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CRITICAL MULTICULTURAL SCIENCE EDUCATION: DILEMMAS, CHALLENGES, AND OPPORTUNITIES

by

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ABSTRACT

Despite the historical confusion about what multicultural education means, there is a building consensus within the field that recommends a structural transformation of schools in order to better support the diverse American population and to cultivate the democratic values upon which this country was founded. This transformation necessarily affects all persons involved in schools and all academic disciplines. This paper examines the application of principles of multicultural education to school science. Brief reviews of the history of multicultural education and of 20th century science education reforms show these histories converging in the 1980s as multicultural science education (MCSE) entered the academic discussion. A review of the MCSE literature indicates that research efforts have focused on instructional methods and curricular content reforms. Studies of changes to science instruction show some positive effect on academic achievement. Studies of content reforms are limited because of conflict within the research field over what content should be included in science curricula. Despite this conflict, researchers agree that the definition of 'science' drives the content of science curricula. There is also agreement that students should learn about the nature and history of science, they should be encouraged to examine controversial issues, and teachers should make an effort to make science more relevant to students' lives. These suggestions are intended to promote achievement and interest in science across the student population, and to build democratic values such as a sense of equality and justice for all people across religious, racial, and cultural differences. In order to prove the effectiveness of these recommendations, significant further research in the area of multicultural science education is required.
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PREFACE

Though I started my post-secondary education knowing I would be a scientist, I was profoundly influenced by my exposure to cultural relativity theory and an introduction to post-modern philosophy in the first class I took in college: Anthropology 101. Since that time I have approached my studies in science with the spirit of critical inquiry. I have often wondered about the history, culture, and religious influences behind scientific experiments and decisions. Information to answer such questions is not always readily accessible, nor is it often presented as a central component to science education. As my interest in teaching science has grown, my questions about the apparent lack of multicultural science education, as compared with multicultural humanities education, have also gained greater urgency. The research and writing of this paper has given me the opportunity to explore these questions and to learn about the resources that will be available to me in my pursuit of teaching multicultural science.

I could not have completed this project without the support and assistance of many people near and far. First I would like to gratefully acknowledge those who have provided comments on, discussions about, and editorial support for the writing of this manuscript: Leah van Eenwyk, Laura Conkey, Heather Bradley, and especially Michael Vavrus, my faculty reader. Additionally, I would like to thank my housemates: Jodi Bernstein, John Carleton and Ty Carleton, and members of the 2003 MIT cohort for providing laughs, perspective, and thesis-breaks throughout this project. I am also most grateful to my family: Peter, Frances, Ted, and Liza Trafton for their support, both emotional and financial, in my pursuit of post-graduate study.
Science curriculum, like all school curricula, has changed in response to reforms spurred by recent research, society’s values and recent history, including the civil rights movement. One reform movement that has been particularly influenced by civil rights efforts is multicultural education. Multicultural education sprang from the civil rights movement of the 1960s and 1970s. Since that era, multicultural education has taken many different forms and been interpreted and applied in many different ways (e.g., Atwater, 1993; Banks, 1991, 1999; Carey, 1993; Hodson, 1993, 1994, 1999; Lee, Menkart & Okazawa-Rey, 1998; Sleeter & Grant, 1988; Tietd & Tietd, 1999). Despite this breadth of applications and interpretations of multicultural education, until recently, only the most radical forms advocated widespread inclusion of science among the disciplines to which multicultural education was applied (e.g., Gill & Levidow, 1987). During the late 1990s a fascinating discussion developed in the field of science education that debates the extent of the applicability of multicultural education to science instruction and curricula based on a philosophical debate over whether science is universal or relative (e.g., Harding, 1994; Matthews, 1994; Stanley & Brickhouse, 1994, 2001).

My research into multicultural curriculum reform was guided by the following question: What are the effects of applying principles of multicultural education to science curricula? In addressing this question, I explore the general interpretations of multicultural education as well as its conservative and radical criticisms. I give my attention to the recent dialogue within the field of multicultural science education and the controversy over whether or not science education can be multicultural.
Rationale

As a future science teacher, I am interested in teaching in such a way that the material my students learn is relevant and applicable to their lives, and that such knowledge is empowering by its ability to inspire hope and encourage active citizenship. Science surrounds us, not only in workings of the natural world but also in our industrial technologies. Thus, scientific understanding can be powerful. Scientifically literate citizens can contribute in a positive way to our communities through the development of new technologies as well as through recognition of inequities, such as environmental injustice. The ability to speak both to research scientists and to lay citizens is a source of power that can enable those with such skills to work for social justice.

One problem is that many students lose interest in science during middle school (Atwater, 1995). Students lose interest for many reasons, but one of the most common is that students perceive science as less relevant to their lives. Another reason for disinterest is the underepresentation of diverse contributors to scientific thought, making it difficult for girls and students of color to see themselves reflected in the curriculum or envision themselves in scientifically related careers. Additionally, traditional science curriculum tends to silence non-Western ways of knowing, discovering, and understanding the natural and physical world. Teachers should listen to their students to understand these reasons and then work to change their teaching approaches as necessary.

Multicultural education can provide an approach to engaging students’ interest in science. Yet, multicultural education seems to mean something different to everyone; with each definition comes a separate set of goals that its advocates hope to attain through implementation. Because of the lack of clarity within multicultural education and
the assumption that it is yet one more curriculum unit that a group of advocates want teachers to insert into the already busy school calendar, temptation exists among teachers to dismiss multicultural education as yet another fad reform. Current multicultural theorists, however, call for a holistic approach to reform that permeates the curriculum and has as much to do with methods as with content. In order to explore how principles of multicultural education can be applied to science in this way, I examine the range of accepted definitions of multicultural education and the current thinking on multicultural science.

**Multicultural Education**

Multicultural education originates from the demand of the civil rights movement that educational discrimination (among other discriminations) cease (Banks & Banks, 1993). The term began to appear in the late 1960s and has since been associated with educational practices that address racism in schools as well as achievement inequities between whites and students of color (Banks, 2001b). May (1999a) states “a central claim has been that multicultural education can foster greater cultural interaction, interchange and harmony, both in schools and beyond” (p. 1). Yet, rather than addressing these issues alone, the term multicultural education has been applied to such a wide range of educational theories and ideas that it has become difficult to know the goals and intents of curriculum and theory that are described as multicultural. Based upon an extensive review of the literature on multicultural education, Sleeter and Grant (1988) developed a typology for categorizing multicultural education into five types. A brief overview of these types is helpful here as many researchers have utilized these types as a way to describe various approaches to multicultural education.
Sleeter and Grant (1988) identify one type as teaching the exceptional and the culturally different. It is characterized by the notion that teachers need to “build bridges” between “culturally different” and “mainstream” students so that the disadvantaged student “can better meet the traditional demands of the school and American life” (p. 35). A second type focuses on human relations. Goals for this type of multicultural education include tolerance, reduction of stereotyping, and the promotion of “harmony between racial groups” (p. 78).

Another approach is single-group studies which is intended “to reduce social stratification and raise the status of the group with which they are concerned” (p. 105). Sleeter and Grant (1988) explain that a single group study approach intends to “give students of color a sense of their history and identity in American society, increase their awareness and self confidence, and provide a greater sense of direction and purpose in their lives” (p. 107). This approach is most frequently encountered at the college level, for example, in the form of women’s studies and African-American studies classes or departments. A major purpose is to boost achievement for students who belong to the oppressed group under study, although courses are typically open to all students. K-12 examples include special social studies units for “Black History Month” or holidays such as Cinco de Mayo. In this paper, as in much of the research in multicultural education, single group studies are instead called ethnic studies.

Sleeter and Grant (1988), somewhat confusingly, call their fourth type multicultural education. This name is intended to reflect the majority of ideas represented in academic literature as opposed to those found in teacher guides and method books, which tend towards the previously described types in their intents. Multicultural
education in the academic literature aims to promote respect and value for diversity, human rights, social justice, equality of opportunity and equity of power.

The final type of multicultural education that Sleeter and Grant (1988) identify is *education that is multicultural and social reconstructionist*. This type is conceived as a complete transformation of the educational program as opposed to being “one of several kinds of education” (p. 175). According to Sleeter and Grant, this type multicultural education requires reframing the educational whole in such a way that it is pervaded by a “critique of modern society” that is concerned with “eliminating oppression of one group of people by another” (Brameld, 1956, cited in Sleeter & Grant, 1988, p. 175). Its major goal is to prepare “future citizens to reconstruct society so that it better serves the interests of all groups of people, especially those who are [currently oppressed]” (p. 176). For brevity, this more socially active form of multicultural education is often called transformative multicultural education (e.g. Banks, 1999). Transformative versions of multicultural education have been present since the early development of the field, yet tends to be more peripheral and less frequently applied (Washburn, Brown & Abbott, 1996).

**Antiracist Education**

Instances of transformative forms of multicultural education that question systems of oppression are rare as compared with those that take a more additive approach (Washburn, Brown & Abbott, 1996). As a result, radical educators and theorists produced an alternative to multicultural education and called it antiracist education. Antiracist education critiques mainstream multicultural education for its inability to address the “structural inequalities faced by minority students” (May, 1999b, p. 11). This absence
implicitly allows for the maintenance of institutional racism (Grinter, 1992; Lee, 1994).
The "major goal [of antiracist education] is to end racism in individuals and institutions" by teaching "the economic, structural and historic roots of [racial] inequality" (Morelli & Spencer, p. 168). The antiracist tradition has produced some meaningful and important contributions, primarily in the realm of theory, related to multicultural pedagogies and science education. Yet, antiracist education has received criticism for emphasizing a "black-white dichotomy" that can result in effectively excluding other racisms and the complex interconnectedness with the wider reach of inequality (May, 1999b, p. 12).

Critical Multicultural Education

Prominent multicultural researchers currently advocate a form of multicultural education that is most closely aligned with Sleeter and Grant's (1988) category of education that is multicultural and social reconstructionist, but also includes aspects of multicultural education. Critical multiculturalism is based in the idea that simply reforming existing societal norms is insufficient to effect any real change to the structural inequities that exist in today's society. Thus, many multicultural reform efforts are exposed as a shallow, and actually in favor of maintaining the status quo (c.f. McLaren, 1994). As a result, transformation, rather than reformation, is viewed as a vehicle for change. Transformative multiculturalism exists within, and is often synonymous with, critical multiculturalism. In this paper, I use the terms interchangeably. Critical multicultural education seeks to bring together the strengths of antiracist education and multicultural education with the intent to "foster...students who can engage critically with all ethnic and cultural backgrounds, including their own" (May, 1999b, p. 33). According to May (1999b), critical multicultural education "would allow both minority
and majority students to recognize and explore complex interconnections, gaps, and dissonances that occur between their own and other ethnic and cultural identities, as well as other forms of social identity” (p. 33). A critical examination of social identities, both ascribed and chosen, by all students opens the possibility for inquiry into the vast and varied systems of oppression in the dominant culture. Inquiry of this nature fits with the goals of antiracist education without rejecting the contributions of multicultural education.

Banks (1995, 2001a) identified five dimensions of multicultural education to enable teachers and researchers to better understand and implement transformative multicultural education. These dimensions are (1) **content integration**, (2) **the knowledge construction process**, (3) **prejudice reduction**, (4) **an equity pedagogy**, and (5) **an empowering school culture and social structure**. Banks (2001a) explains that **content integration** concerns the examples teachers use to illustrate the concepts within their subject areas. He emphasizes that “the infusion of ethnic and cultural content...should be logical and not contrived” (p. 8). **The knowledge construction process** consists of the strategies that teachers use to engage students in a critical examination of the factors that have influenced their own, as well as historical knowledge construction within their subject areas. Banks states: “Students need to understand, even in the sciences, how cultural assumptions, perspectives, and frames of reference influence the questions that researchers ask and the conclusions, generalizations, and principles they formulate” (p. 9). **Prejudice reduction** as the “dimension of multicultural education [that] describes the characteristics of students’ racial attitudes and strategies that can be used to help them develop more democratic attitudes and values” (p. 11). An **equity pedagogy**,
according to Banks, is one that is focused on the promotion of academic achievement for all students. In order to achieve this focus, Banks suggests that teachers learn "about the cultures, values, languages, and learning characteristics of their students" (p. 14) and modify their instructional methods to capitalize on the strengths, or assets, brought by each student. Creating an empowering school culture and social structure requires making changes within whole schools in addition to individual classrooms. Some examples of school-wide areas to examine include "labeling practices, sports participation," testing and "grouping practices," "tracking," and participation in "gifted programs" (p. 14). Banks emphasizes that these dimensions provide a helpful categorization tool, but that in practice they are overlapping and interrelated. Despite these connections, Banks underscores the importance of each dimension to transformative multicultural education.

Research Limitations

This investigation is limited to the application of multicultural education to middle and high school grades. Since many works do not distinguish between middle school, high school, and even the undergraduate level, such works have been included in this research. However, the selection of examples is made with an eye to age-appropriateness and relevance so as to maintain the greatest applicability to the secondary classroom. Where necessary and possible, specific age groupings are specified.

The majority of published work on multicultural education originates from England and countries that were formerly British colonies. Because my intent is to teach in the United States, my interest is focused on the U.S. To the greatest possible extent I use empirical study data originating from within this country. I have not, however,
limited my investigation into theoretical works to those published in or originating from the United States so as not to silence important contributions to what really is an international dialog.

This paper presents a review of research on and theory of multicultural education and multicultural science education rather than a review of the many various programs and curricula that exist to meet multicultural goals in science. The focus in this study is on program characteristics that are indicative of particular goals and strategies in multicultural science education instead of specific programs that are most frequently published without any reference to their effect on students and schools.
CHAPTER 2: HISTORICAL BACKGROUND

In order to provide a historical background for addressing literature related to the application of multicultural education to science curricula (see Chapter 3), I begin this chapter by discussing multicultural and science education separately. First, I provide historical contexts for multicultural education and its related antecedent, intercultural education. I follow with a description of ethnic studies that links intercultural education to multicultural education. Finally, I describe the current trend in multicultural education theory of movement towards unification of the field. This unification explicitly calls for the integration of principles of multiculturalism across all subject areas. I focus my exploration into science curricula on historical reforms with intents that mesh with multicultural goals. I also address 20th century developments in the philosophy of science that lead to the possibility of accepting multicultural science.

