 percent Mexican American, 17 percent Pacific Islander, 21 percent African American, 12.25 percent Native American, and 4 percent other. 40 percent of these students had a first language other than English. The ethnic background of the staff participating in the study has been largely Latina/o for all four years.

Each year from 1998 to 2002, 50 students participated in this program for an intensive six week period during the summer. The programs goal is to promote academic and cultural identity development through the implementation of culturally responsive practices. The academic aspects of the program included participating in courses on biomedical science, statistics, literacy, and technology; participating in fieldtrips; and participating in mandatory recreational periods. The culturally responsive aspects of the program included using hands on experiences, developing relationships and understanding between staff and students, providing intellectual and cultural scaffolding, and integrating students everyday experience into the classroom. The staff focused on issues of status equalization which involves creating an environment with no dominant group, bicultural affirmation which involves mixing cultural practices in a respectful way, and attainment of codes of power which could also be described as the tools of the cultural norm.

Rodriguez, Jones, Pang, and Park (2004) collected data from written assessments and student interviews. Quantitative data addressed whether or not the program increased the students academic competencies in science. The instrument used for collection of Quantitative data was that Test of Integrative Process Skills (TIPS) which tests student ability to identify variables, hypotheses and definitions; to design experiments; and to interpret data. The researchers collected qualitative data from group interview in which they tried to determine whether the program helped participants to form cultural identities.

The findings from the quantitative data determined that there was a significant increase in the posttest TIPS scores compared to the pretest scores. The TIPS instrument is designed to show when test takers become better scientific thinkers and better problem solvers. Pretest mean scores ranged from 20.16 to 20.35 over the four years with a standard deviation of 5.22 to 6.16. Posttest mean scores ranged from 23.82 to 25.30 with a standard deviation of 5.39 to 6.67. A mean comparison for pre and posttest scores determined the increase significant at a level of $p < .05$.

Rodriguez, Jones, Pang, and Park (2004) shared comments provided by students as qualitative data. Student interviews suggested that students felt safe in this environment, that there was no conflict between ethnic groups within the program, that they appreciated the diversity in the program, that they had opportunities to learn about other students' cultures, and that the program pushed them to improve themselves. In general participants felt powerful, comfortable, and accepted. The researchers analyzed these comments and suggested that they were representative of status equalization, biracial affirmation, and code of power processes taking place. (Describe)

Again, this article is credible but is not substantial on its own because of the experimental design used by the investigators. This study's strengths include the overwhelming positive nature of the student comments, particularly with regard to their awareness of the culturally relevant practices implemented and their appreciation of those practices. Additionally these researchers went a step further than other action research papers in that they used a pretest/posttest model and conducted statistical analysis of their findings which gives the quantitative data more credibility.

However, like other action research articles mentioned, there is no control group involved in this study and no way of relating the students' academic success with the conditions of the environment. These two areas of assessment are unfortunately treated separately. Another weakness of this study is that the selection process in this study is particularly problematic because the group may be seeking participants who are highly motivated in science and inclined toward the framework of social rules set up within the program. The students in this study are ethnically diverse but the authors provide no information about the history of the participants as students or about any previous cross-cultural challenges they may have had.

Summary

This section reviewed two examples of potentially cultural practices that have found useful niches within their science classrooms. In response to a study by Lee and Fradd (1995) suggesting Haitian students' cultural incompetence in the science classroom, Hudicourt-Barnes (2003) presented a number of cases in which the Haitian practice of Bay Odans, a sort of argumentation, led to lively debates and refinement of scientific ideas in the science classroom with Haitian students. Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001) presented another set of case studies in which, difficulty with language led one Haitian student to refine his scientific ideas and become more aware of language, and the use of imagination assisted a Hispanic boy in developing an experimental design.

Chapter Summary

Chapter three presented a critical review of the current research available in the field of multicultural science education. This review began with a presentation of ten articles attending to the question of the impact that culture has on science education. While most of these works were correlational, all suggested that culture does have an impact on students' attitude and achievement in science. This consensus recommends that the issue not be ignored, but does not address how the issue should be handled.

The review then continued with an exploration of the impact of practices consistent with multicultural science education on attitudes and achievement. The studies presented here suggested that the incorporation of students' worldviews and prior knowledge can increase students positive attitudes toward science and their motivation in science. This part of the review also noted that pedagogical techniques that are supportive of diversity and consistent with multicultural science education appear to support the learning of science by all students rather than a specific marginalized group, such as African American students in urban centers. Finally the last few studies presented the creative use of students culturally gained skills, for example a form of argumentation, in the science classroom.

This review consisted of a somewhat eclectic sampling of articles that painted a fairly accurate representation of the quality and scope of work in the field, though any of the subsections could be represented by many more studies. In addition, there are many other fields of interest within multicultural science education that unfortunately had to be left out of this review. Examples include the interaction of science education and language, the role of teachers as barriers to multicultural practices in science, the effectiveness of preservice programs in helping teachers address diversity in the science classroom. Unfortunately there is a lack of research with regard to particular practices, for example, which way is the most effective to incorporate indigenous knowledge into a curriculum. As such this review is limited in terms of its implications and usefulness for classroom practice. Additionally unfortunate is the quality of many of the studies presented, many of which were correlational survey based or small action research studies. This will be further discussed the following chapter.

