Cultural Studies of Science Education 5

Julie A. Bianchini
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Angela Calabrese Barton
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Alberto J. Rodriguez *Editors*

Moving the Equity Agenda Forward

Equity Research, Practice, and Policy in Science Education

Springer

Moving the Equity Agenda Forward

Cultural Studies of Science Education

Volume 5

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Introduction to Volume

Julie A. Bianchini

Moving the Equity Agenda Forward presents current equity-related research, practice, and policy in science education and points to directions needed for future work. Its purpose is to inform critical discussion and transformative action to push us closer to the goal of a science education for all students: to help refine our methods for investigating equity; to deepen and broaden our understanding of the processes of science teaching and learning; to better address persistent inequities across science classrooms, schools, and policies; and to craft new initiatives to engage and instruct all students in science. This volume is not a review of literature.

Moving the Equity Agenda Forward is officially endorsed by NARST. Indeed, this volume grew out of the efforts of an ad hoc committee constituted by the NARST Equity and Ethics Committee in 2007. The ad hoc committee was charged with examining the strengths and weaknesses of existing equity-related scholarship in science education. Through conversations, surveys, and self-reflection, members of this committee identified five key areas of research that have defined and must continue to shape the field: science education policy; globalization; *context and culture*; discourse, language, and identity; and leadership and social networking.

In the now completed volume, scholars' work is organized into these five key areas of research identified by the NARST ad hoc committee. Cutting across these five sections, or parts, are core questions regarding race, class, language, gender, and other socializing categories, as well as issues of power and positioning. These parts are introduced below.

Science Education Policy. Authors critically examine both past and current policies in science education and discuss how they support or constrain efforts to achieve equity.

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Globalization. Authors explore how students, teachers, and researchers can use the knowledge and practices of both local and global communities to teach and learn science in K-12 schools.

Context and Culture. Authors underscore the importance of attending to and better understanding the fluidic nature of context, culture, and/or place to promote science for all in classrooms.

Discourse, Language, and Identity. Authors investigate diverse ways teachers and students' discourses, languages, and/or identities shape the teaching and learning of science.

Leadership and Social Networking. Authors discuss how science education researchers can better support teachers, colleagues, and organizations in pursuing equity and diversity goals.

Each part includes an introduction and three to four chapters written by emerging to well-established science education researchers in the USA. In the introduction, the lead editor identifies crosscutting themes and raises questions for readers to consider. To promote coherence across chapters, authors include how their work speaks to two sets of questions: (1) What do the theoretical and methodological lenses used in this scholarship enable? What do they constrain? (2) In what ways can ideas in this chapter be used to inform research, practice, and policy? More specifically, what is the "so what" for graduate students and new scholars intending to conduct research on equity and diversity? What are the implications of this research for classroom teachers and for policymakers? To strengthen the quality of the chapters presented here, editors and authors engaged in a thoughtful review of each other's work, providing suggestions and offering insights on successive drafts.

Because editors and chapter authors work in the USA, to increase the breadth of perspectives included in this volume, we invited scholars from other countries to craft responses to each of the five parts. These five international respondents represent diverse geo/political locations and kinds of spaces/places, as well as both genders and different races/ethnicities. They include those who conduct equity-based research and those who are not equity researchers per se but whose work speaks to equity in education. Each international respondent addresses the following two questions in his or her discussion of chapters: (1) In your view, how do these chapters speak to scholars and school contexts in your country, in particular, or in countries outside the USA, more generally? (2) What issues, theoretical frames, and/or methods could add to the arguments presented in these chapters? We recognize that our effort to include international voices in this volume is only partial. Our five international respondents speak to studies conducted in the USA, rather than present their own research. Further, our international respondents do not represent all areas of the globe: There is no international respondent, for example, from the continent of Africa.

The epilogue to our volume attempts to hold true to our title – to discuss ways the research presented here can indeed help move the field of science education forward. We remind readers that our purpose in creating this volume was to provide more than a forum for current scholarship on equity and diversity in science education.