Intercultural Education

Whereas the term multicultural education was coined during the civil rights movement, advocates for including diverse cultural material in school curriculum in the United States had their first impact during the second and third decades of the 20th century between World War I and II. This voice arose out of dissatisfaction for discriminations faced in school by the children of turn-of-the-century immigrants from Eastern Europe (Montalto, 1982). The rise of anti-Semitism during the inter-war years also spurred the creation of the intercultural education movement.

Movement founder Rachel Davis DuBois was a white Quaker pacifist interested in harmonious relations between different groups of people. She was inspired by her interactions with black academics and leaders such as George Washington Carver and
W.E.B. DuBois (not related to Rachel) to take on the attitudes of the white “majority” in order to foster improved social interactions. R. DuBois promoted a human relations approach through assemblies and content integration of ethnic curriculum directed towards white, American students of Western European ancestry. R. DuBois received a great deal of support from ethnic communities during the early 20th century. For example, she was welcomed into the National Association of the Advancement of Colored Persons. Despite her progressive pushing of boundaries on race relations, R. DuBois used the information and advice from ethnic leaders for the benefit of white “majority” children. Reflecting on this bias later in life, she stated, “Looking back after forty years, [I] admitted to being unaware at the time of the psychological implications of cultural studies for the minority child” (Montalto, 1982, p. 101). R. DuBois acknowledged that her efforts, aimed to change the attitudes of white children, might have felt tokenizing to children of color. Educational efforts focused on benefiting the self-concept of children of color were not developed until later, primarily by black leaders as part of the civil rights movement in the 1960s. The intercultural education movement faltered in the 1940s as a result of internal conflict over whether assimilation or cultural pluralism should be the movement’s goal. The political climate at the time was tipping toward nationalism as tensions mounted prior to the bombing of Pearl Harbor in 1941, and R. DuBois was forced out of the very movement she initiated (Montalto, 1982).

Though the intercultural education was weakened by pressure from a strong nationalistic assimilation movement during World War II, racial and ethnic tensions rose once again after the war as populations, which were once more geographically distinct,
migrated to city centers for economic reasons. This prompted a return to intercultural education, now referred to as “intergroup education” (Banks, 2001b). Again the focus for intergroup education was to reduce prejudice and racial tensions. Although educators within the movement were also concerned with helping students develop democratic values, the overall tone emphasized human similarity in spite of difference that categorized these efforts as a human relations approach (Banks, 2001b). Studies conducted by researchers during the 1950s showed that in order to develop more democratic racial values, intergroup curriculum must be implemented “within a democratic classroom” for a “sufficiently long period” (Banks, 2001b, p. 8). Studies also identified the power of society’s institutions and structures to inculcate student racial attitudes. Despite identifying the importance of these characteristics, “intergroup education materials devote little attention to issues and problems of institutionalized racism, power and structural inequality” (p. 9). The focus on “colorblindness” and culture-blindness promoted within the intergroup education eroded support for the movement among people of color. This weakness in intergroup educational practices combined with dissatisfaction with the slow pace of desegregation in the 1960s led black leaders to leave the intergroup education movement in favor of separatism, promoting an empowering version of ethnic studies (Banks, 2001b).

**Ethnic Studies**

Civil rights leaders in the 1960s and 1970s were motivated by frustration from being minimized by mainstream culture. Since “the America envisioned by most intergroup leaders was a nation in which ethnic and racial differences were minimized and all people were treated fairly and lived in harmony” (Banks, 2001b, p.10), intergroup
education was discarded. An escalating sense of racial pride and confidence spurred a separatist ideology that built upon earlier ethnic study work (e.g., R. DuBois) to develop empowering curriculum specifically for students of color. Banks (2001b) explains that “during this period there was little demand for the infusion of ethnic content into the core or mainstream curriculum—that demand would not emerge until the 1980s and 1990s” (p. 10). The ethnic studies movement was characterized by content integration with a focus on the historical and continuing struggles of people of color. Many of the contributions to the ethnic studies literature emphasized “ways that ethnic groups of color had been victimized by institutionalized racism and discrimination in the United States” (Banks, 2001b, p. 10). These ethno-histories expanded the ways in which Americans viewed and studied history and culture. The ethnic studies movement focus on content integration in the humanities has had a lingering effect on multicultural education. Many teachers assume that multicultural education is “primarily [a] curriculum reform that involves only changing or restructuring curriculum to include content about ethnic groups, women, and other cultural groups” (Banks, 2001b, p. 4). This limited form of educational change is characteristic of ethnic studies, does not mandate reform across all discipline areas, and, therefore, was primarily implemented in humanities courses.

**Emerging Multicultural Education**

Multicultural education emerged out of ethnic studies with the goal of bringing cultural content once again to a larger (more diverse) audience. In the mid-1980s when Grant and Sleeter (1985) and Grant, Sleeter, and Anderson (1986) conducted reviews of all extant multicultural education, they noted a wide range of, and often the lack of clarity in, the definitions theorists were using for multicultural education. Their typology (see
Chapter 1) arose out of a review of that literature as part of an effort to clarify and classify the many pedagogical strategies called multicultural education that they encountered.

**Criticism of Multicultural Education**

In their reviews, Grant and Sleeter (1985), and Grant, Sleeter, and Anderson (1986) addressed criticism leveled at multicultural education. The reviewers identified four main criticisms of multicultural education:

- It would be socially divisive, hindering the development of allegiance to a common culture and language; it would represent a new form of segregated schooling, blocking minority students from access into the mainstream; earlier immigrants were able to assimilate without school support in preserving in their ethnic cultures and languages; and neither bilingual nor multicultural education has definitively proven successful in raising minority student achievement levels.

  (Grant & Sleeter, 1985, p.107)

These criticisms were based on the goal of assimilation and the notion that there existed a united and homogenous American culture. Assimilation continued to drive criticisms of multicultural education and as a result, these four issues continue to appear in critiques. For example, Schlesinger (1991) criticized multicultural education for its potential to tear apart a supposedly united American culture. Furthermore, Schlesinger argued that multicultural education is not concerned with the intellectual growth of students, but serves as "social and psychological therapy" (p. 25). Additionally, recent critics in the popular sphere have grouped multicultural education with affirmative action and bilingual policies and critiqued these as entitlement programs (e.g., Gray, 1991;
Krauthammer, 1990). In light of these arguments, criticism of multicultural education has changed little, even as the theories that multicultural education is based have evolved.

**Brief Recent History of Multicultural Education (1985-Present)**

Since the reviews by Grant and Sleeter (1985) and Grant, Sleeter, and Anderson (1986), the amount of literature on multicultural education has exploded. In the mid-1980s, only a couple hundred books and articles included the term (Grant & Sleeter 1985, Grant, Sleeter & Anderson, 1986). Now, thousands of publications are retrievable by searching book and journal cataloging services using the subject heading “multicultural education.” Clearly the past fifteen years have seen the expansion of the field. Whereas intended definitions of multicultural education still display a range of meanings, leaders in the field have emerged lending a greater level of credence to a combination of Grant and Sleeter (1985) categories “multicultural education” and “education that is multicultural and social reconstructionist.” The uniting of multicultural education under a critical and transformative multicultural banner has been catalyzed by the theoretical consensus reached on the need to include structural changes that include and go beyond content focused curriculum reforms (Banks, 2001b).

**Predecessors to Multicultural Science Education**

Most early science reforms that attended to individual learner’s perspectives addressed only one or a few multicultural goals. They set the stage, however, for the greater possibility of acceptance of multicultural science because the ideas were not completely new or foreign to teachers and administrators. Despite these predecessors, the term multicultural was rarely applied to science education until the 1990s.
Early in the 20th century, a call was put forth to develop the "humanising influence" of science by focusing on the cultural and historical aspects of science in addition to the utilitarian and technological components. The joint purposes of humanized science were to create a scientifically informed electorate and a compassionate citizenry (Newton, 1986). An associated benefit of humanizing science was to increase student interest and enhance learning. Advocates of humanizing science reasoned that the "image of science acquired from science education is an inadequate reflection of reality" (Newton, 1986, p. 3). Because science does not happen by itself, efforts to humanize science intended to provide context for scientific principles and discoveries. Newton observed that "the most commonly suggested way of humanising science over the last 80 years has been through the history of science and the lives of scientists" (p. 4).

Humanized science content acknowledges the significance of the role that culture plays in the research and development of science. While humanized science focuses on the culture and history of Western science, this acknowledgement of the role of cultural influence is critical to the development of multicultural science education.

From a more philosophical standpoint, the role that culture plays in science has been examined through post-modern philosophies of science. The 20th century intellectual and philosophical development of ideas of cultural relativism, post-modernism or, to some, post-colonialism in and among privileged Western ideologies led to an increased awareness and recognition of the validity of non-Western perspectives. In anthropology, this movement was lead by Franz Boas and Margaret Mead, two pioneers in the naming of perspectives. These anthropologists identified the problems that derive from describing cultures from outside the culture. They recognized that the cultural values of the
anthropologist played a role in the way that the culture under study was described. This observation lead to discussions of insider and outsider perspectives and the questions about previously held notions of observation and objectivity. This anthropological example illustrates the phenomenon that occurred across academic disciplines and demanded the interrogation of contexts.

Kuhn (1970) points out that the application of postmodern contextual theories to the history of science demanded a reinterpretation of the discarded "myths" of earlier versions of scientific thought. As science historians examined the context of outdated aspects and sub-fields within Western science, they noted that discarded theories appeared no less scientific and no more heavily influenced by cultural contexts than modern theories. This observation led Kuhn to ponder:

If these out-of-date beliefs are to be called myths, then myths can be produced by the same sorts of methods and held for the same sorts of reasons that now lead to scientific knowledge. If, on the other hand, they are to be called science, then science has to include bodies of belief quite incompatible with ones we hold today. (Kuhn, 1970, p. 2)

Kuhn (1970) advocated the latter perspective that led historians of science towards a less accretionary and linear view of their subject. This view required science historians to pose different types of questions. Rather than asking developmental questions such as how an older version of science contributed to modern science, science historians began to pursue contextual questions such as how a certain scientists' views and discoveries related to his contemporaries, teachers, and students, for example. By examining the context of scientific exploration at different points throughout Western scientific history,
Kuhn showed that the history of science is dominated by periods of "normal science" in which base assumptions about the composition of and interactions within the universe inform the nature of inquiry. These periods are punctuated by revolutions, during which a preceding base assumption is rejected in favor of one that is incompatible. Kuhn noted that "each [revolution] produced a consequent shift in the problems available for scientific scrutiny and in the standards by which the profession determined what should count as an admissible problem or as a legitimate problem-solution" (p. 6). Here Kuhn illustrates the significant role that attitudes and beliefs play in the determination of scientific projects at any given time. Yet the distinctions Kuhn makes are primarily temporal: normal science precedes as well as succeeds scientific revolution and exists exclusively within a universal conception of Western science and Western thought. Even his investigation into the definition and limits of science is contained entirely within the realm of Western academia; for example, limits are explored through practitioners' conceptions of the fields of economics and psychology. Through his work on the historical trajectory of Western sciences, Kuhn initiated a process of critical and contextual examination that enabled more recent philosophers and historians of science to apply such investigation more broadly. Questions of legitimacy within science and of contextual perspective are of significant importance to determining whether multicultural science is itself legitimate.

In an exploration of the legitimacy of multicultural science, Harding (1994) addresses three questions: (1) "does science have non-Western origins?" (2) "are there any other knowledge traditions that deserve to be called science?" (3) is "modern science
culturally western” (pp. 347, 349, 353)? A review of Harding’s responses to these
questions that led her to conclude that science is, in fact, multicultural can be helpful.

Of the three questions, the first is the least controversial. Harding (1994)
identified two ways Western Modern Science (WMS) has borrowed from “third world”
science. One is conscious and familiar and the other is hidden and exploitative. The
former includes examples such as the borrowing of numerical and mathematical concepts
(e.g., zero) that were developed in Islamic culture as well as the borrowing of substances
such as gunpowder that was developed in Chinese culture. The latter includes examples
such as agricultural knowledge of “new-world” plants including potatoes and corn, and
slave labor originating from Africa and the Americas to sustain the growth and
development of Western science. Harding points out that borrowing is essential to
science in so far as its absence effectively eliminates creativity in the field. Clearly, WMS
has drawn greatly on non-Western ideas, yet the West’s “failure to acknowledge the
origins and importance to ‘real science’ of these borrowings...[has served] to trivialize
the achievements of [non-Western] scientific traditions” (Harding, 1994, p. 348). The
recognition of such borrowing legitimizes the notion of multicultural science on this
primary level.

Secondly, Harding (1994) interrogates the workings of non-Western knowledge
traditions to see if any “deserve to be called sciences” (p. 349). She cites many examples
of sophisticated observations and concepts that went “unborrowed” by WMS only to be
reinvented and rediscovered. Harding asks, if such concepts count as science now, should
we not count them as distinct sciences within the cultural-historical context in which they
were first developed? By way of illustrating the historical validity of non-Western
science, Harding calls attention to the efficiency of Chinese civilization in “applying human natural knowledge to practical human needs” (p. 350). WMS attempts to do exactly what was being effectively accomplished in China from the first century BC through the fifteenth century AD. Part of Harding’s investigation into where WMS draws the line between what counts as science and what does not involves a thorough deconstruction of the importance of the delineation. That is to say, “belief in the reality of this demarcation, as in the reality of the science versus pseudoscience duality, is necessary to preserve the mystique of the uniqueness and purity of the West’s knowledge-seeking” (Harding, p. 350). Harding’s point is that the “self-image of the west” requires dichotomization because clear-cut distinctions in and of themselves carry so much cultural value (p. 350). This cultural value is pervasive in Western scientific notions of objective and value-free science and persists despite the work of mid-century academics, who made the case for subjectivity across academic disciplines. If freedom from cultural values is the mark of true science, then WMS itself clearly does not qualify. Therefore, if WMS concedes that cultural values have shaped it, then it must not exclude from the definitional umbrella of science non-Western knowledge traditions on the basis of their reflections of cultural values. This concession expands the reach and legitimacy of multicultural science to include previously excluded historical knowledge traditions.