Chapter four will now present a summary of the first three chapters with a more in depth summary of the research findings from chapter three. Chapter four will also discuss implications for classroom practice based on this research and areas in need of further research, both discussed in relation to the context presented in the rationale and history chapters.

CHAPTER FOUR: CONCLUSION

Introduction

The purpose of this paper was to determine through the completion of a critical review of research in the field of multicultural science education a) the ways in which culture has an impact on science education and learning and b) how multicultural education practices might address the interaction between culture and science in the classroom.

Chapter one introduced the purpose of this review and described the epistemological view points at its heart. Chapter one described the importance of science education at this juncture in history and views on how different cultural view points can contribute to the wealth of scientific progress. Chapter one introduced the opposing views of science as either a universal or cultural construct, and considered how much faith should be put into the way that Western cultures practice science and how much acknowledgement should be given to the cultural nature of the scientist. This chapter also explored traditional science education and posed the question of whether the practices typical of creating an elite group of scientists are capable of providing all people with equal opportunities in their science education. In doing so the chapter addressed different theories of learning. Finally, the rationale described different types of multicultural education and described how multicultural science education fit into this framework, and acknowledged the complexity of multicultural science education. Important definitions and limitations to this review were also included.

Chapter two, organized chronologically, presented a brief history related to multicultural science education. It started with a description scientific traditions belonging to cultural groups considered marginalized by science. Following that description, the history entered into a discussion of science education in the United States, in terms of its original purpose in the educational system, and its use, purposeful or not, as an oppressive force that is traditionally androcentric and Eurocentric. A very brief history of multicultural education was given, as being tied directly to the abhorrent treatment of African Americans in the United States, and arising from the civil rights and ethnic studies movements in the 1960s. The history of science education was again pursued following reform movements based on political and economic concerns. Finally, chapter two discussed multicultural science education as having become more prominent within the past twenty five years and being supported by a number of current reform documents.

Chapter three presented a critical review of the current research on multicultural science education. The first ten papers discussed data relevant to the question of whether culture impacts science education and learning. These papers illustrated that the way people think students should learn science changes across culture. They also showed that as the student's culture diverges from the culture of Western science, the student's attitude toward and achievement in science often suffers. The next twenty three papers belonged to the second section of chapter three and were divided into two categories: papers addressing multicultural practices with regard to worldview, ways of knowing, and prior knowledge; and papers addressing learning preferences and skills. The 9 papers in the first half of section two suggested that incorporation of indigenous knowledge into curriculum can increase attitudes, achievement, and motivation in science. However, some authors pointed out other variables that hold much sway over science education in areas where this practice might be employed. The second half of this section suggested that practices that are culture specific, or in urban environments constructivist or empowering, can improve students' attitude and achievement in science. Again, some authors suggested that there are other factors more important than culture involved in students' science learning.

This final chapter, chapter four, summarizes the findings from the current research on multicultural science education presented in chapter three, discusses implications from the research for classroom practice, and offers suggestions of areas in need of further research in the realm of multicultural science education.

Summary of Findings

Impact of Culture on Science Education

The ten studies in section one of chapter three explored, through a variety of view points, how culture impacts science education and learning. The first four of these studies demonstrated structural, teacher based, and classroom-based implications for the interaction of culture with school science (Cogan, Wang, and Schmidt, 2001; Chiu, Chow, and Mcbride-Chang, 2007; Brok, Fisher, Rickards, and Bull, 2006; Khine and Fisher, 2004). The remainder of these studies addressed the issue of how a student's culture impacts their science learning (James, 2006; Kesamang, 2002; Medina-Jerez, 2007/2008).

The incorporation of the first four studies in this section is not intended to prove anything, but rather to suggest the scope of the interaction between culture and science. Cogan, Wang, and Schmidt (2001) conducted a rather large international study with eighth grade students which sought to determine what culturally or nationally specific patterns arose in terms of how science curriculum was organized. The findings of this study implied through analysis of content standards, textbooks, and teacher instruction that differences in the presence of various topics across countries is potentially representative in cultural differences in how different populations address science education. However, it must be noted that this study did not take into account the way that science courses are divided, which may be one of the largest factors in the trends that were noted.

In another cross national study, Chiu, Chow, and Mcbride-Chang (2007) proposed that culture may impact science education in terms of the learning strategies employed in the classroom. This study involved gathering self-reported strategies from 15 year old students. Interestingly, the researchers found that students' self reported metacognition was positively linked to achievement scores in individualistic countries; while students' peer reported use of metacognition was positively linked to achievement scores in a number of collectivist oriented countries. These results were significant to $p < .05$ or less. This study was more trustworthy than the previous, however, both are one shot case studies producing correlational data.