We intended to encourage researchers to re/consider tensions and questions in current equity-related work and to prompt them to conduct additional, innovative research in needed areas – to suggest ways researchers might collectively build from existing good ideas about teaching, learning, and schooling and construct new theories and approaches necessary to advance the field.

We argue that this volume provides one example of the kind of purposeful and scholarly collaboration we advocate. Each of the editors of this volume has chaired the NARST Equity and Ethics Committee. Each contributed in unique and important ways to shaping the volume's purpose and substance. Through our invitations to and discussions with chapter authors and international respondents, we have produced a volume that represents a tapestry of rich insights and diverse positions. We wish to acknowledge the hard work of our chapter authors and international respondents. We also thank our copy editors, Jane Sinagub and Amanda Stansell, for their insightful questions and attention to detail.

We close by emphasizing to readers that there is still much equity-related work to be done. While this volume takes an important step in informing conversations and actions to move the equity agenda in science education forward, it does so with obvious limitations others can and must address. For example, this volume does not include all voices of US and international science education researchers that should be heard. It also does not carefully examine all equity-related topics in need of attention: Briefly touched on or entirely missing from this volume is discussion of First Nations students, children of migrant workers, and students with disabilities. In reading, responding to and pushing beyond the ideas outlined in this volume, we hope the science education community can indeed fulfill NARST's mission, reflected in its tagline, to improve science teaching and learning through research.

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Part I
Introduction: Science Education Policy

Okhee Lee (Lead Editor) and Julie A. Bianchini (Co-editor)

Education policies for science education play roles that are distinctly different from the policies for language arts and mathematics primarily because science has not traditionally been regarded as a "basic skill" unlike literacy and numeracy. Yet the profile of science education has recently been raised by the inclusion of science in the No Child Left Behind (NCLB) Act which began in 2007. The current attention on science education has been reinforced by economic realities pointing to the need for increased knowledge of science and technology. It is historically unprecedented that science is required for assessment systems in all states and is part of accountability measures in many states. Such policy change forces states, districts, and schools to allocate additional resources to science education. This presents significant challenges to under-resourced school systems as they consider how to divert a portion of already limited funding and resources to science education while maintaining funding for developing basic literacy and numeracy.

The three chapters of the *Science Education Policy* part address policies for science education reforms as these policies relate to equity issues with nonmainstream students. The chapters collectively offer historical accounts of equity policies in science education reforms. George DeBoer describes the history of equity policies starting in the late nineteenth century until today. Then Sherry Southerland delves into recent equity policies, in other words, the test-based accountability of NCLB. Finally, Nancy Brickhouse presents the emerging policies of the Obama administration, specifically Race-to-the-Top funds and the Next Generation Science Standards.

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The authors couch equity issues from theoretical and conceptual lenses. DeBoer explains evolving conceptions of “science for all” before and after the civil rights movement of the 1960s. There was rare mention of race, class, or gender in discussions of equity policies before 1960, whereas it becomes a dominant theme thereafter. Before 1960, the discussions centered around the appropriate science for future science experts, on the one hand, and science for citizenship, on the other hand. After 1960, the discussions tended toward the rights of underrepresented and underserved groups. Southerland explains the impact of NCLB on science teaching and learning of nonmainstream students using Cuban’s (1988) idea of first-order and second-order changes in education. Brickhouse explains conceptions of inequality embedded in Race-to-the-Top funds and the Next Generation Science Standards in terms of standards-based reform, market-based reform, and epistemological and cultural issues.

The authors discuss how equity policies in science education reforms evolve against the backdrop of major social events in national and international contexts. Throughout different periods of science education reforms, equity policies have been linked to national economic interest, military power, common culture, affirmative action, and/or moral imperative. These varying agendas coexist while often competing against one another. DeBoer suggests that a focus on equity as moral imperative would lead to more persistent efforts to achieve equity and more consistent and effective policies and outcomes.