The third question Harding (1994) addresses concerns the present, rather than the historical nature of scientific systems. After showing that cultural values have shaped Western science historically, Harding asks whether such values are reflected in WMS today. Whereas Kuhn (1970) explained that the validity of scientific questions is determined by the set of shared understandings that constitute the framework for “normal
science," Harding argues that WMS counts problems as scientific only when solutions are needed to sustain Eurocentric expansion. A systematic scientific devaluation of questions that address any needs other than those of the dominant West and North necessarily reflects cultural values. Therefore, "claims for modern sciences' universality and objectivity are a politics of devaluing local concerns and knowledge and legitimizing 'outside experts'" (Bandyopadhyay and Shiva, 1988 cited in Harding, 1994 p. 357). Yet one of Western science's underlying claims is that science is objective and value-free. Harding explains that value-neutrality is paradoxical in that it is in and of itself a cultural feature and therefore does not represent the absence of cultural influence. Thus, she concludes that WMS is not free from cultural influence. On all three points examined, Harding found philosophical legitimacy for multicultural science. Despite her position outside the realm of curricular and theoretical development for K-12 science and associated research, Harding's philosophical work has had significant impact on discussions in multicultural science education. Harding's influence is highlighted in relevant studies of multicultural science education in chapter three.

The Face of Science Education without Multicultural Influences

Because 20th century education has been the subject of so many reforms, it is difficult to characterize a typical science education prior to the influences of multicultural education. A traditional science education, however, often included a focus on the acquisition of principles, definitions, equations, and theories of WMS. When the history of science was taught, it emphasized the lives and work of male scientists from Northern European countries, Newton and Copernicus, for example. Laboratory work was typically an exercise in repetition of simple and/or historical experiments with prescribed
steps and known outcomes. Additionally, access to traditional science education was not open to all of America’s students. Between 1955 and 1970, science education changed drastically to meet the demands of expanding high school enrollment and of university scientists and mathematicians who felt that college students were not adequately prepare to pursue careers in science (Collette & Chiappetta, 1989). Still, educators and policy makers have attempted to implement science education for all students only as recently as the 1980s. Whereas multicultural science education is not the only motivation for science-for-all reforms, multicultural science education reforms do assume that all students should learn science. It is important to note that the actual content of science classes across a whole country and a century have necessarily varied significantly. Yet the exclusivity within science and its strong Western emphasis has some measure of familiarity for many 20th century science students.

**Conclusion**

The development of multicultural education during the 20th century followed a course of crystallization and expansion of its meaning and purpose. This development was not linear; it exhibited a more circular pattern as education reforms responded to the shifting cultural climates throughout the 20th century. One important factor emphasized in this historical investigation is that the expansion of multicultural education into disciplines outside of the humanities required the kind of paradigm shift that legitimized a contextualization and critique of the notions of universality and role of cultural influence in the sciences. Without questioning the Western notion of “one and only one universally valid scientific and technological tradition,” the concept of multicultural science would not make sense (Harding, 1998, p. 6). Legitimizing multicultural science is
prerequisite to multicultural science education. At present the limits on and definition of
multicultural science are not settled as science educators continue to debate the extent to
which multicultural science education is useful and educative.

In the next chapter I review recent literature related to the application of
multicultural principles to science education. I also examine the nature of the
philosophical-scientific debate in the realm of science education as well as how the
nebulous nature of multicultural definitions inform the current theoretical state of
multicultural science education.
CHAPTER 3: INTEGRATIVE REVIEW OF THE LITERATURE

The previous chapter described Banks’ (2001a) five dimensions of multicultural education in detail. They include “content integration,” “knowledge construction,” “prejudice reduction,” “equity pedagogy,” and “an empowering school culture.” Research in multicultural science education focuses on curriculum content and pedagogical strategies that have been influenced by constructivism i.e. “knowledge construction,” though some researchers cite goals that overlap into other Banks categories. Many researchers contend that pedagogical reforms are sufficient to address multicultural science education goals, whereas others argue for limited curricular reforms. Still others demand complete transformation of school curricula that includes, but is not limited to, science curricula. This third group most frequently cites strategies similar to Banks’ five dimensions of multicultural education. This chapter explores important work in both pedagogical and content dimensions, yet, as Banks emphasized, it is important to note that none of these categories exists completely independently from rest.

The emphasis on pedagogical and content categories is evident from Southerland’s (2000) classification of the debate into instructional and curricular multicultural science education. Instructional multicultural science education reforms focus on the pedagogical practices of science teachers by emphasizing the importance of considering students’ perspectives, “particularly when [their] world views vary with those generated through a traditional, western conception of science” (p. 291). Debates in this category concern how science education can be adapted to “effectively teach science as it is traditionally defined” to students with diverse worldviews (p. 291). In contrast, curricular multicultural science education reforms examine the content of science
curricula. The debates in this category are not only concerned not with how to redefine our epistemological conceptions of science, but whether such redefinition is wise or desirable.

In this chapter, I use Southerland’s (2000) division between instructional and curricular multicultural science education to organize my review of the theoretical and empirical work related to the application of principles of multicultural education to science curricula. The first part of the chapter reviews research concerning science instruction methods inspired by multicultural education. The work reviewed in the instructional multicultural science education section focuses on ways teachers can vary methods of science instruction in order to facilitate an understanding of western modern science (WMS) for a more diverse student population. One of the most significant influences on instruction methodology is constructivism. The second section, curricular multicultural science education, addresses work examining changes made to science curriculum content in light of multicultural education. That section highlights the ongoing debate among educational researchers over whether the content of science is multicultural. A third section examines the state of multicultural science education today. This last section includes a look at the intersection between national science standards and multicultural science education.

**Instructional Multicultural Science Education**

Instructional multicultural science education is grounded in the widely accepted notion that teachers and schools have the responsibility of providing science education for all students. Researchers in this field have been searching for and testing ways to address the educational needs of culturally diverse student populations. Much of the
concern that drives this branch of multicultural science education reform derives from the profound underrepresentation or disproportionality of people of color in science-related professions. The purpose of research in this field is to ensure that, in the future, scientists from different cultural backgrounds are represented more closely to their proportions in the general population. A corollary purpose is to ensure a higher level of scientific literacy across the entire population. A body of research that attempts to identify factors that appear to inhibit science achievement is reviewed in the first part of this section. Once factors are identified, many of these researchers recommend removing them by focusing on assimilation, reinforcement and remediation so as to increase exposure to and familiarity with WMS and thus hopefully improve retention of people of color in the sciences (Burns, Gerace, Mestre, & Robinson, 1982; Mulkey & Ellis, 1990). The second part of the instructional multicultural science education section examines the role constructivism has played in multicultural science education. Through constructivism, multicultural science education researchers have examined the learning styles of and cognitive approaches taken by students from a variety of cultural backgrounds. Additionally, constructivist researchers have studied how students move from everyday knowledge and language to scientific knowledge. Throughout this section research assumes a definitions of science knowledge and language that consist of the theories, principles, laws, and vocabulary of WMS. This assumption remains consistent regardless of whether or not research is informed by constructivism.

Reforms Addressing Factors that Inhibit Science Achievement for People of Color

Burns, Gerace, Mestre, and Robinson (1982) collected data on Latino students enrolled in science and science-related programs at the college level and examined
factors that influence career choices of people of color. They used a combination of exams and clinical interviews in an attempt to “identify some of the factors which might adversely affect the cognitive development of the technical student” (p. 50). The tests focused on engineering students' abilities to perform mathematical, logical physical science, and language tasks and were administered to both native Spanish and monolingual English speaking groups (Burns et al., 1982). Burns and her colleagues also conducted a pilot study of Latino and “non-minority” junior high school students in order to gain insight into the types of career decisions that those students in that age group were considering in regard to science and technology. This second study was conducted on a very small scale. Both studies collected background information from students. In the study of engineering students, one finding was a strong positive correlation “between performance at math tasks and [English] language proficiency” (p. 50). This finding indicated that a certain level of linguistic competence in English is required for technical understanding. Other significant findings included evidence that Latino students came from lower socioeconomic backgrounds and had lower parental education levels. Similarly, the study of junior high school students revealed that lower parental education levels, lesser understanding of technical careers, and a greater level of interest in vocational occupations were present among Spanish-speaking Latino students.

In order to retain Latino students and other students of color in technical and scientific academic programs, Burns et al. (1982) recommended sustained and adequate financial aid, informational seminars introducing career options, remedial courses, tutorials, workshops, and intensive academic counseling. These recommendations were “found to be extremely successful” at the Minority Engineering Program at the
University of Massachusetts (p. 53). The researchers stressed that the sample size in their study of junior high school career interests was too small to make any reliable conclusions. Rather than recommend further study in this area, they recommended the implementation of remediation and acculturation programs to address the perceived weaknesses of the Latino students.

Mulkey and Ellis (1990) produced a study that examined the retention of people of color in the “scientific talent pool (students having interest and ability in science)” (p. 205). This investigation was conducted through the collection and examination of longitudinal academic data for groups of high school students beginning in their sophomore year and extending though their first year of college. An experimental group received treatments that included some of those recommended in the Burns (1982) study, such as exposure to role models, tutoring, and academic counseling. The control group did not have access to these enrichment services and activities (Mulkey & Ellis, 1990). Using sound sampling and statistical techniques, Mulkey and Ellis found that students in the experimental group completed more math and science courses in high school and were more likely to graduate from high school. They also found that overall academic achievement as measured by GPA was similar between the two groups. Mulkey and Ellis recommended further study in order to increase the validity, reliability, and generalizability of studies of retention programs for people of color in science. Their recommendation to collect more data in the areas they examined indicates that the researchers felt reasonably certain that they had successfully identified the important factors involved in retention in and loss from the scientific talent pool. This study posited that science interest and retention is contingent only on the level of familiarity that
students have with tenets of a universal vision of WMS. Mulkey and Ellis illustrated this position by showing that programs to increase familiarity have some positive measurable effect on retention.

Other researchers have indicated that factors beyond familiarity with western science influence participation and retention of students of color in math and science. Atwater, Wiggins and Gardner (1995) studied the attitudes that urban middle school students have towards science. The students in the study completed a test that measured their “attitudes towards different objects related to self, science and family” (p. 667). The researchers eliminated from the sample those tests that were returned with any incomplete answers. They stated their concern that a high percentage of those students who submitted incomplete tests may be those whose reading and writing abilities, as well as attitudes toward school and science, were low.

Through analysis of the data collected Atwater, Wiggins, and Gardner (1995) found that students did not have a clear understanding of the connection between school science and science careers. While most students felt uncertain, rather than positive, about their science teachers, curricula, and intentions to take more than the required science courses, almost 50% of the students planned to pursue a science related career. The implication of this finding is that if students’ attitudes inform their academic decisions, many will not remain in the scientific talent pool regardless of their career aspirations. Atwater, Wiggins, and Gardner state that “because America’s economical, environmental, and political problems require a scientifically educated populace, it appears that a large majority of urban students will be unable to contribute to these endeavors” (p. 676). They argue that science curricula need to be modified in order to
"meet the needs of our urban students" (p. 676). No recommendation for how to meet those needs is provided in this study. They do recommend further study in order to provide empirical links between science attitudes and science achievement, since no achievement data was collected in this study.

Another factor identified as potentially affecting the retention of students in the science talent pool is the treatment they receive from their teachers. Contreras and Lee (1990) collected data using ethnographic methods to compare treatment of students in two different ways: (1) between an enriched class and a regular class and (2) between a black female teacher and a white male teacher. Each of the two teachers was repeatedly observed teaching each of the two class types. The data collected included time spent on each task in the classroom, including role call, discipline, and instruction. Significant differences in treatment between the enriched and the regular classes were evident in the data collected on the white male teacher. The treatment differences amounted to significantly less instruction in the regular class than in the enriched class. This difference influenced the opportunity for students to participate in an extended field trip experience because "citizenship grades" were dependent on behavior and determined students' eligibility. No such significance was found in behavioral treatment between the classes of the black female teacher. Her expectations for enriched students, however, were higher, evidenced by their work on a library research project thought to be too cumbersome for the regular class.

Contreras and Lee (1990) described their conceptual framework for conducting this study as a "cultural perspective," according to which "differential treatment occurs when cultural values of the school or the teacher (usually mainstream culture) are
inconsistent or even in conflict with cultural backgrounds of students (usually ethnic minority groups)” (p. 434). They reported disengagement of students in the white male teacher’s “problem” class and hypothesized that this disengagement stemmed from treatment differences deriving from cultural conflict. Based on their findings, Contreras and Lee recommended that teachers and schools find a balance between “maintaining continuity of students’ cultural backgrounds” while simultaneously ensuring that students are equipped to participate in the “wider society” (p. 442). Additionally, they encouraged teachers to think about, rather than ignore, cultural difference in the classroom in order to lessen the possibility of inadvertent discrimination. Contreras and Lee recommended that further research be conducted to gain a clearer understanding of factors that contribute to differential treatment and the ways in which groups of students respond to those differences. Because the link between differential treatment and achievement is already well established in the research on the self-fulfilling prophecy of teacher expectations, no recommendations for further study on this connection were made in the Contreras and Lee study.

A study conducted by Osborne (2001) linked anxiety to achievement by testing the psychological theory of stereotype threat. Stereotype threat theory posits that students of color across academic disciplines and women in math face elevated levels of anxiety in testing situations because they know that prevailing cultural opinion is that they will not do well. Stereotype threat is another possible factor that can contribute to a lower retention of people of color in the scientific talent pool. Osborne collected data on over 15,000 high school seniors nationally by using a combination of achievement tests and questionnaires. In order to determine how students felt while taking the tests and gather
demographic information, questionnaires were used to prior both prior to and immediately following the achievement tests. Osborn stated:

[Feelings] were measured on a dichotomous yes (1) and no (0) scale with the stem item ‘How did you feel while you were taking the tests?’ and included the following items: tense, under pressure, under strain, nervous/jittery, uneasy, calm, afraid of not doing well, and uncomfortable. (p. 297)

Additional data was collected on “prior academic preparedness assessed by student reports of average grades” (p. 298). Through multiple statistical analyses of the data Osborne was able to show that anxiety is not only associated with achievement, but it also explains “significant portions of the racial differences in academic performance” (p. 291). Achievement differences in math between the sexes were partially mediated by anxiety “although the effect sizes were very small” (p. 291). The results from the Osborne study generally support the stereotype-threat hypothesis that indicates elevated anxiety is indeed a factor correlated with the academic performance of students of color and girls.