Brok, Fisher, Rickards, and Bull (2006) examined eighth grade California student perceptions of their classroom environment. Ethnicity analysis revealed interesting results in that class make up with regard to ethnicity was linked to various scales. For example the percentage of Hispanic students in the class correlated negatively with the perceived cooperation, the percentage of African American students related negatively with perceived cooperation and involvement, and the percentage of Native American students in the class correlated positively to perceptions of student cohesiveness. An additional finding showed that an increase in the number of ethnicities in the classroom significantly increased student perceptions of cohesiveness. It seems logical that if there is no dominant group in a room, there would be less sense of division within that grouping.

Khine and Fisher (2004) specifically addressed the culture of the teacher as an aspect of the learning environment that can impact science education and found that students in secondary science classes in Brunei responded more positively to cultural characteristics of Western teachers than Asian teachers and that this is correlated with their attitudes in the classroom. Taken together these studies do not prove anything, but do indicate that culture can interact with science education in many ways.

The next six studies addressed the question of what impact a student's culture can have on their attitude and achievement in science.

James (2006) and Kesamang (2002) both performed studies correlating indigenous students' cultural congruency with their attitudes and, in the

Kesamang study, achievement. In James' (2006) work, the research findings suggested that having a strong Native American identity is correlated with having negative perceptions about science and technology. Kesamang (2002) determined that Setswana students have a positive view of science; although he also revealed a negative correlation between socio-cultural background and attitude toward science and socio-cultural background and science achievement.

Medina-Jerez (2007, 2008) published two case studies. The first study released involved an exploration of the conceptions held by middle and high school students in Colombia about nature, and the second, an exploration of how students from the same demographic perceive their worldviews to interact with the Western science taught at school. This work revealed that the students were inclined to describe nature in ways that relate to their own world before relating nature to Western science. Most students described nature in terms of its origin in God. The findings from the second study suggested that students addressed science as something compartmentalized from their worlds. The researcher inferred that part of the problem may be in the teaching practices.

On American soil, Catsambis (1995), revealed interactions related to the students' ethnic background and science attitudes among eighth graders. With regard to science achievement, this work demonstrated that African American and Latino students received lower grades and scored lower on tests than White students. In addition, with the exception of the African American females, the Caucasian students were less afraid to ask questions in science class. African American and Latino students also aspired less for careers in science

In the Netherlands, Dekkers, Bosker, and Driessen (2000) displayed that interaction between social background characteristics is not always negatively related to school success in science with secondary students. While the researchers indicated no mechanism in the results, the research results suggested that choice of taking science classes is influenced in complex ways by socioeconomic status, sex, and ethnicity. For example, ethnic minority girls professed taking fewer science classes than any other group, regardless of high or low socioeconomic status. Ethnic minority boys, on the other hand, demonstrated a strong susceptibility to decreased success as represented by enrollment in science courses due to low socioeconomic standing.

Finally, in another study conducted in the Netherlands by Langen, Rekers-Mombarg, and Dekkers (2006), the researchers determined that group differences exist in selection of math and science courses for secondary students. The research findings suggested that ethnicity is significantly related to number of science courses taken. Girls demonstrated a distinctive pattern where minority girls with low parental education chose to take substantially more science classes compared to non-minority girl. Additionally, non-minority girls with high parental education took more science classes than ethnic minorities with high parental education. This work hinted that group specific choices exist and are related to educational disadvantage within the study population.

Summary

There are a number of weaknesses present in many of the experimental designs of the above mentioned studies. Many of the studies did not include enough information in their presentation to be reproducible, many functioned with small sample sizes, and all were one shot case studies. All of these studies are weak, and none of them show any causality. Also, many of the researchers presented descriptive quantitative data with no statistical analysis. However, given that all studies are in agreement that there are culturally specific attitudinal patterns toward science, the issue gains more credibility even if each article does not. The suggestion that it is valid and important to claim that culture can have an impact on a students science experience is in consensus with ethnicity specific achievement patterns in science and with a seminal article from the field of multicultural science education. Oakes (1990) wrote this article, a survey of the available data at the time, with the result that the community of science educators no longer felt that they could ignore the cultural aspects of the science classroom.

Impact of Multicultural Education Practices on Science Attitudes and Achievement

World Views, Ways of Knowing, and Prior Knowledge

This section contained nine studies; six demonstrated the impact of pedagogy incorporating marginalized students worldviews on science attitudes and achievement and the last three articles presented caveats to the work preceding it.

Jegede and Okebukola (1991), aimed to determine whether discussion of socio-cultural topics related to science topics improved students attitudes toward learning science with grade ten students in Nigeria. The research findings demonstrated that the experimental group had significantly greater positive views of their experience than the control group, significantly higher science scores, more freedom to give their opinions, and realized the contents relevance to their own lives. This work was included as it was one of the first of its kind in the field of multicultural science education.

In another study, Herbert (2004) explored student learning after participating in a unit involving the incorporation of traditional beliefs with Western science. This work occurred in Trinidad and Tobago with middle and high school age female students. The findings supported that processes of collateral learning were taking place in these units.