The authors agree on what equity policies in science education reforms should entail. They highlight that establishing rigorous standards is the foundation that must be in place to reduce the variability in the quality of the enacted curriculum, instruction, and assessment, as stated by Brickhouse. Yet they express concerns about whether adequate resources and opportunities are provided to implement equity policies in the classroom. They also express concerns about whether student diversity in terms of language, culture, race, class, gender, and exceptionality is recognized and valued in diverse local contexts. Policies without adequate resources and opportunities are only empty words. Furthermore, resources without consideration of nonmainstream students’ home language and culture could result in assimilation to the mainstream at the cost of losing students’ cultural and linguistic identities.

The authors highlight both the potential and the danger in the outcomes of equity policies for science education reforms with nonmainstream students. Southerland questions why achievement gaps for nonmainstream students remain, even though NCLB is intended as equity policies. DeBoer expresses that the continued and steadfast support for an equity agenda among policymakers gives us reason to be optimistic, yet the failure to fully realize our goals demonstrates that we cannot be satisfied with talk alone. Brickhouse advocates that science education researchers should give more consideration to shaping a research agenda so that the research is read and valued by those who shape actual education policies and practices.

The authors also highlight both the promises and the trepidations of science education researchers to be engaged in research on equity policies for science education reforms. DeBoer warns that educators often tend to be “ahistorical, choosing to operate in the moment, as if every idea is new." Then he argues that "an understanding of history is an important way to broaden one's perspective in all areas of scholarship and policymaking." Southerland claims that "the next generation of researchers in science education, particularly those interested in issues of equity and diversity, should take great care to describe how the current misaligned environment of accountability 'bears down on even the best teachers' to make reform-minded practice a near impossibility and actively share these descriptions in a compelling manner in an effort to inform policy." Brickhouse points out that there are "tremendous opportunities for young scholars to build on the scholarship in this volume, yet to also design research that speaks to policymakers who are currently influenced by ideas of systemic and market-based reform."

Finally, Mei-Hung Chiu, the international respondent, provides thoughtful comments on the three chapters. After discussing major trends of the policies on equity in US science education, she offers her views on these policies from an international perspective, particularly from her vintage point of a science educator from an Asian country. She warns US science educators of the danger of standardized curriculum guidelines and high-stakes examinations that dominate the education systems in Asian countries/regions. She advises US science educators to "avoid the paradoxical situation faced by Asian countries/regions where there is a tradeoff between students' high performance and their low motivation in learning science."

The three chapters of the policy part along with the commentary remind us that science education research and practice occur in the context of education policies that, in return, reflect major social events within the USA, internationally, and from historical perspectives. Across all three chapters, there are underlying currents of hopes and concerns about how science education researchers position themselves in either shaping or reacting to emerging policies related to nonmainstream students. Readers should be grateful to these authors for allowing us opportunities to think deeply and critically about such issues in our own work.

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Chapter 1
Science for All: Historical Perspectives on Policy for Science Education Reform

George E. DeBoer

Introduction

This chapter explores the historical commitment of the USA to provide all citizens with the knowledge of science and technology needed to participate fully in society and to pursue careers that contribute to a further understanding of the physical world and to the society's economic progress. The chapter reviews the period from the late nineteenth century until today, a period of massively expanding scientific discovery and technological development, during which time social institutions made a commitment to extend opportunity to all citizens, at least in the policy documents they produced if not always in practice.

I discuss the challenges that present themselves to the educational system of a society that is ambitious in its desire to continuously improve its economic well-being through the development of exceptional talent, even as it tries to educate a public that is knowledgeable about what scientists and engineers do, sympathetic to their efforts, yet critical enough to make wise decisions regarding investments in science and technology. In addition, this is a society that values democratic principles of fairness. From its earliest days, US society has rejected hereditary privilege void of merit. But it has had difficulty finding the proper balance between the extremes of a leveling egalitarianism and the disparities that result from a highly competitive meritocracy. A meritocracy inevitably leads to differences in accomplishment. Is it enough that all persons have opportunities to succeed, or is equality of outcome expected as well? Do vastly disparate outcomes, especially when linked to gender, race, ethnicity, or social class, signal that these unequal outcomes would

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not be likely to occur by chance alone and, therefore, suggest some degree of systemic unfairness that exists in the society?