The preceding set of studies indicated that there are a number of factors related to science achievement differences between students of color and students of European ancestry. Factors, such as attitudes, differential treatment, and anxiety levels indicated that achievement differences are complex and cannot be explained only by the level of familiarity with WMS. The studies reviewed above recommended reform models that address factors directly with reinforcement and remediation. Specifically, they emphasized on behavioral reinforcement of transmitted “correct” knowledge and remediation of students coming from “high-risk” backgrounds. Other researchers have
approached instructional multicultural science education reforms from the perspective of constructivism. These researchers have examined the learning processes of students as individuals rather than as cultural groups for whom factors inhibit science achievement.

**Constructivism in Instructional Multicultural Science Education**

Science education studies in the epistemological tradition of constructivism have contributed significantly to the development of instructional practices that facilitate academic achievement for all students. There are many sub-schools of constructivist theory, all of which make space for recognizing students as individual learners and supplant the long-popular stimulus-response teaching and learning style advocated by behaviorists. Atwater (1996) described constructivism as “a nonrepresentationist model of knowing in which the mental representations that people construct are regarded as learning with no necessary correspondence with an objective and a priori scientific ontology” (p. 827). Constructivism in multicultural science education encompasses all the explanations that students adopt to understand scientific phenomena. These understandings are often culturally specific and may or may not correspond to WMS theories. The debate in instructional multicultural science education over knowledge construction concerns how best to assist students in moving from culturally specific prior knowledge to scientific knowledge.

In terms of Banks' (2001a) dimensions of multicultural education (see Chapter 1), instructional multicultural science education can be implemented in ways that address knowledge construction. Science education researchers have applied constructivism in three ways in an effort to address the learning needs of diverse student populations. First, researchers in psychological constructivism have examined students’ preconceptions of
science and the processes individual students use to acquire knowledge. Second, researchers in social constructivism examine knowledge acquisition in the context of a particular group or class. Third, constructivist researchers have studied and theorized about the ways students move from everyday knowledge, which may include preconceptions, to science knowledge. Each of these applications of constructivism to science instruction research is explored in the sections below.

**Psychological Constructivism and Multicultural Science Education.**

Psychological constructivists emphasize the benefits of teachers' attempts to discern the ways students learn in order to tailor teaching and pedagogy. The focus in psychological constructivism is on individual knowing and includes cognitive features such as prior knowledge, epistemological and metaphysical beliefs, and cognitive styles. The review in this section focuses on how studies of prior knowledge and cognitive styles have contributed to the instructional multicultural science education debate.

Some constructivist scholars question the narrow interpretation made by practicing classroom teachers of prior knowledge. Geelan (1997) argues that from a constructivist perspective, learning about students' cognitive styles is not equivalent to assessing previously incorporated school science concepts. Thus, administering a test or leading a discussion or brainstorming activity with the purpose of determining the existing knowledge of students only provides the teacher with "already memorised school facts" (Prior What?, para. 1). Assessing prior knowledge, according to important constructivist scholars, includes an effort to understand the structural process of knowledge construction, such as a students' cognitive style.
Field sensitivity tests are commonly used to assess cognitive styles. These tests assess how much a subject relies on external clues to make sense of ambiguous situations. Witkin (1978) observed that some subjects depend far more greatly than others do on contextual information to solve physical, social and logical problems. One example of a field sensitivity test assesses students' ability to discern a figure that is imbedded in a pattern. This test identifies two cognitive styles: field independent—those who can easily identify the hidden figures, and field dependent—those who are distracted by the obscuring design. Witkin has shown that cognitive styles identified with field sensitivity tests is consistent across multiple test types, and remains constant within individuals over time. Because of the traditional emphasis on autonomy and objectivity, most studies have shown that "field-independent students are likely to do better than field-dependent students in such fields as the natural sciences, mathematics, architecture, and engineering" (Witkin, 1978, p. 47). Students typically choose career paths based on the classes they enjoy and in which they do well. Though cognitive styles play a role in the career selection process, Witkin argues that on both ends of the field sensitivity spectrum the jobs selected represent a wide range of social statuses. Witkin uses this explanation to emphasize the argument he makes throughout his work that cognitive styles are value-neutral.

In addition to examining cognitive styles, psychological constructivism is concerned with the preconceptions that students bring to learning. Clement, Brown, and Zeitsman (1989) warned educators not to assume that preconceptions are misconceptions that will hinder scientific understanding. They argued that preconceptions, which align with an aspect of scientific understanding and in which a student is confident, could serve
as an "anchoring conception" upon which teachers can build for further scientific understanding. For example, an "anchor" might exist for a student who believes with some confidence that a coiled spring exerts an upward force onto a hand that is compressing it. Analogies stemming from the "anchor" to less intuitive concepts, such as a table exerting an upward force on a cup that is placed upon it, could, with an explicit link to the "anchor," become more accessible. Clement et al. posited that understanding the "anchors" and "non-anchors" (misconceptions) of a group of students can lead to more successful science instruction for that student group. Chances for success in science might be greater because the researchers "assume that it is desirable to be able to ground new material in that portion of the student's intuition which is in agreement with accepted [scientific] theory" (p. 1). In order to improve instruction, a method for determining anchoring conceptions was devised and tested. In this study, Clement et al. examined a diagnostic test they developed to determine anchoring conceptions for physical science students. They utilized two-part selected response questions. The first part measured physical science understanding, and the second measured the students' confidence in their answers to the first part. The researchers hypothesized that a high level of confidence in a preconception consistent with an accepted scientific theory indicated that there was "reason to believe that the student's answer was not simply memorized by rote" in a previous encounter with WMS school science (p. 3). The diagnostic test was administered to high school students who had not yet taken physics, but who were then enrolled in other science classes in three western Massachusetts high schools. After taking the test, five of the students were subjects for clinical interviews with the research team.
Data from the Clement, Brown, and Zeitsman (1989) study indicated that some anchors were “group anchors,” that is, they were anchoring conceptions for a high proportion of students within the tested groups. Citing experience with experimental lessons in their own teaching of introductory physical science classes, the researchers suggested that when a concept is an “anchor on a pretest for about 70% of students in a sample, most other students will indicate that the idea makes sense to them after a minimal amount of instruction, such as a demonstration” (Clement et al., p. 3). Thus, building on “group anchors” could enhance science comprehension for whole classes of students. The researchers found, however, that within the sample groups some concepts that they expected to be strong group anchors were not actually anchors for very many students at all. In addition, researchers identified some anchors as “brittle”: those in which students had a strong level of confidence in one situation, but could not extend their confidence to a new situation that was theoretically analogous in eyes of the physical science teacher. Based on these results, Clement et al. suggested that teachers pretest students preconceptions in an attempt to identify strong anchoring conceptions for each group of students, and that teachers not assume that the strength of an anchoring conception will lead to immediate understanding of analogous applications of scientific theories. Additionally they suggested that “the most appropriate time to test for anchors may be just before beginning a unit in which an anchor is needed,” because they observed that scores tend to rise during a course “even when [students] have not had direct practice on the test questions” (Clement et al., p. 11). The researchers postulated that experiences with related topics could favorably influence the confidence level student place in particular anchoring conceptions.
Social Constructivism and Multicultural Science Education. In contrast to psychological constructivists, social constructivist scholars question the possibility of knowing each student's cognitive style. Geelan (1997) argues that "from a constructivist perspective, we have no direct access to the construct system of another—when we attempt to understand their understandings, we are ourselves involved in a construction process, one of constructing their constructions" (Constructing Others' Constructs, para. 1). The incorporation of the teacher into the knowledge construction framework acknowledges the social nature of learning and knowledge construction. Atwater (1996) explains that "the learning and teaching of science has to do with the students and the teacher seeing and coming to see in certain ways. The mental representations of the students and the teacher are regarded as socially occasioned" (p. 827). Under this framework, the teacher is relieved of the duty of attempting to determine students' cognitive styles and is instead invited to participate in the construction of science knowledge. Thus, the move to incorporate social context assists teachers in transitioning from teacher-centered classroom to one consisting of collaboration within a group of learners (Geelan, 1997, Reiss, 1993). The transition to a collaborative, group-centered environment dismantles the power structure inherent in teacher-centered classrooms.

Through a theoretical review of science philosophy, cognitive psychology, and developmental pedagogy, Millar and Driver (1987) demonstrated that students learn science through interactions with one another in the context of science concepts. They emphasize:
The challenge for science education is to find contexts which are charged with relevance to pupils’ concerns, and which offer strategies and frameworks for deepening their understanding of scientific concepts and the cultural contribution of science which really engage the intellect—head and hand—and fire the imagination. (p. 56)

Within relevant and engaging contexts, Millar and Driver argue that teachers and students construct meanings through interactions that draw upon the ideas and experiences of one another. The researchers noted that the ideas brought to these interactions depend on prior understanding of the situation or of similar situations. Teachers or other students who have a scientific understanding of a situation, can, through participation in the group discourse, assist the group in the construction of scientific understanding. Yet, Millar and Driver emphasize that in order for individual students to appropriate scientific understandings, a combination of social and personal knowledge construction must occur. Millar and Driver highlight “the presence of the individual mind by viewing science knowledge as personally and socially constructed, rather than ‘objective’ and revealed; science theories are provisional, not absolute and unchanging” (1987, p. 57). Atwater (1996) helps to link Millar and Driver’s social constructivist theory to multicultural science education by arguing that “the implication of this epistemology for learning and teaching is that what students observe and predict about natural phenomena and the approaches they take in problem solving and experimenting depend crucially on the way they construe their world” (p. 838). In this sense, knowledge construction takes place in a social context and depends on the students’ perceptions of the world around them. Such perceptions are seemingly inextricably linked to the cultural background of each student.
An important part of affirming the cultural background of each student requires teachers to approach students’ prior science knowledge as viable knowledge rather than simply as “incorrect knowledge” or “misconception.” Reiss (1993) argued that a rigid teacher-centered model of constructivist teaching functionally operates on the premise that students arrive with incorrect knowledge that needs to be modified or replaced. Yet there is rarely only one way to solve a scientific problem so as to produce an appropriate solution (Reiss, 1993). As an alternative, Reiss proposed that teachers value “the variety of ways of thinking that students bring to their science lessons” by recognizing that such ways of thinking “have so far served them well” (pp. 39, 40). According to this perspective, knowledge constructions that ‘work’ must be deeply imbedded in cultural and social contexts. Unless those contexts are similar to the dominant culture of WMS, such knowledge is likely to be dismissed as ‘incorrect’ or, at best, ‘everyday knowledge’ that is irrelevant to science.

The Construction of Everyday Knowledge and Science Knowledge. Among researchers examining the relationship between science knowledge and everyday knowledge, there are two dominant views: (1) science knowledge and everyday knowledge are separate and incompatible and (2) knowledge exists on a continuum, meaning that science knowledge and everyday knowledge are not necessarily distinct. In this section I present research that typifies each of these viewpoints. Representing the view that a dichotomy exists between everyday knowledge and science knowledge is a study conducted by Lee, Fradd, and Sutman (1995). They showed how social, linguistic, and cognitive practices of students of color from non-dominant ethnic groups served as
potential barriers to student learning and achievement in science. In contrast, Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001) concluded, based on long-term observation of students from various cultural and linguistic backgrounds, that everyday knowledge can extend naturally and continuously to science knowledge. Despite their differences, social interactions were central to the treatments examined in each of these studies. Verbal and non-verbal data was collected for interactions between students and between students and teachers. This research focus on interactions rather than on individual students indicates these two groups of researchers' exploration of the implications of social constructivism. Both research teams employed social constructivist principles in their efforts to determine viable instructional multicultural science education methods.

Lee, Fradd, and Sutman (1995) examined and compared science knowledge, vocabulary and cognitive strategies among four diverse groups of elementary students. The groups were representative of large cultural and linguistic groups in two urban southeastern elementary school. Study groups included “(a) monolingual English-speaking students, (b) African-American students who spoke both standard English and Black vernacular English, (c) bilingual Hispanic students, and (d) bilingual Haitian students” (p. 800). The researchers engaged 32 students in 16 dyads; dyads were formed within cultural and linguistic groups so that each of the four groups in the study was represented by four dyads. Drawing on the influence of social constructivism in instructional multicultural science education, dyads were intended to stimulate social and academic communication in an effort to allow students the opportunity to construct science knowledge socially. Additionally, eight teachers participated in the study. One
male and one female from each of the cultural and linguistic groups were selected by the
researchers to provide assistance to and collect data from the student subjects in the
study. The teachers were trained to elicit and analyze language samples in order to gather
data about science knowledge, cognitive strategy, and science vocabulary in the context
of science tasks. Each dyad participated in three different science tasks, and each task
lasted 30-50 minutes. Data was collected using both audio and video recording. A coding
system was applied to transcriptions of verbal and non-verbal communications, and the
code scores were analyzed using both qualitative and quantitative methods. Based on
analysis of the code scores, Lee, Fradd, and Sutman found that "compared to
monolingual English students, students from nonmainstream backgrounds had more
difficulty with science knowledge and vocabulary" (p. 809). The researchers suspected
that fewer personal experiences with, less prior knowledge of science tasks, and a lack of
specific vocabulary to discuss these tasks contributed to the greater difficulty with
knowledge and language experienced by bilingual children and children of color. Lee,
Fradd, and Sutman observed, "Students whose language skills appeared limited also
seemed to have less well developed science knowledge, while students who expressed
more elaborate language were better able to explain science concepts and use science
vocabulary" (p. 809). The researchers found that, though more research needs to be done,
this relationship appeared to extend beyond vocabulary usage differences to real
differences in understanding is taken into account. Lee, Fradd, and Sutman concluded
that when everyday knowledge and vocabulary are far from that of science, the everyday
appears to be a liability to acquisition of science knowledge.
In contrast to Lee, Fradd, and Sutman (1995), Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001) argue for the continuity and compatibility of everyday knowledge with science knowledge. They illustrated this continuity with a pair of case studies from science classrooms that found poor students and students of color learning in an environment that allowed their everyday knowledge to be considered an asset rather than an obstruction to science learning.