Two studies explored the incorporation of Hawaiian traditional ecological knowledge into curricula. In the first, Gibson and Puniwai (2006) found, through the incorporation of this knowledge in an authentic way and in a way suggesting the harmony of this knowledge with Western science, that the participating middle and high school students felt that they learned a lot, had positive outlooks about their experience, and were interested in learning more about the interaction of science and culture. Feinstein (2004) conducted the second study presented in this context; it involved participants at the high school and college levels. This study was different from the first in that the population was not all Native Hawaiian. Similar methods were employed in both studies. In this study students also reported learning a lot, and also reported the work as motivating them to the extent of transforming the identity of one of the participants.

Klos (2006) conducted an action research project in South Africa that explored whether the inclusion of indigenous knowledge in a science support program for college level students could be linked to mastery of science related literacy skills. She found that students demonstrated successful understanding, motivation in the course, positive perspective of the course, and positive self concept through analysis of the results.

Barton (1998), addressed the issue of the usefulness of a science education that is culturally relevant. Specifically Barton questioned what a science curriculum would look like created from the vantage point of homeless children and found that different life situations have a large impact on how students think about science, and that when this is done, students generally marginalized by science might become quite interested in it, at least this was the case with three elementary age girls. The researcher also determined that the borders of science had to be less definite or traditional in creating a science curriculum with these children.

The next three studies presented in this section addressed conflicting view points about the importance of cultural background in the determination of science attitudes. First, Zhao (2007) presented a case study of established Asian American scientists exploring the question of whether or not culturally appropriate pedagogy is necessary in science for this group. The research findings revealed that the interviewees disagreed that their cultural heritage interfered with their science experiences. Instead they argued that the holistic thought patterns in East Asian thinking supported their pursuit of scientific understanding, as did an appreciation of the artistic aspects of science. However, the scientists acknowledged the lack of a systemic scientific approach such as exists in Western science, and therefore this dominant tradition becomes a necessity. These scientists generally supported exposure to both practices.

The last two studies in this section presented critical caveats to the multicultural work presented in this section, namely in terms of the complexity of the situation. Dzama and Osborne (1999) sought to determine the extent to which traditional beliefs impact student performance and what other variables are in effect with high school age students in Malawi. The findings demonstrated a number of correlations between the available data including a significant negative correlation between traditional attitudes and beliefs and performance on a science test. However, the researchers also revealed that traditional beliefs and attitudes accounted for only 11 to 20 percent of the total variance in scores. Nielsen and Nashon (2007) explored the reasons that high school students do not have as much access to science in rural British Columbian towns that are not linked to student culture. The researchers revealed barriers including lack of staffing, lack of specialized teachers, and poor teacher-student relationships resulting from a lack of time to develop trust.

<u>Summary</u>

This section reviewed the research presented in, *Impact with Regard to Practices Involving World Views, Ways of Knowing, and Prior Knowledge*. The first six studies in this section are in agreement, across different cultural contexts, that the incorporation of students' worldviews and prior knowledge into science curriculum can increase students positive attitudes toward science, their science identity, and their achievement in science (Jegede and Okebukola, 1991; Herbert, 2004; Klos, 2006; Gibson and Puniwai, 2006; Feinstein, 2004; Barton, 1998). Particularly interesting are the studies working with Hawaiian traditional knowledge, because the studies were designed differently and included very different sets of participants, and still produced similar results. However, all but the Jegede and Okebukola (1991) research involved small sample sizes, were designed as action research with insufficient presentation or minimal analysis, and many of the work were conducted outside of the classroom setting. In addition, many of these works look only at the use of such practices with the population of interest rather than with a diverse population, which does not address some of my own interests in pursuing the topic of multicultural science education.

The last three studies in this section presented perspectives in conflict with the suggested usefulness of incorporating the ways of knowing from students marginalized from science. Zhao (2007) interviewed with Asian scientists and reflected that they felt their cultural heritage was not an impediment to studying science. Dzama and Osborne (1999), and Nielsen and Nashon (2007) suggested that while culture is part of the picture, it will not be a panacea as there are also a number of other factors that should be considered in students' science experiences.

Culturally Specific Practices and Skills

This section contained thirteen studies; nine revolving around practices consistent with multicultural science education and suggested for students in urban areas, particular African American students, while the last four focus on the incorporation of cultural practices from Haiti in the science classroom.

In the first study in this section, Parsons, Travis, and Simpson (2005) explored the learning preferences of eighth grade students and what the impact is when these learning preferences are actualized. Specifically, the research group framed these preferences in terms of the black cultural ethos including practices that involve movement, verve, and communalism. The findings from this work demonstrated that students with a strong preference for practices congruence with BCE practices improved more on their post test scores regardless of their cultural/ethnic background. This study was perhaps the most trustworthy in design of all presented in chapter three.