The first case study examined the relationship between everyday language and science terminology among students in a Haitian Creole (HC)/English bilingual classroom. In this middle school classroom, students were encouraged to participate in “science circle,” a student forum for debate and discussion of science observations and phenomena. Students used everyday language, HC or English, stories, jokes, and anecdotes over time to arrive at conceptual understandings of important biological concepts. Based on observations of science circle, and a follow-up interview, Warren et al. (2001) noted how one student was able “think with language,” first with HC, then English, in order to refine his understanding “about the differences between grow and develop” (p. 539). The researchers concluded that languages are extremely flexible. Thus, even languages that do not include the translations for precise scientific terminology can be employed to build and convey complex scientific understandings. Warren et al. stated, “A view of vocabulary or of language learning in science that focuses on the appropriate production of particular terms obscures the living complexity and generativity of real language use” (p. 539). This suggests that science teachers who view students’ linguistic abilities as assets to the learning process must welcome a variety of forms of expression
into the classroom, rather than focussing entirely on developing particular scientific vocabulary.

The second case studied by Warren et al. (2001) examined children’s experimental reasoning. In contrast to most experimental reasoning studies, Warren and her colleagues attempt to expand their notion of “ideal scientific reasoning” beyond logical inference and deductive reasoning. To achieve this broader notion, they designed fairly open-ended tasks in which experimentation is approached more as an exploratory process—of constructing meanings for emergent variables—than a process of logical inference through which one identifies variables and uncovers relationships already designed into the experimental setup. (p. 539)

Since typical studies employ logically structured procedures for students to guide inquiry, this experiment design allowed the researchers to study knowledge construction processes without limiting student creativity. As a result, the authors’ understanding of sense-making and knowledge construction that resulted from this study expanded their notion of “what counts as scientific reasoning” (p. 539). Through their observations of students developing an experiment to determine whether ants prefer light or dark, Warren et al. witnessed student approaches that appeared to be very distant from logical inference. Yet, the researchers found that by imagining themselves into the ants’ world, evaluating claims, [and] constructing rather than identifying variables...specific material elements (i.e., variables and conditions) of the experimental world were confounded [in order to] design a world in a way which looked in the end fully canonical. (p. 547)
Warren et al. concluded that children could use their everyday knowledge and language to solve complex problems that arise in their daily lives, regardless of linguistic or cultural background. Based on this recognition, they advocated viewing the everyday knowledge and language that all students possess as "invaluable intellectual resource[s]" capable of, rather than lacking, "complexity, generativity, [and] precision" to assist them in learning about and "explain[ing] the world around them scientifically" (p. 548). This approach necessarily requires more effort and time than the teaching and testing of scientific vocabulary and scenarios, yet Warren et al. recommend these changes to science instruction in order to promote interest and involvement among students.

While both the studies (Lee, Fradd, & Sutman, 1995; Warren et al., 2001) use social constructivism to understand and develop instructional multicultural science education approaches, Warren et al. acknowledge a broader range of acceptable pathways for students to arrive at scientific understanding. Part of their acknowledgement may be based on the amount of time allotted to observation of students in the Warren et al. study. Warren and her colleagues observed students over the course of up to a year of time, whereas Lee, Fradd, and Sutman observed students engaged in three different tasks lasting less than one hour each. In the first case study example in the Warren et al. work, students in science circle communicated with each other using questions, stories and analogies that gradually led toward an understanding of scientific language based on everyday language discussions and understandings. Thus, if Lee, Fradd and Sutman had continued to work with students over a period of a few weeks, rather than in time slots of less than an hour, everyday language and knowledge may not have been seen as such a liability. Both Lee, Fradd and Sutman and Warren et al. agreed that when everyday
knowledge and language are closer to science knowledge and language in the first place, comprehension and employment of science concepts and vocabulary comes more readily. Lee, Fradd and Sutman pointed to a lack of precision inherent in many first languages or dialects as a factor posing problems for students attempting to incorporate science language and knowledge. From the perspective of Warren et al., however, it is not the language itself that is perceived as a hindrance, but that the incorporation of such scientific linguistic conceptions requires time for those students whose everyday language does not contain analogous terminology. Warren et al. arranged their study so that they could see how the everyday knowledge and language of all students served as an asset to science learning, whereas Lee, Fradd, and Sutman sought to determine impeding factors to science knowledge acquisition.

**Curricular Multicultural Science Education**

While there is widespread consensus on the need for instructional practices that take into account and support cultural differences between science learners in U.S. schools, the question of whether schools should include multicultural curriculum content is the locus of an ongoing and fierce theoretical debate within the field of science education. The intensity of the debate derives from the extent to which the concept of epistemic universality has been linked to WMS. The question of what constitutes science and thus what should be taught in science classrooms is hotly debated. In this section, I discuss theoretical viewpoints representative of the range of opinions in the field of science education.

Multicultural science education theorists across the debate over the curricular content agree on a number of important starting points that frame this debate. Prominent
voices in the debate agree that the definition of science significantly influences the acceptable content in school science curricula (e.g., Coborn & Loving, 2001; Siegel, 1997; Southerland, 2000; Snively & Corsiglia, 2001; Stanley & Brickhouse, 1994, 2001). The result of this consensus is that a large portion of the debate among science educators, informed in part by philosophers of science, is over what counts as science. Lewis and Aikenhead (2001) summed up another important point of consensus among the major participants in this debate. In a brief introductory article to a recent journal issue devoted to multicultural science education, they stated that the issue’s contributors agreed that “all systems of knowledge about nature are embedded in the context of a cultural group...and that science (Western science) is the system of knowledge about nature that is predominant in Western culture” (Lewis & Aikenhead, 2001, p. 3). This consensus, according to Lewis and Aikenhead, has had the effect of steering the debate away from questions regarding role that culture plays in science, and towards questions concerning “the role that non-Western nature-knowledge systems should play in the school science curriculum” (2001, p. 3). The result of these agreements has led multicultural science education theorists concerned with curriculum content to two major questions: (1) whether the definition of science (school science) should be expanded to include systems of nature-knowledge that developed or exist outside of Western culture, and (2) what effect the inclusion of non-Western knowledge would have on students in American schools.

Curricular Multicultural Science Education Using a Broad Definition of Science

Snively and Corsiglia (2001) addressed the power of the definition of science over the content of school science curriculum by calling it a “de facto gate keeper” (p. 6).
They argued that a singular or universal, narrow definition “displaces pragmatic local indigenous knowledge that does not conform with the formal aspects of the ‘standard account’” (p. 6). The result of this displacement is that classroom science privileges Western science knowledge and devalues indigenous knowledge by not teaching it. Thus, Snively and Corsiglia argued that WMS is “just one of many sciences that need to be addressed in the science classroom” (p. 6). Other sciences were described by the term traditional ecological knowledge (TEK), which was taken to “generally represent experience acquired over thousands of years of direct human contact with the environment” (p. 11). Many researchers, including Snively and Corsiglia, point to the contributions of TEK to such subspecialties within WMS as astronomy, agriculture, and pharmaceuticals (Harding, 1994; Murfin, 1992; Snively & Corsiglia, 2001). The value of including TEK in the definition of science, according to Snively and Corsiglia, is that it legitimizes teaching of such contributions, and helps to sustain indigenous knowledge systems that in combination with WMS have potential to “create future sciences that better meet the needs of diverse societies” (p. 23). Snively (1995) assembled a guide for including both WMS and TEK in science curriculum development that was adapted and included in the Snively and Corsiglia 2001 publication (see appendix). The stated purpose of these guidelines was to help “students and future practitioners...make sense of a society continually being shaped and reshaped by science and technology,” in a way that, according to Snively and Corsiglia, cannot be achieved by the simple acquisition of WMS facts and concepts (p. 29).

While Snively and Corsiglia (2001) contend that broadening of the definition of science could help fill in the gaps of knowledge about the natural world that are left
unattended to by WMS, Stanley and Brickhouse (2001) aligned their case with science philosophers who argue that there is no single true understanding of the natural world. They argued that the natural world is neither "uniformly organized nor static" and that attempts to understand the natural world in a scientific way cannot be tied together into a unified science, but rather are more easily characterized by "multiple sciences" (p. 43). Stanley and Brickhouse (2001) cite science philosopher Hacking to illustrate the difficulty that philosophers of science have in finding unity across science accepted by WMS. Hacking (1996) observes that "there is no set of features particular to all the sciences, and possessed by only the sciences. There is no necessary and sufficient condition for being a science" (p. 68, as quoted in Stanley & Brickhouse, 2001). Using Hacking's insight, Stanley and Brickhouse make the point that the lack of unity within WMS presents a problem for the exclusion of other nature knowledge systems from science based on their lack of unifying characteristics. Stanley and Brickhouse explore the implications for science education brought by the theory of disunity within science. First, they use disunity to make a case for including "cross-cultural studies" in science classes. Stanley and Brickhouse reemphasize a point made in their earlier paper by recommending that teachers include "a few well-chosen examples of sciences from other cultures [as a] way of showing how Western science is a particular way of thinking about the natural world, rooted in Western culture" (1994, p. 396). Second, they explicitly recognize the controversial nature of the theory of disunity and its implications on classroom science, and propose teaching about these and other controversies in WMS to students in the classroom with the intent of helping students better understand the nature of science. I return to the discussion of teaching about the nature of science after
exploring the definition of science and its curricular implications from several other perspectives.

**Curricular Multicultural Science Education Using a Narrow Definition of Science**

Siegel (1997) and Matthews (1994, 1998) each argue in favor of a narrow definition of science and modest use of and goals for discussions of the nature of science in science classrooms. Matthews contends that WMS is universal, rather than "just one among a number of equally valid and truthful sciences" (1994, p. 181). He defines universalism as a way of knowing that exists outside of cultural bias. He suggests that the goal of universal science is to find truth and that the process that people take to meet this goal "transcends human differences" (Matthews, 1994, p. 182). Matthews expands on this definition in a widely quoted passage:

The core universalist idea is that the material world ultimately judges the adequacy of our accounts of it. Scientists propose, but ultimately, after debate, negotiation and all the rest, it is the world that disposes. The character of the natural world is unrelated to human interest, culture, religion, race or sex. Ultimately the concept is judged by the object and not the other way around. Just as the volcanic eruptions are indifferent to the race or sex of those in the vicinity, and lava kills whites, blacks, men, women, believers, nonbelievers equally, so also the science of lava flows will be the same for all. For the universalist, our science of volcanoes is assuredly a human construction with negotiated rules of evidence and justification, but it is the behavior of volcanoes that finally judges the adequacy of our vulcanology, not the reverse. (Matthews, 1994, p.182)
In this passage Matthews explicitly asserts the role of humans in the construction of scientific theories, yet his philosophical argument is that there exists one truth in the material world and that the truth itself is the ultimate judge of the validity of science. That is to say, no matter who and for what purpose science is conducted, the degree to which it stands up to the singular truth of the material world determines its quality. As such, the different approaches that people from different cultures may take in doing science will be equalized as theories are accepted or rejected by nature itself.

Siegel (1997) makes the case that WMS is a universal science and is compatible with multiculturalism in so far as there exists a universal moral obligation to address the “views and interests of other cultures” that have been and continue to be neglected by “members of dominant, majority cultures” (p. 97). He argues that this moral obligation requires that “dominant, majority cultures” treat “dominated...minority cultures with respect” (p. 101). Specifically relevant to this discussion, Siegel continues:

[Members of dominant majority cultures] must treat the scientific ideas of these [dominated] cultures with respect. But so treating these cultures and their scientific beliefs and ideas does not require that those ideas be treated as correct, or as correct as the scientific ideas of the dominant, hegemonic culture. That is, there is nothing morally suspect about suggesting to anyone, including members of non-Western cultures, that their views about the natural world are epistemically or scientifically deficient. Indeed, insofar as education involves the systematic, planned enhancement of student belief systems, as well as the equally systematic development of student attitudes, dispositions, and critical abilities (and, most importantly for the purposes of this discussion, the systematic exposure of
students to unfamiliar information and insights which are deemed by educators to be educative), the exposure of non-Western students to Western science seems to be exactly what science education for such students should be all about. (pp. 101-102)

The purpose of science education, according to Siegel, is to teach students from all backgrounds about WMS and its “power...to explain natural phenomena and deepen our understanding of them” rather than to teach about natural phenomena and the many possible ways of understanding them (p. 102). Yet in doing so, science educators are obliged to recognize and respect the variety of culturally associated ways of understanding that students bring to the science classroom. The job of the science teacher then becomes one of separating science (WMS) from inferior “scientific beliefs” in the culturally diverse classroom without putting these less scientific down. Siegel comments on his awareness of the potential difficulties that this approach may pose; he states his concern that abuse of this strategy can make “non-Western students...feel stupid or backward” (p. 102). He commends the efforts of multicultural science education advocates for their emphasis on prevention of further instances of such abuse. To mitigate the possibility of abuse, Siegel suggests that a “maximal awareness of the diverse beliefs and backgrounds of students” be coupled with respectful and sensitive teaching of WMS (p. 104).

A Role for the Nature of Science in School Curricula. In addition to advocating against the abusive use of culturally hegemonic academic disciplines, Siegel (1997) concurs with multicultural science education theorists in support of the inclusion of the
philosophy and nature of science into science education curricula. He suggests that there exists great potential value for bringing "questions concerning the interrelationships between science, its epistemology, and the cultures within which it is embedded and practiced" into the science classroom (p. 103). Siegel implicitly claims that teaching about the nature of science would help students better understand the superiority and universality of WMS. He states "no friend of universalism in science education need fear such questions; rather, any such friend should welcome them, since pursuing them will provide the opportunity for students to learn about those features of science which universalist are so fond" (p. 104). In this work, Siegel advocates the use of a narrow definition of science, so as to ensure that the science that students learn in school is WMS. He also stands firmly behind the notion that WMS is universal and that its universality can be proved to and understood by students through the study of the nature of science.