Elmsky (2005) sought to determine the impact of programs embracing the interests and behaviors of low socioeconomic standing high school age African American intercity youth. The students created a 40 minute video entitled *Sound in the City* during their ten week summer break. Elmsky (2005) described the students initial wanderings in the creation of the movie as being very Western science oriented, involving the defining of sound related concepts. Eventually, the students related the information to their worlds, particularly, they related many of the sound concepts to rap music. In the creation of the movie, the students also employed the skills they had at rap, dance, speaking, and the creation of visual aides. The researcher noted that as students progressed in relating the physics material to their own experiences, and supported each others learning in the pursuit of making the project their own. In addition the researcher referred to energy, movement, verve, and orality, characteristics correlated with African American culture as suggested by the previous work by the Parsons group (2005). Additionally, this study found the project to be empowering for the students.

Moore (2007) supported the use of similar practices through a discussion of three teachers’ coping strategies in high schools in low performing school districts. These teachers shared information about the district that provided insights into their work ask teachers, the backgrounds of the students and the changes that have taken place in that district. The teachers reported students’ perceptions of the schools as being poor quality and of themselves as being inferior. To combat this perception, the teachers employed various pedagogical and communication strategies in line with multicultural science education. For example, one teacher entered his students into an engineering contest. The students worked hard and doubted themselves along the way, but ended up winning multiple prizes and being featured on the news. This teacher stated that this gave the students pride and lifted their spirits.

Kahle, Meece, and Scantlebury (2000) explored whether standards-based teaching practices, such as a community orientation, inquiry based teaching, and multiple modes of presentation, make a difference in terms of achievement for diverse students in urban environments at the high and middle school levels. The results of this work also suggested that the African American sample did better, in terms of achievement, with this sort of instruction.

The Lynch, Kuipers, Pyke, and Szesze (2005) research group investigated a similar question about the impact of standards based instruction via a highly rated science curriculum, on the achievement and engagement of diverse students in an urban setting at the eighth grade level. However, these researchers compared the results of subgroups, unlike the previous study which only looked at data for African American students. In doing so they found that all students, rather than one marginalized group, benefited from the instruction in terms of achievement and motivation, thus not closing the achievement gap. Ethnographic aspects of this research, showed that the White male in the group of four students functioned as the authority in the group, partially as a result of using more scientific language, despite misconceptions that he presented to the group.

Similarly, Odom, Stoddard, and LaNasa (2007) conducted an investigation which addressed the relationship between particular student centered instructional practices and diverse students attitudes and achievement in science. Student centered practices examined in this study included group experimentation, learning from classmates, an emphasis on talking in problem solving, and evidence based communication practices. Teacher centered practices included the use of handout notes, taking notes, teacher demos, and homework. Not surprisingly, within this diverse eighth grade population, the data suggested that student centered practices had a significant and positive correlation with both student achievement and attitude.

Research by Cardona, Spiegel, Alves, Ducommun, Henriques-Pons, and Araujo-Jorge (2007) also pointed to these sorts of practices being cross culturally appreciated. This group sought to determine the cross national applicability of a biology game created in Brazil, specifically they wished to evaluate the acceptance of the game in terms of motivation with tenth grade students in Switzerland. The researchers found a similar response to the game in Switzerland as in Brazil, generally the students enjoyed it and revealed that they would like more similar lessons.

Similar to the three concluding articles in the previous section, Russel and Atwater (2005) and Hanson (2007) both examined what factors that African American students attribute to their pursuit of science or enjoyment of science experiences. In both cases the researchers found factors other than culture self professed by students to be critical to their science experiences including parental influence, teacher influence, and precollege experiences in science. These works also reported awareness of racism in these pursuits and feelings of not being welcomed in the scientific community. Interestingly, many of these students had hands on, real world relevant science experiences prior to college, which might indicate a lack of resources as being a far more critical factor in the poor performance of urban students in science.

Summary

The nine studies reviewed here focused primarily on methods considered consistent with the NSTA's definition of multicultural science education in the context of urban schools with high attendance from African American students. Essentially, all of these studies suggested that practices such as incorporating movement into class, use of cooperative learning, multiple presentation options, and inquiry based hands on learning are beneficial for marginalized students (Elmsky, 2005; Moore, 2007; Kahle, Meece, and Scantlebury, 2000; Odom, Stoddard, and LaNasa, 2007).

However, the research including comparison groups all indicated that these methods support the learning of science by all students and thus do nothing to address the achievement gap and unequal opportunity for marginalized groups in science education (Parsons, Travis, and Simpson, 2005; Lynch, Kuipers, Pyke, and Szesze, 2005). This leads to the question of whether supposedly cultural characteristics of African American students, are really cultural, and additionally, what then are the critical factors in giving these students opportunities for equal achievement. The Cardona, Spiegel, Alves, Ducommun, Henriques-Pons, and Araujo-Jorge (2007) study also demonstrated cross cultural acceptance of a pedagogical tool that is similar to those that are consistent with the descriptors in other studies in this section. Finally Russel and Atwater (2005) and Hanson (2007) both explored the self perceived science experiences of African Americans, and in both cases the study participants suggested a number of factors as being important to their pursuit.

The studies presented in this section are more structurally sound than the work presented in the worldviews section. A number of the experiments here were designed as pretest-post test experiments that included control groups, though, there is still the presence of a few action research studies presenting insufficient information. As a whole, these works support each other and are dependable. All of the studies indicate that pedagogical techniques that may be described as consistent with the black cultural ethos, multicultural science education, constructivism, or student centered practices are beneficial for African American and other diverse students from urban centers. However, they also appear to be supportive of everyone, leaving the question of the impact of culture in the science education of African American students. The results of these works may indicate low socioeconomic status and a lack of resources as being more relevant factors, as they are present and in the shadows of most of these studies.

Examples from Haitian and Other Settings

The following three studies focused on more obvious cultural practices that found usefulness within the science classroom for Haitian and Hispanic students. This section started with work by Lee and Fradd (1995) which was similar to the studies presented in the first section of chapter three illustrating an impact of culture on science attitudes and preferences. The researchers observed elementary students from four ethnolinguistic backgrounds for their learning strategies in completing science tasks.

Lee and Fradd (1995) found that the Caucasian, African American, and Hispanic students had similar frequencies of strategy usage while the Haitian students demonstrated strategies less frequently. They characterized the Caucasian students as referring to metacognition in their science explorations the most, the African America students as using analogies the most, and the Hispanic students as using collaboration the most. They characterized the Haitian students as infrequently using cognitive strategies saying “they used more incipient strategies, such as observation and imitation” (Lee and Fradd, 1995, p. 808).

In response, Hudicourt-Barnes (2003) presented a series of case studies which explored whether Haitian children, in grades five through eight, are capable of actively engaging in science classrooms through the description of the use of a culturally relevant argumentative technique. The researcher described students becoming active in the science classroom through making assertions, defending claims, reconsidering perspectives, and challenging each other. Similarly Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001) presented two case studies documenting successful use of strategies suggested to be culturally specific in the science experiences of Haitian and Hispanic students. Their research presented a Haitian student that was able to refine his scientific ideas and become more aware of language after being involved in a colloquial and experience based discussion about a science topic, and the use of imagination assisted a Hispanic boy in developing an experimental design.

Summary

This section reviewed two examples of cultural practices that have found purpose within their science classrooms. In response to a study by Lee and Fradd (1995) suggesting Haitian students' cultural incompetence in the science classroom, Hudicourt-Barnes (2003) presented a number of cases in which the Haitian practice of Bay Odans, a sort of argumentation, led to lively debates and refinement of scientific ideas in the science classroom with Haitian students. Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001) presented a similar demonstration.

These studies are interesting, though they are presented by the same research group which does not add to their credibility. These studies would benefit greatly from other examples from other cultures.

Summary

This section reviewed the research findings presented in chapter three, a representation of the current research available in the field of multicultural science education. This review was broad in its scope but created a representative sample of the research available in the field. The complexity of the issue complicates the implications for classroom practice derived from these findings.

This summary of findings began with a presentation of ten articles attending to the question of the impact that culture has on science education. Although almost all of these works were correlational, all suggested that culture does have an impact on students' attitude and achievement in science. It also proposed that this interaction is generally negative when the students' culture and the culture of science are at odds or incongruent. This consensus recommends that the issue not be ignored, but does not address how the issue should be handled and additionally does not propose a mechanism for the interaction.

The summary of findings then continued with an exploration of the impact of practices consistent with multicultural science education on attitudes and achievement. The studies were organized into groups focusing on the incorporation of students' worldviews and prior knowledge or the incorporation of students' cultural practices and skills. The summary of findings with regard to the incorporation of students' worldviews demonstrated that the practice can increase students' positive attitudes toward science and their motivation in science. The summary of findings with regard to the incorporation of cultural practices or skills noted that pedagogical techniques that are supportive of diversity and consistent with multicultural science education appear to support the learning of science by all students rather than a specific marginalized group, such as African American students in urban centers. Finally the last few studies presented the creative use of students' culturally gained skills, for example a form of argumentation, in the science classroom. Chapter four continues into a discussion of this review in terms of the implications it recommends for classroom practice.

Implications for Practice

The findings from this review are generally in favor of being aware of the cultural factor in the science classroom and of the implementation of multicultural science practices. Unfortunately these studies are not in-depth enough to advocate particular practices as being more appropriate or useful than others. Additionally, much of this work was conducted outside of the classroom setting, in action research projects or summer programs. This leaves the reader, rather than with concrete steps to take, with a philosophical issue to consider, specifically, what one supposes the goals of science education should be. Critics of multicultural science education assert that these practices dumb down the material, take too much time, and cannot support the elite thinkers needed to go into the science industry (Southerland, 2000). However, current reforms uphold the importance of science education for all people, particularly as a way to enrich the worldviews present in the realm of science and potentially lead to new insights in addressing world problems. At the same time, these reform documents do not currently state how to go about teaching science across diversity (Russel and Atwater, 2005). One finding from these studies is that, a science for all curriculum, will undoubtedly take many shapes across different contexts.