Matthews (1998) asks, "What do we want to achieve when teaching about the nature of science" (p. 161)? To answer this question, he acknowledges competing philosophies of science that have arisen since the early 20th century that have informed debates about the nature of science. He argues that an understanding of epistemological ideas concerning the nature of science is necessary for students to be able to "distinguish good science from parodies and pseudosciences" (p. 163). Yet he states his concern that teaching about the nature of science might lead educators toward the promotion of their particular philosophical views amongst their students. Matthews states that "bringing epistemology and philosophy into focus in science education and putting the nature of science into curriculum documents will be to no great avail if it merely becomes the
occasion for students repeating the opinions of their teachers” (p. 168). The danger in this approach, Matthews argues, is that education becomes less a process of teaching students to be independent thinkers and more a process of brainwashing. To combat these ills, Matthews suggests introducing students to “elementary philosophical questions” (p. 169). He cites research indicating that school and university students are unable to competently work through questions requiring complex reasoning. Therefore, he advises against “overwhelm[ing] students with cutting-edge questions” (p.169). Matthews gives some examples of “low-level” questions that students can both handle and learn from:

What is a scientific explanation? What is a controlled experiment? ... How do models function in science? How much confirmation does a hypothesis require before it is established? Are there ways of evaluating the worth of competing research programs? Did Newton’s religious beliefs affect his science? ... Was Planck culpable for remaining in Nazi Germany and continuing his scientific research during the war? And so on. (p. 169)

Matthews suggests that a well-rounded examination of questions such as these in the school science classroom can help lead students toward greater intellectual independence. Yet teachers should be wary of pushing their own philosophies. Hence, Matthews argued, if teachers are cautious and all that students learn is some elementary logic, they should be satisfied in their educational role. Matthews considers logic to be a critical component of scientific understanding, and he states that the benefits of limited philosophical understanding far outweigh the costs of preventing students from having the opportunity to independently evaluate scientific philosophies and ideas.
Like Siegel (1997) and Matthews (1994, 1998), Coborn and Loving (2001) and Southerland (2000) argue that the definition of science should not be expanded to include TEK. Similarly too, they contend that non-western nature-knowledge systems should be welcomed into the science classroom as an important way to teach about the nature of science that includes both its strengths and weaknesses. Coborn and Loving, like Southerland, advocate for an additional use for the incorporation of multicultural content into the school science curriculum in order to combat the rise of "scientism" in western culture. Southerland defines scientism as the recognition of "science as the only legitimate, intellectual approach to constructing useful knowledge" (p. 295). Scientism, by this definition, describes the familiar phenomenon of people in Western cultures accepting without question all explanations that are said to be "scientifically proven."

Coborn and Loving (2001) concur:

The problem [of scientism] is not that science dominates at what it does best: the production of highly efficacious naturalistic understanding of natural phenomena. The problem is that too often science is used to dominate the public square as if all other discourses were of lesser value. (p. 62)

With this examination of scientism, Coborn and Loving indicate that WMS is superior to other thought systems when the problems to be addressed are limited to ones that are scientific. Outside the realm of scientific questions, reliance on science becomes less trustworthy and more scientistic. Southerland (2001) stresses the importance of acknowledging the limits of science:

Science can produce valid knowledge, but it is limited in scope by the assumptions underlying its own methodology. I argue that recognition of the
limitations of science in no way undermines the utility of scientific knowledge, but it does allow for recognition of the legitimacy of other systems of thought. (p. 296)

In this statement Southerland indicates that WMS is one of many valid thought systems, each of which has unique limits. Yet, she warns against equating all thought systems under a broader definition of science because this, too, has the effect of promoting scientism. Southerland states “When we collapse the many epistemically different ways of knowing science, we once again signify that knowledge defined as science is the only valid source of meaning, even though we now have a different definition of science” (p. 298). So, despite its multicultural inclusions, this broader variety of scientism is no less dangerous than any other, in fact, Southerland argues it may be worse, especially when it influences science curriculum content. She questions whether the time spent on learning multicultural content is damaging to culturally diverse students by displacing the traditional curriculum, the understanding of which is critical to full participation in the greater economy of power that exists in American culture.

Coborn and Loving (2001) also consider the issues of power and scientism in their warning against extending the definition of science to include other nature-knowledge thought systems, such as TEK. They argue that TEK would ultimately lose what power it has to answer questions within its domain by being subsumed into the WMS system. Coborn and Loving state:

[TEK] would lose because the new additions [to science] would inevitably be taken as mere “tokens” of cultural inclusiveness rather than serious participants in the discourse of science. This tokenism would be reinforced by the inability of the
new additions to compete where Western science is strongest—technical precision control, creative genius, and explanatory power. And, the new additions would lose by being co-opted into the cultural chauvinism [that] scientism now holds in much of modern life. (p. 62)

So, in addition to Southerland's concern over a broader, more multicultural scientism, Coborn and Loving underscore the problem of tokenism within this broader definition of science. Similarly, Coborn and Loving argue that simply adding TEK to the school science curriculum does not address the problem of tokenism. Rather, they suggest that teaching TEK must be done with explicit purposes in mind. They list some potential benefits of using TEK in the science classroom:

- It offers students a chance to see how the practice of science can benefit from the insights of another domain of knowledge. It helps students see that some of the insights from science can be arrived at by other epistemological pathways. And, it helps students see what is unique about science—what science can do that other domains of knowledge cannot do. (p. 63)

With this statement, Coborn and Loving highlight the usefulness of TEK for teaching about the nature of science. Additionally, they suggest that students from all backgrounds have something to gain from an appreciation for the places where WMS and other "domains of knowledge" overlap, and where they do not.

Southerland (2000) and Coborn and Loving (2001) consider WMS to be a universal science, and both argued that it is not universalism in science that threatens TEK. Southerland explicitly points to scientism as the main threat against TEK. She aligns herself with Matthews' and Siegel's definitions of universalism, that is, that the
natural world is the “final arbiter of knowledge statements,” but she expresses concern that the criticism of universalism in science derives from the conflation of it with scientism (Southerland, p. 295). Coborn and Loving, make a similar point, by stating that “the real difficulty multiculturalists have with the Standard Account is not its claim to universality, but its exclusiveness” (p. 61). They elaborate, saying that the exclusion from WMS of TEK and sciences based in cultures that are not Western frustrates advocates of TEK because of the “dominant intellectual position that Western science has come to hold in the public sphere” (p. 61). In effect, Southerland and Coborn and Loving make the same point: universality is the wrong target for curricular multiculturalists to attack.

According to these theorists, TEK has great intrinsic value; it has contributed historically and has potential to contribute to future scientific endeavors. It also can contribute to science education to work against scientism, rather than universalism, which is seen as an inappropriate target.

**Curricular Multicultural Science Education Conclusions**

Clearly, the definition of science is currently a volatile topic in both research science and science education. In the realm of education the discussion is particularly heated because it is generally agreed upon that the definition of science dictates curricular content in school science classes. Yet those in favor of expanding the definition of science to include TEK, and those in favor of a narrower definition of science do not necessarily disagree on whether TEK should have a place in school science. The purpose of its inclusion varies with the philosophical approaches of science education theorists. Most theorists agree that TEK can play an important role in teaching about the nature of science, whereas only some consider usefulness beyond this purpose. Those theorists
who conceive of broader applications of TEK point to its utility in promoting cross-cultural understanding, equity, and empowerment of students from all cultural backgrounds (Stanley & Brickhouse, 1994, 2001; Corsiglia & Snively, 2001; Hodson, 1993, 1997; Southerland, 2000; Coborn & Loving, 2001). Many researchers and theorists in science education have conceived of strategies and ideas for the use of multicultural content integration in science education that have great transformative potential. Because many of these ideas are buried in the current debate rather than occupying a distinct place of their own in the academic literature, a discussion of transformative multicultural science education is taken up in Chapter 4.

Multicultural Science Education Today

The most recent edition of national standards for science education (National Science Education Standards, 1996) placed strong emphasis on the importance of instructional methods in science. The content standards however, are explicitly presented as learning targets rather than as a prescribed curriculum. Thus, the National Science Education Standards (NSES) state that “the scope, sequence, and configuration of the concepts, processes, and topics are left to those who design and implant curricula in science programs” (p. 23). For curriculum design, however, NSES recommends taking into account the “interest, knowledge, understanding, abilities, and experiences of students” (p. 30). Instructional methods, such as inquiry-based learning are advised by NSES, and content standard categories included the nature and history of science and science in personal and social perspectives. Without making explicit mention of multicultural science education, NSES “recognize[s] that many individuals have contributed to the traditions of science and that, in historical perspective, science had
been practiced in many different cultures” (p. 21). NSES emphasizes that science is a specialized and limited way of knowing that is characterized by empiricism, skepticism, and logic. Thus the authors drew a line around what is and what is not science.

In addition to making recommendations on content and instruction, the National Science Education Standards (1996) discuss factors that influence teaching behavior and strategies in science. NSES recognizes that the quality of the relationship, and the depth of understanding between teacher and student, as well as each teacher’s perceptions and beliefs about science as a discipline influence teacher actions.

Bianchini, Whitney, Breton, and Hilton-Brown (2002) investigated the process of making science education inclusive of women and people of color. This qualitative study examined views and beliefs of secondary and university science teachers related to student experiences and success patterns in science classes, the way they structure, teach and assess to promote inclusion, and the nature of science and its biases. The researchers collected data using a combination of questionnaires and semistructured interviews before, during and after a yearlong workshop series intended to promote scientific literacy among women and people of color. All participants in this study were university scientists at a single, large, public university serving a diverse student population. The sample was not random, as the participants elected to be involved in the study. Through the use of statistical analysis of variance among and spread within questionnaire responses, the researchers found that the views and practices of scientists differed little between the sexes and over time. These results indicated that the sex of the scientist did not determine his or her philosophy of science, rationale for patterns of success, pedagogical strategies, or the multicultural content his or her courses. The results also
showed that these factors did not change significantly during the yearlong program. The data exhibited a range of beliefs and views of science and a range of teaching practices among the study subjects. The purpose of this study was intended to show if there would be change over time and correlation of views on science and gender. The researchers, however, did not perform statistical analyses to examine potential correlation between beliefs and views and teaching practices.

In addition to quantitative analysis of survey data, the researchers qualitatively examined interview responses. They found that this work yielded insight into how science teachers might help retain women and people of color in the scientific talent pool. In many of the interviews, teachers described increased interest and student involvement when their science classes were modified to be more inclusive. Teachers listed examples of modifications they could use to create a more inclusive science class: more attention to historical contributions of women and people of color, increased relevance to everyday life, and broadened assessment techniques. Yet the interview results identified the many constraints the teachers felt when thinking about and attempting to make curricular or instructional changes in their classes. In general, “participants found modifying course content to be a greater challenge than transforming instructional practices” (p. 64). Teachers identified large class sizes and increased work and effort on their part as the chief constraints to making instructional changes to their courses. Based on the data collected, the researchers identified three major areas of constraint to curricular modifications to university science classes including “(a) lack of time and resources to research underrepresented groups’ contributions, (b) instructional and disciplinary expectations to cover large amounts of material, and (c) mismatches between the
concepts of their disciplines and the goals of the [researchers'] project” (p. 64). The teachers of physical and technical sciences, in particular, struggled with this third constraint. One teacher noted the positive impact of including discussions of contributors to science in her class, but considered any efforts of inclusion beyond this technique to be limited by her discipline. The teacher stated, “‘Talking about scientists as people...really brought in students,’...[t]he rest of ‘molecular biology just is not by nature going to be real inclusive’” (p. 66). Teachers of life science courses such as human anatomy and immunology regularly viewed the constraints of scientific disciplines as less insurmountable. In one teacher’s human physiology course, time was devoted to the examination of “race from a biological perspective” (p. 67). He included research representative of a wide range of perspectives in order to highlight the presence of racism in historic research, and to show the current understanding that there is a lack of biological basis for races among humans. Despite these efforts, this teacher “did not see discussions of gender and ethnicity as particularly relevant to present day science; he thought racism and sexism integral to science’s history, but not its present” (p. 68). Through the interviews, Bianchini et al. found that, despite their yearlong treatment, university science teachers found the integration of instructional and curricular multicultural reforms to be challenging and sometimes irrelevant.

Throughout the course of the Bianchini, Whitney, Breton, and Hilton-Brown (2002) study, a debate over the nature of science was as regular feature among participating teachers. The researchers noted that teachers’ “views ranged from seeing the production of scientific knowledge as constrained by the gender and ethnicity of its members, to science as transcending personal, social, and cultural biases” (p. 67). This
range is reflective of the range represented by the theories of science education specialists in the preceding section, indicating that the debate over the nature of science is lively across many levels of science education. Bianchini et al. did not present data relating teachers' views on the nature of science to the extent to which the teachers adopted multicultural content or instruction.

In a longitudinal study of multicultural education in the United States, Washburn, Brown, and Abbott (1996) examined the quantity and quality of district-wide multicultural education programs in 1974 and 1995 using questionnaires. For both survey years, the researchers requested responses from all school districts serving 10,000 or more students. Despite a greater level of complexity in the 1995 survey and shifting demographics, which caused some districts serving 10,000 or more students in 1974 to be excluded from the 1995 survey, helpful comparisons can be drawn between the data collected in each survey. Washburn et al. used Sleeter and Grant's (1988) typology in the development of the 1995 survey to characterize the goals and purposes of multicultural education programs in the districts queried (see Chapter 1 for description). They found that fewer large school districts had multicultural education programs in 1995 than in 1974 and that most district programs in 1995 had been in operation for five or fewer school years. Thus, few school districts that had multicultural education programs in 1974 kept them in continuous operation during the intervening years. Greater than 85 percent of schools in 1995 operated a multicultural education program at each grade level, yet most districts had significantly less than full student participation in multicultural education programs. Data showing academic disciplines participating in district programs was only collected in the 1995 survey, and then only for programs
characterized by the districts as “ethnic studies” curricula. Approximately half of the 255 districts with multicultural education programs in 1995 characterized their programs as inclusive of “ethnic studies” curricula. Of these, only 31.7 percent listed science as a discipline included in the program. Common elements of these programs (across all disciplines) included ethnically specific history, social customs, and beliefs. Though the research of Washburn et al. did not emphasize discipline specific multicultural education, the data shows clearly that the majority of districts surveyed do not include any ethnic-cultural historical perspectives in science curricula.