One implication from this review is that there needs to be a thorough consideration of the context, of the students, of the pedagogical tools, and of what is being replaced before implementing any multicultural science practices.

It is quite clear, as presented in the first section of chapter three and consistent with theories from the likes of Vygotsky, that there is an inter play between the students' culture and science that can result in negative outcomes. It seems safe to say that multicultural practices presented in chapter three that are consistent with constructivist learning theory and student centered teaching should be practiced in all types of classrooms.

However, as research in this field develops, it will be important for teachers that are paying attention to continue considering their students as individuals first, though also in relation to their respective culture or cultures. This is also important because the goals of multicultural science education are not limited to providing all students with equal access to science in segregated populations. Rather, it should also function to serve the cause of social justice through careful inclusion in standard curricula, making all students more aware of systems of oppression, of their role in those systems, and of their own identities and purposes.

Summary

This section suggests that the current research in the realm of multicultural science education has not evolved enough to be considered without great care. Chapter three demonstrated that culture and science are intertwined and also that often, the use of multicultural strategies have a positive impact on student attitudes and achievement. The following section will discuss in-depth why, despite this seemingly positive presentation of multicultural practices in science classes, it is important to be always considerate and open to opposing perspectives as a proponent of the multicultural view point.

Further Research

The previous section, addressed the conclusions that were substantiated by the research review in chapter three. This section will address the reasons why other conclusions could not be substantiated as a result of deficiencies in the field of research.

While there have been historical undercurrents of humanistic science movements through time, multicultural science education has only emerged prominently in educational debates and research within the past twenty five years. Additionally, as I discovered in conducting research and as supported by Krugly-Smolska (2007), there is a rather large and comprehensive body of work addressing the many faces of multicultural science education, however, a huge amount of the literature on multicultural science education is of the persuasive essay sort. As this work is rooted in fundamental epistemologies surrounding the nature of science and learning, these debates, and such publications continue to be produced currently.

As far as the research in the field is concerned, it seems to have barely begun to produce studies that have decent validity, support explicitly described practices, and investigate the mechanism involved in the interactions between student culture and Western science culture. As such there are many critical developments that need to occur within the field of multicultural science education research. First, this section will address particular shortcomings in design of research populations within this field.

Research Samples

A number of issues emerged in the review of the current research having to do with the way the researchers organized or selected their research samples. As a minor point, a large portion of the studies presented here were done with students in the eighth grade. Perhaps, this is because this age seems to be where students are starting to have an awareness of their identity and its relation to the world. This sort of reasoning has been suggested in gender studies (Catsambis, 1995). If this is the case, then it is logical and important to represent this issue at this age. Though, while preferences may be developing earlier students education, many students do not start thinking realistically about their path until high school or college. As such, it would be important to conduct more studies looking at motivation and attitude in a high school setting.

Similarly, a large proportion of the studies presented in chapter three take place with people living in impoverished areas, yet the researchers tend to note the poverty in passing. Particularly in the work with African American students, where there seems not to be a culturally specific way of increasing their attitudes or achievement in science, the issue of poverty becomes a critical candidate for exploration and none of these studies approached that cultural perspective. There are other populations that would be particularly interesting to investigate as well that seem to be relatively absent from the research in the field, unless the research is done over seas. Particularly I am thinking about Asian Americans.

This population is interesting to investigate because of their apparent ease of "cultural border crossing" (Aikenhead, 1996). This cultural heritage of this group shares some similarities with some Native American perspectives such as a preference for holistic perspectives, and a history of oppression by European Americans.

A more important critique of the populations studied has to do with what I perceive to be the purposes of multicultural science education. One purpose is to allow all students equal access to science and enjoyment of science. In these cases, it makes sense to do research which focuses on a particular marginalized population and chart their progress in response to various interventions. Many of the studies presented under the Worldviews section of chapter three do this, such as the work by Jegede and Okebukola (1991) and the work by Gibson and Puniwai (2006).

Another purpose is related to the proclaimed need for a richer variety of perspectives within science, as it relates to facing the problems of tomorrow. In this case it becomes important to do similar research in settings that are composed of diverse groups, partially because of what facing those problems will require in terms of communication and acceptance and partially because there is less appeal toward developing a wealth of knowledge about multicultural science practices if they can only be applied in segregated settings. How will Caucasian students respond to science units that incorporate traditional ecological knowledge? The work of Feinstein (2004) and Lynche, Kuipers, Pyke, and Szesze (2005) are the only two works presented in this review that explore multicultural practices in diverse groups. This sort of work is particularly lacking within the American classroom setting. It has been suggested, that a reason for this, and for why humanistic reforms in science have not taken more root in the science classrooms, is because the teachers serve as barriers to implementation and interest in supporting investigations (Nielsen, 2007).

Additionally, a number of studies in the first section of chapter three, particularly those of James (2006) and Kesamang (2002) only consider the attitudes of the marginalized population without comparing them to students suggested to have an easier time navigating scientific culture. Finally these studies and studies having to do with practices are often conducted abroad in somewhat homogeneous populations. While this section described factors related to the populations studied in this field of research, the next will describe sort comings around the complex nature of multicultural science education.