In analysis of the data, Washburn et al. (1996) explained the decline in multicultural education since 1974 by stating that though “the 1980s [was] a time of great development in multicultural education theory, [it also] was a period of diminution in multicultural education practice” (p. 75). They go on to note that programs initiated in the early 1990s seemed to be reflective of the theoretical developments that occurred during the 1980s. This observation is based on the high percentages of districts that described the curricular and instructional aims of multicultural education programs similar to Sleeter and Grant’s (1988) “multicultural education,” and “education that is multicultural and social reconstructionist.” Additionally, Washburn et al. recognized a strong link between the presence of state policies and guideline for multicultural education and the presence of multicultural education programs. That is, states with multicultural education policies were significantly more likely to have programs than those without such policies.

Despite the finding that districts had curricular and instructional aims for multicultural education, the Washburn et al. (1996) study found that the most frequently cited (39.5%) goal was improved human relations. Districts indicated their “human
relations" aims by characterizing school goals through the selection of this survey statement: "promote positive feelings among students, reduce stereotyping, promote students’ self-concepts" (p. 99). Several groups of researchers have examined the connection between multicultural education and human relations. Perhaps paradoxically, preliminary investigations into the effectiveness of multicultural education with a "human relations" focus indicates that these programs do not significantly reduce prejudice (Kehoe, 1994).

Morelli and Spencer (2000) identified multicultural education and antiracist education, rather than "human relations," as "the primary curricula through which school educators are combating the effects of racism and bigotry" (p. 166). They define both multicultural and antiracist education as curricular and instructional reforms "designed to develop more positive intergroup attitudes and pride in heritage," but distinguish the two by highlighting a purpose of antiracist education, which is to end, or at least decrease, individual and institutional racism (p. 168). Morelli and Spencer used surveys and interviews in five school districts across five northwestern states to collect data on the perceptions of, need for, and use of multicultural and antiracist education, and incidence of bigotry and racism. Forty-four teachers, counselors, social workers, and administrators at elementary, middle, and high school levels completed surveys and interviews in the five districts studied. Respondents indicated a high instance of racism and bigotry within schools and their communities; 90% reported incidents during the three years preceding the study. Additionally, respondents in the schools with a higher proportion of students enrolled in English as a Second Language courses (15-40%) indicated a high incidence of “name calling and taunting” (p. 170). The researchers stated that several “respondents
explained that racial and ethnic differences were outwardly tolerated because ethnic minorities did jobs whites preferred not to do” (p. 171). Based on this data, Morelli and Spencer concluded that instances of racism in the districts studied were relatively frequent.

In response to their teaching practices, participants in the Morelli and Spencer (2000) study cited resistance within the community and lack of available material as major reasons for not including multicultural or antiracist material in their curricula. Additionally, some teachers did not consider racism and bigotry to be major problems in their communities or relevant to their disciplines. Those in the latter group were primarily math and science teachers. Still, the researchers found that “50 percent of teachers not currently using [multicultural or antiracist education] stated that these curricula are needed” (p. 172). This means that more teachers were interested in using multicultural education to address racism and bigotry than actually were at the time of the survey.

Morelli and Spencer quoted one respondent speaking on the low use of antiracist education among teachers: “‘It...won’t happen here until there is a crisis’” (p. 173). This teacher implied that the community in which she worked would have to experience a race-based tragedy before enough people would see the necessity of teaching anti-racism in the schools. Based on their findings, the researchers expressed concern over “whether regional efforts to eliminate racism and its effects are genuine” (p. 172). They recommended the implementation of state-level policies that explicitly address racism, bigotry and oppression in schools, community education and involvement in prevention strategies, and the provision of training and resources for teachers in multicultural and antiracist teaching techniques.
McGregor (1993) demonstrated the promise of antiracist education and role playing on the reduction of student prejudice through a meta-analysis of research examining the effectiveness of such programs. She located 26 empirical studies that met her established criteria for role-playing or antiracist teaching by thoroughly searching educational and psychological databases and contacting scholars in relevant fields. Using the originally published data, McGregor standardized the study results using the established technique of calculating effect size, which gives each finding within each study a “score” for the effectiveness of the treatment and conditions it used. McGregor conducted data analysis and comparison on the effect size data using conventional statistical procedures including multiple regression techniques. Only 17 of the 26 studies that McGregor identified included sufficient published data to calculate effect sizes. For the studies that examined role-playing (13 of the 17), McGregor found that “the average student in the experimental group exhibited less racial prejudice after treatment than 64% of the students in the control group” (p. 219). The effects for antiracist teaching (7 of 17 studies) were somewhat greater, with “the average student in the experimental group exhibit[ing] less racial prejudice than 66% of the students in the control group.

Based on the application of regression modeling to the effect size data, McGregor found that four variables were significant at the 0.5 level. First, the age of the children in the study was found to be significant. Thus, when younger children were the subjects of the study, their effect size, equivalent to their change in racial prejudices, was greater. McGregor interpreted this data as indicative of the more malleable attitudes of younger children. Second, the publication status of the study was a significant determinant of effect size. Those studies published in reviewed journals had higher effect sizes than
those published as dissertations. McGregor interpreted this data as reflective of the standards of many journals, which require statistically significant results for publication.

Third, the regression coefficient for the publication year of the studies analyzed indicated significant determinance, but opposite of the common finding that recent studies proved more effective. Rather, McGregor found that older studies had higher effect sizes than more recent studies. She provided two possible interpretations of this finding: either “racist attitudes have become more entrenched over time, and therefore more difficult to change,” or studies are working with populations that hold generally less racial prejudice, and therefore, the effect size, which measures amount of change, would be lower (p. 222). The fourth significant finding in McGregor’s meta-analysis study indicated that smaller sample sizes were related to greater effect sizes. Her interpretation of this data is based on the idea that smaller student-teacher ratios are more “conducive to attitude change” (p. 222).

Additional findings in McGregor’s (1993) meta-analysis study include a lack of significance in the difference of effect between antiracist and role-playing techniques for reducing prejudice, and that the longer the term of the study, the less effective the treatment against prejudiced attitudes. This latter finding surprised McGregor, because she had expected that, since attitudes tend to be held strongly, longer treatments would produce more change than shorter treatments. Her surprise prompted an examination of other variables that might have been linked to duration. This examination showed that duration and geographic location were inseparable, and that the effectiveness of the treatment may be more strongly linked to location than duration.
Taken together, McGregor (1993) concluded that instead of instigating racism, as critics have often complained, antiracist teaching is an effective method for the reduction of racist prejudices, especially when implemented with young children. McGregor criticized the research techniques of many of the studies she analyzed for their additive quality and short duration. Additionally, she noted that teacher training, input, compatibility, and commitment were regularly not included in study design or implementation.

Conclusion

Based on the review of the literature presented in this chapter, it is clear that the range of philosophical convictions held by science education researchers complicates the application of the principles of multicultural education to science education. Despite the clearly stated goal for multicultural education to direct systemic change, affecting instructional, curricular, and administrative areas of school and across all subject areas (Banks 2001a, 2001b), science educators have been slow to adopt such complete reforms. Instead, many science educators have advocated solely instructional reforms in order to address disproportionality and embrace constructivism and inquiry-based teaching techniques. Such reforms are considerably less controversial, and as a result, have been implemented widely enough to enable the collection of viable data. Curricular reforms, on the other hand, have been hotly debated, and philosophy of science has played a significant role in the debate. Because there has been little agreement among researchers and teachers about the extent to which science content should be modified to include multicultural topics, studies generating data indicating the effects of multicultural science on student interest, retention, and racial attitudes have not been widely undertaken. An
analysis of the reasons for and implications of the degree of application of principles of multicultural education to school science are addressed in present and historical perspectives in the next chapter of this paper. Additionally, recommendations for further research are presented.
CHAPTER 4: CONCLUSIONS

In the final chapter of this paper, I return to the central question of this study:
what is the effect of applying principles of multicultural education to science education?
With this question in mind, I examine the relationship between the history of
multicultural science education and the current research and theoretical debates. Two
historical paths have led to the possibility of discussing multicultural science education.
The first is philosophical and the second is educational.

The historical section of this paper discussed the importance of the work of
anthropologists including Franz Boas and Margaret Mead on objectivity in the middle of
the 20th century. In their work, these anthropologists struggled with the difficulties of
observing other cultures without letting their own cultural biases interfere. Prior to this
time it was assumed that objective observation was not only ideal, but also possible to
achieve. Based on these struggles, researchers in other scientific disciplines began to
examine their work for culturally derived biases that might be interfering with objective
observation. The emergence of the civil rights movement drove demands for the
reexamination of standard historic, scientific, and artistic accounts to recognize the
Eurocentricism behind the culturally derived biases right here in the United States. The
voices of those challenging the notion that a unified American culture ever existed grew
in strength, highlighting the idea that cultural biases that interfere with descriptions of life
in remote parts of the world are no less in effect in the United States. As a result of this
historical development, one component of the standard account examined by scholars is
the underrepresentation of contributions to science made by people and cultures from
around the world.
As stated in earlier sections of this paper, researchers and theorists within the multicultural education field currently strive for critical multicultural education. To review, critical multiculturalism is based in the idea that simply reforming existing societal norms is insufficient to effect any real change to the structural inequities that exist in today’s society. Because of the totality of the transformation required of societal structures, aiming at individual sectors of society constitutes the maintenance of existing structural inequalities. This totality necessitates extending transformation throughout all disciplines in order to be convincing and meaningful. The widening acceptance for critical multicultural education theory led to the enlarged circle of discussion for multicultural science.

Once it was possible to discuss the application of principles of multicultural education to school science, two questions emerged: (1) why apply multicultural education to science, and (2) what would this application look like? A variety of purposes, stemming from various groups with interest in science education and education in general have been presented to answer the question of why. From those in the field of traditional Western science, multicultural science has been seen as a method of addressing disproportionality and achievement gaps, and combating scientism. Those who approach science education from critical multiculturalism tend to see multicultural science education as a part of a transformation capable of addressing the larger goals, including but not limited to those listed by science education reformers. Some researchers coming from both scientific and multicultural education backgrounds express concerns over multicultural science education. It must work to cease the alienation of children of color and from diverse cultural backgrounds, and it must not place those very same
children at a greater disadvantage than they already are by weakening the science curriculum in the name of multiculturalism with the effect of further disempowering students. Despite these concerns, researchers tend to concur that the application of some principles of multicultural education to science education is desirable. Yet, what multicultural science education should look like, remains a widely debated topic (see Chapter 3). Following a review of the research findings reported in this paper, I present a selection of practical strategies for applying transformative multicultural education to school science curricula in light of the research I reviewed.

**Discussion of the Research Findings**

Instructional multicultural science education, an approach that aims to mitigate disproportionality and cultivate interest in science, is often based in efforts to assimilate students to Western modern science (WMS). Programs that focus on increasing student contact with WMS through workshops, financial, and advisory support such as those represented in the Burns, Gerace, Mestre, and Robinson (1982) study, are exclusively directed towards assimilation. Women and students of color in such programs have exhibited slightly higher than average rates of retention in the sciences (Burns et al., 1982, Mulkey & Ellis, 1990). Because of their frequent focus on assimilation and lack of opportunity for critical engagement of students, instructional reforms are themselves not often consistent with principles of critical multicultural education.

Other instructional reforms focus on the way students acquire knowledge. In this paper, constructivism is examined because it is most frequently associated with multicultural education. Constructivism in science education is effective, both as a way to assimilate students, by replacing culturally derived, but incorrect “everyday knowledge”
with scientifically derived "correct knowledge" (Clement, Brown, & Zeitsman, 1989; Lee, Fradd & Sutman, 1995), and as a way to help students move between cultures by building on prior understandings (Warren, Ballenger, Roseberry & Hudicourt-Barnes, 2001). Constructivism in this latter incarnation is consistent with Banks' (2001a) dimensions of multicultural education because it emphasizes understanding science as one of many equally valid perspectives. Still, to be consistent with constructivism in the strictest sense, students should have the opportunity to construct knowledge about science and simultaneously about their knowledge construction processes. Regardless of its emphasis, the application of constructivism to science education can be, at best, seen as only one necessary component of multicultural science.

Curricular multicultural education operates in the realm of content integration. Similar to simply emphasizing knowledge construction, the addition of multicultural curriculum content alone is not sufficient for education to be considered multicultural (Banks 2001a). According to Banks (2001a), some evidence of each component must be present for transformative possibilities in multicultural education. Yet the integration of multicultural content is one of the most challenging components for science education. Few research studies have examined the effects of curricular multicultural science education on students because such studies are difficult to conduct. Science teachers and science education researchers perceive barriers that make content modifications challenging. Some of these barriers include (a) high expectations for the quantity of content coverage in science classes that make teachers at all levels feel rushed and less able to add or change course content and (b) the wide range of philosophies of science present in the population of teachers (Bianchini et al. 2002). Thus, research has focused
on teacher attitudes and the effectiveness of trainings to increase the likelihood of teacher participation in multicultural content reforms. The investigation into theoretical debates over the inclusion of multicultural science content in school science classrooms indicates that there is agreement across the discussion that the nature and history of science should be included into the science curriculum. The effect of such inclusions on students have not been thoroughly studied; however, such recommendations are consistent with those put forth by some prominent multicultural education theorists (Banks 2001a; Coborn & Loving, 2001).

Additional findings indicate that multicultural education programs can effectively reduce prejudice (McGregor, 1993) and that prejudice reduction and improved human relations are the most frequently stated goals of multicultural education programs in the United States (Washburn, 1995). Despite these findings, research indicates that reforms with these goals in mind are infrequently applied to school science curricula (Washburn, 1995).

**Practices for Transformative Multicultural Science Teaching**

Despite the difficulties of applying principles of multicultural education to school science many researchers have made recommendations that have transformative potential. It is important here to note that though well-respected researchers make these recommendations, they are largely theoretical and require significant future testing in order to characterize their effectiveness.