Addressing Complexity

Studies such as the one presented from Dzama and Osborne (1999) that analyze where the variance emerges from in student attitudes and achievement in science are incredibly important. Similarly, I was unable to find any studies indicating a mechanism for the interaction between a students' culture and their experience with the culture of science. The reason why these two types of study are so important becomes clear in the review of studies suggesting culturally relevant teaching practices for African American students. Parsons, Travis, and Simpson (2005) refer to a Black Cultural Ethos, a construct referred to a large number of studies, in the study presented from this group. This Ethos is described as a set of learning preferences for African American students that includes an incorporation of movement, hands on work, cooperative learning, sound, and energy. However all of the studies in this section suggest that the incorporation of these strategies are supportive of learning in general and, while have a positive impact on science outcomes for African American students, do not provide them with anything more than other students.

Therefore, what a number of authors describe as a culturally particular practice could actually be described as good teaching via constructivist theory, or a manifestation of Howard Gardner's multiple intelligences. This critique highlights some of the danger that emerges from labeling classroom practices as culturally supportive when this may not be the issue at hand. Doing so can perpetuate stereotypes, and even be considered racist as was the case with Zhao (2007). Until the research in this field more assuredly determines causal factors, mechanisms involved, and particular practices that are useful, there will continue to exist a conflict between the multicultural perspective seeming logical and inline with best practice and the complexity of the multicultural issue setting the stage for socially dangerous situations.

Summary

The previous section reported on areas in the field of multicultural science education that are in need of further research. While the current research in the field is generally positive, it is far to broad and haphazard to be directly applicable in class. In particular, researchers have yet to amass work in American populations in diverse classroom settings that suggests that multicultural science practices are worth in with regard to giving marginalized populations equal opportunity in science and with regard to increasing the resources within science as a result of altering the field to be open to alternative view points. Additionally, the work in the field is not stringent enough at this point in time to feel comfortable labeling many of these interactions as cultural issues, though on a logical level it makes sense to me that Western science includes approaches and perspectives that are not all inclusive. The research presented in chapter three demonstrated that it is important to be aware of the interaction between culture and science. However, the nature of the research in the field requires that teachers exercise caution in the classroom and in interactions with students when they suspect that cultural issues in the classroom may be impeding a students progress in science.

Chapter Summary

The purpose of this review was to determine what interaction exists between culture and science and also to determine what affect multicultural science education practices have on achievement, motivation, and interests in the science education in samples of culturally diverse students.

Chapter one outlined the epistemological context in which these questions arise. First the chapter described the root of the issue at hand as laying America's history of immigration and oppression, as being relevant to achievement gaps in science among marginalized students, and as being important in terms of increasing the scope of scientific thought in addressing the problems of the future. This chapter described relevant perspectives on the nature of science and perspectives on learning. The chapter also outlined the different types of multicultural education and portrayed how multicultural science education fits in to those frameworks.

Chapter two outlined the historical developments related to the issue at hand. The chapter first surveyed scientific developments from African and Native American cultures that preceded similar developments in Western nations. The chapter then proceeded to depict the history of science education in the Untied States, particularly with reference to its goals and interactions with marginalized groups. A brief presentation of the roots of multicultural education was included, and the discussion of science education after its rise to prominence continued. Chapter two finished with a discussion of multicultural science education, particularly in terms of important figures in the field and current reform documents.

Chapter three presented a review of the current research in the field of multicultural science education. This review was organized to answer the questions that drove this review. First the chapter hinted at the scope of the interaction between culture and science and particularly focused on how the students' culture can impact their science experience. Second the chapter explored the effect of multicultural practices including the incorporation of the students' worldviews and the incorporation of culturally relevant practices on students' attitudes and achievement in science. These sections suggested an overall positive impact but were presented with the critical caveats surrounding the degree to which culture impacts science experiences and if what we see as a cultural phenomenon is in actuality.

Chapter four reviewed the research findings in chapter three and presented summaries for each of the subsections in chapter three critiquing the overall trustworthiness of the research. After this summary, the chapter discussed the degree to which these research findings can or should be implemented in the classroom and then moved onto a discussion of the weaknesses in this field of research that determine that degree.

Through this process this review demonstrated that culture and science, as a cultural construct, interact on many levels and thus the interaction of culture and science is an issue that deserves attention if our goal is to provide equal access to science to all students. This review also demonstrated that multicultural science practices, while generally positive, are incredibly complicated and require great care in implementation. In addition, this review determined that the field of multicultural science education needs much more attention to many aspects of the research supporting it.

The United States has always been a nation steeped in diversity and is continuing to become more diverse. Current science reform documents advocate the of teaching science across diversity but do not suggest specifically how this should be done. This paper explored multicultural science education practices as a potential tool in teaching across this diversity, and while if found the research in the field wanting, it hinted that the result of using these practices is generally positive in terms of attitude and achievement and as the field develops more fully, such practices may become more prevalent in teaching science to all students.

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