One of the most resounding recommendations made by researchers in multicultural science education is to teach students at all levels about the nature of science. Helping students identify what science is good for and what it is not is an
approach that is regularly promoted by researchers who are primarily concerned with fighting scientism as well as those who are interested in radically changing the curricular content of science courses to reflect traditional ecological knowledge (TEK) (Coborn & Loving, 2001; Southerland, 2000; Snively 1995; Snively & Corsiglia, 2001). Researchers concerned with scientism indicate that students who learn about the nature of science may be more capable of seeing science as one of many legitimate ways of knowing. This argument is intended to help students understand that learning WMS does not require a devaluation of TEK. Stanley and Brickhouse (1994) recommended, “A few well-chosen examples of sciences from other cultures [as a] way of showing how Western science is a particular way of thinking about the natural world, rooted in Western culture” (p 396). Other researchers similarly recommend bringing TEK into the classroom to teach this important lesson (e.g. Snively & Corsiglia, 2001). Further study of how this approach impacts students' interest in and understanding of science should be conducted. Its presence as a content standard in the 1996 National Science Education Standards (NSES) document, however, lends legitimacy to the study of the nature and history of science at all grade levels.

As in the NSES document, the nature of science is often coupled with the history of science as a recommended curriculum topic. Many researchers working in multicultural science education emphasize the importance of teaching about the contributors from various cultural backgrounds who helped make science what it is today (Atwater, 1993; Murfin, 1992). One reason for this effort is to help students from all backgrounds more easily connect with science curricula. Another reason, as emphasized by Atwater (1993), is that teachers who recognize diversity among the historical
contributors to science are also likely to “recognize the potential for students from different cultures to contribute to science because of their different ways of understanding and experiencing the world” (p. 35). The expectations of teachers have been widely shown to impact the performance of students through research into the phenomenon of the self-fulfilling prophecy. As such, teachers who view students’ individual and cultural backgrounds as strengths to the science, rather than liabilities, are likely to see improved interest and performance in science courses and careers among a wider segment of the student population.

Hodson (1993) cautions that using examples of science from other times and other cultures as the sole implementation of multicultural science is insufficient and may be damaging. Regarding programs that focus only on the nature and history of science, he states that “we risk charges of tokenism and irrelevance to contemporary needs, and even of reinforcing stereotypes of primitive peoples in faraway places engaged in quaint and puzzling activities” (p. 689). Suggestions for avoiding such charges are put forth by many researchers and tend to recommend measures that attempt to increase the relevancy of curricula to students’ lives. One approach to making science more relevant to students’ lives is through the investigation of scientific issues that are personally and socially interesting to students. The NSES content standards include the category “science in personal and social perspectives” that includes content standards such as “personal and community health,” “population growth,” “natural and human induced hazards,” and “science and technology in local, national, and global challenges” to name a few. Yet, as is the case for all other NSES content standards, no direction is provided on how to meet
the goal of teaching personal and social issues in science. Hodson (1994) suggests three
guidelines to clarify how teachers can personalize science learning:

Personalization of learning means ensuring that (i) learning is rooted in the
personal experiences of individual learners; (ii) science and technology are seen
as more person-oriented and science/technology education is infused with sound
human and environmental values; and (iii) every student has the opportunity to
pursue investigations and to tackle technological tasks of their choosing and their
own design. (p. 75-76)

The first and third of Hodson’s recommendations, items (i) and (iii) above, require
teachers to deviate from pre-planned curriculum units that are often used year after year,
and instead place added emphasis on getting to know individual students in order to
better support their interests. Teachers who have attempted this type of reform often
report that it requires additional effort and provides additional rewards (Bianchini et al.
2002). Steps for developing multicultural science curricula based on student interest are
included in appendix A.

Hodson’s third recommendation for personalization highlights an effort that is
partially based in constructivism and is intended to get students doing science. One way
to encourage students to do science was presented in Warren et al.’s (2001) study. The
researchers examined the process that children engaged in when attempting to answer a
question (in this case: do ants prefer light or dark). The researchers observed a high level
of student involvement and of critical thinking as the students determined how best to
approach the problem. Another way for teachers to promote students doing science is to
encourage and support them in pursuit of questions that they generate (Hodson, 1994). A
more detailed version of Hodson's recommendations for multicultural science education can be found in appendix B.

In addition to personalization and getting students doing science, a third recommended method for increasing the relevance of science curricula to students' lives is allowing students and community members a higher level of agency in determining the curriculum content. Stanley and Brickhouse (2001) recommended that teachers and local curriculum developers seek the opinions of students and members of the community regarding their expectations and desires for learning and for their concerns about WMS. To illustrate, they state:

We might want to know the extent to which non-Western students are concerned that learning about WMS is a threat to the survival of their culture and to what extent they might desire access to WMS. ... The students' wishes, their positioning within both the school and society, are important factors to consider. Multiple and perhaps competing values of respect, empowerment, critical thinking, and survival would have to be taken into account. (p. 45)

Stanley and Brickhouse argue that students should be involved in determining curricular aspects of their science courses and that their desires to include studies that help maintain cultural heritage are as valid as their desires to learn the tools and skills of WMS. In fact, they claim that the process of making such curricular decisions could itself be greatly educative.

Though critical of many practices within curricular multicultural science education, Southerland (2000) also calls upon values such as survival, critical thinking and empowerment in making her recommendation to give students greater agency in
determining their science curriculum content. She deplores curricular multicultural science for its frequent insistence on telling students what is best for them by making curricular decisions that might limit access to the powerful knowledge that WMS wields within Western cultures in favor of curricula intended to “support students’ cultural heritage” (p. 298). Southerland argues that too often curricular multicultural science education sees students as “incapable of dealing with epistemological and political arguments” (p. 299). Thus, Southerland states:

The decision of what knowledge is of importance to students is often made by others (curriculum developers, science educators, teachers). Thus students’ ability to make informed decisions, their agency in the learning process, is not recognized. By ignoring students’ agency, we fail to develop it. (p. 299)

Despite the fact that some researchers hope that students will choose more multicultural content and others hope they will select more WMS content, there is agreement across the field of multicultural science education that students should have some measure of say in their science curriculum content. The other important point of agreement is that students can learn from this process. This recommendation requires drastic change to the way many teachers plan for and conduct their classes and may be met with opposition from those who are working to advance the current state and federal standards-based reform efforts.

The last recommendation is the suggestion that there are benefits to teaching students about controversial and current issues in science. This recommendation itself is surrounded in some controversy. Some researchers suggest staying away from controversial issues so as to have an easier time implementing curricular content reforms.
(Murfin, 1992). Others suggest that avoiding controversy in the science classroom denies students the opportunity to learn that controversy exists in all fields of science and indicates to them that they are somehow incapable or not old enough to deal with controversy (Matthews, 1994, 1998; Southerland, 2000). Southerland suggests that science curricula that are reformulated to include an emphasis on the nature of science throughout, rather than as an additional unit, could provide helpful preparation for students’ investigations of controversial issues. She states “if the science class is structured around both scientific knowledge as well as knowledge about science, students will have a familiarity and comfort with such discussions before emotionally laden topics are broached” (Southerland, p. 303). Furthermore, Southerland indicates that what is perhaps most important is that teachers encourage a classroom culture in which students feel comfortable bringing conflicting issues to an ongoing discussion. It is through such discussions that students can test and develop their own informed scientific opinions and understanding of science. In short, discussions of controversial issues can encourage critical thinking and reasoning skills.

The recommendations of researchers in the multicultural science education field are by and large intended to directly or indirectly promote student interest in science through increasing personal relevancy, agency, and intellectual respect for students. Personal relevancy is cultivated by efforts to personalize science education, by encouraging students to do science, and by involving students in decisions about curricular content in science classes. Students may also find personal connections when a broader emphasis on the history of science is included in science courses. Involving students in curricular decisions also promotes agency and indicates intellectual respect
for students. Teaching about the nature of science is important for combating scientism and for laying the foundations of productive in-class discussions about controversial issues in science. The inclusion of such discussions in science classes further promotes students’ agency and sense of intellectual confidence. These suggestions are aimed at all populations of students, as most multicultural education researchers recognize the benefits of multicultural education practices for all students. In order to prevent unintentional biases in the implementation of these suggestions, multicultural education researchers regularly recommend that teachers critically examine their own feelings and biases related to racial and ethnic differences (Banks, 2001a; Bianchini, 2002).

**Recommendations for Further Study**

In general, the research findings reported in this paper indicate that there are many barriers to the application of multicultural principles to science education. Efforts to unify the goals of multicultural education with science education and to provide for widespread teacher and administrative training would greatly enhance the possibilities for data collection. Additionally, since the duration of students’ contact with multicultural education programs are likely to effect their outcomes (McGregor, 1993), studies of programs that last for longer than a single course or academic year may increase changes in student attitudes toward science, race, and each other. Yet high quality studies of such programs would be able to ensure some level of consistency of experience for subjects in the study between one year and the next that may be challenging given range of views and beliefs held by science teachers (Bianchini et al., 2002). Until some of these hurdles are overcome, however, a lack of empirical data on curricular multicultural science education will continue.
Conclusions and Personal Implications of this Work

I came into this process with the notion that science is one of many lenses through which we can understand the natural and physical world, and I leave it feeling as though my initial sentiments have been reinforced and refined, but not drastically altered. I refine the above statement by changing the word “science” to WMS so as to show more clearly that there are sciences distinct from WMS that also provide unique and interesting ways to understand the world around us. I do believe that there is room in the science curriculum for these sciences because they have contributed so greatly to WMS historically and have great potential for future contributions. Yet, if my charter as a science teacher is to empower students, I must recognize the power of WMS in mainstream culture. Not teaching enough WMS content has great potential to perpetuate the disempowerment of students from all cultural backgrounds. Teaching science content, however, is clearly not enough, no matter what science it is, for in order for citizens to participate in a democracy in which WMS holds a great deal of power there is a certain level of scientific literacy that is required. Literacy is defined as the ability to recognize the strengths and limitations of WMS and other sciences in order to critically determine the validity the work. Citizens must be empowered to take action against discriminatory, racist and improper uses of science. This sort of empowerment cannot be achieved by those who do not possess a solid understanding of the nature of WMS and other sciences. In order to prepare students to be scientifically literate citizens, science education must include instruction on the limitations of all kinds of systems of nature-knowledge, opportunities for students and communities to participate in the selection of emphases in the science curriculum, and occasions for appropriate sociopolitical action projects so that
students can see first hand the power that is to be had in this culture by those who can
critically evaluate various sciences and their uses. Scientific literacy requires an ability to
cross cultural boarders. Learning science should not force students to give up
understandings of the natural world that derive from their cultural heritage. Rather it
should provide an opportunity for students to learn about understandings that are based in
another culture, the culture of Western science, and the tools to move between systems of
understanding thus increasing their ability to participate in and elevate democracy.
APPENDIX A:
STEPS FOR DEVELOPING MULTICULTURAL SCIENCE CURRICULA

Guidelines for including both Traditional Ecological Knowledge (TEK) and Western Modern Science (WMS) in school science lessons:

Step 1. Choose a Science Concept or Topic of Interest (e.g., medicine, cultivating plants, animal migrations, geology, sustainability)

Step 2. Identify Personal Knowledge
- Discuss the importance of respecting the beliefs of others
- Brainstorm what we know about the concept or topic
- Brainstorm questions about the concept or topic
- Identify personal ideas, beliefs, opinions

Step 3. Research the Various Perspectives
- Research the Western modern science perspective
- Research the various indigenous perspectives and, if possible, the local TEK perspective
- Organize/process information
- Identify similarities and differences between the two perspectives
- Ensure that authentic explanations from the perspectives are presented

Step 4. Reflect
- Consider the consequences of each perspective
- Consider the concept or issues from a synthesis of perspectives
- Consider the consequences of a synthesis
- Consider the concept of issue in view of values, ethics, wisdom
- If appropriate, consider the concept or issue form a historical perspective
- Consider the possibility of allowing for the existence of differing viewpoints
- Consider the possibility of a shared vision
- Ensure that students compare their previous perspective with their present perspective
- Build consensus

Step 5. Evaluate the Process
- Evaluate the decision making process
- Evaluate the effects of personal or group actions
- Evaluate the possibilities in terms of future inquiries and considerations
- How did this process make each person feel

Source: Snively and Corsiglia (2001) p. 27.
APPENDIX B: RECOMMENDATIONS FOR MULTICULTURAL SCIENCE EDUCATION

I. Science Education in a Multicultural Setting

1. We should adapt our use of both written and spoken language to avoid disadvantage to those with language difficulties, especially those for whom English is a second language. We should also pay attention to the ‘language of science education’ and provide more opportunities for students to use language to explore and develop understanding.

2. We should employ content that recognizes and utilizes the culturally-determined knowledge, beliefs and experiences of students. In setting science within a ‘human context’, we must ensure that the examples we use are relevant to all cultural groups.

3. We should adopt learning experiences that are culturally more appropriate to those we teach and take account of the differences in religious beliefs, customs and styles of human interaction.

II. Anti-Racist Science Education

1. We should review our textbooks, worksheets and other curriculum materials for the purpose of identifying and replacing all offensive and racially stereotyped content.

2. We should establish more democratic school organizational procedures, more interactive and learner-driven teaching/learning methods, and more student control of curriculum content and assessment methods.

3. We should draw attention to ways in which science and scientific ways of presenting information are sometimes misused to underpin racist attitudes and to legitimate discrimination against minorities.

III. Multicultural Perspectives for Science Education

(‘Taking a Global View’)

1. We should design curriculum materials that use exemplars from a variety of cultures and countries, so providing a ‘global view’ of science and technology.

2. We should ensure that the contributions of non-Western and pre-Renaissance scientists to our Western cultural heritage are recognized.

3. We should emphasize the culturally-specific nature of scientific and technological practice.
4. We should challenge the conventional views that science has a well-defined, infallible and all-powerful method and that scientists are disinterested and value-free in their approach.

5. We should acknowledge that some scientific change and technological development enriches the lives of some, while impoverishing the lives of others. We should recognize that issues of justice, equality and freedom are inseparable from the proper discussion of scientific and technological practice.

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