This chapter is organized in two parts: The first part discusses the concept of "science for all" prior to about 1960 and the beginning of the civil rights movement, and the second part discusses what "science for all" has meant since that time. The division into these two time periods is useful because prior to the 1960s, there was rare mention of race, class, or gender in discussions of science education equity policy, whereas after 1960 it has become a dominant theme. Before 1960, the discussions around fairness and equity centered around the appropriate science for future science experts on the one hand and science for citizenship on the other. After 1960, the discussions tended toward the rights of underrepresented and underserved groups, sometimes linked to the moral failure of the society to provide those groups with the same opportunities as others, but more often linked to economic arguments about the failure to locate exceptional talent within those underrepresented groups and the need to maximize national economic potential.

Science for All Before 1960

During the first half of the twentieth century, "science for all" meant science not only for the bright, socially elite, and college bound, but for all students regardless of their ambitions, talents, or probable life work. As early as 1892, when the Committee of Ten of the National Education Association (NEA) met to discuss the nature of the school curriculum and its relationship to college admission, the point was made that the study of science should not be treated as an elitist activity but as something that all students should be able to profit from (NEA 1894). Of course, the idea of "for all" meant something very different then than it does today, given that only 6.7% of the 14–17-year-old age group attended high school in the USA in 1890. That number soon rose sharply, though, and by 1920, 32.3% of the age group was attending high school (National Center for Education Statistics 1981, p. 49).

Unlike classical studies, which proponents of science in the curriculum said were fixed and dogmatic, science, it was argued, had a democratizing effect on those who studied it because it put the student in the position of asking questions, making observations, and reasoning about the world to draw independent conclusions unconstrained by the voice of authority. The courses that were proposed were meant to be appropriate preparation for life and for college, so there was no need to differentiate subject matter and teaching approaches for the college-bound and non-college-bound student. All who went to high school would learn about science so that they would be able to participate in a world in which scientific discovery and technological innovation were all around them. To be a fully aware and participating citizen in the late nineteenth century meant understanding science as a particular way of thinking about the world, having a basic understanding of the scientific discoveries and technological innovations that had been made, and having the skill to reason inductively from observation to conclusion.

Practical Studies and Vocational Education

By the early twentieth century, the idea that a theoretical study of science was appropriate for all students gave way to the idea that education should have practical value. The highly intellectual education that was proposed for science and other school subjects by the Committee of Ten came to be seen as inappropriate for an increasingly diverse population of individuals who expected schools to offer commercial and industrial arts courses along with the more traditional courses. Moreover, because of the rapid increase in the number of immigrants, a vocationally oriented education was seen by policymakers as a way to efficiently produce citizens who would fit well into American society. Efficiency included offering differentiated programs of study that were targeted to the students' probable life work. Thus, practical studies for non-college-bound students were used to attract more students to the public school system, for building a well-trained labor force that could contribute to the development of the society, and for teaching the youth the values of the society.

The NEA's Committee of Ten had made no mention of vocational studies in the 1890s, but by 1918 a practical and vocational focus so dominated education that the NEA's Commission on the Reorganization of Secondary Education (CRSE) recommended that the entire curriculum be reorganized along vocational lines to meet the demands of the great masses of people: "The work of the senior high school should be organized into differentiated curriculums. …The basis of differentiation should be, in the broad sense of the term, vocational" (NEA 1918, p. 22).

The CRSE did not, however, address how science would fit into a program differentiated by vocational interest. In fact, the science committees barely mentioned a differentiated science curriculum in their reports to the commission. Instead, the CRSE described how all science courses should be redesigned to make them more interesting, useful, and relevant to the everyday lives of students. If existing science courses focused primarily on future academic study, they should be modified to meet students' current needs and interests as well. The application of knowledge to the activities of life rather than as a logically organized discipline was seen as the best way to provide an education that had value for all. At least in science, if not in the other subject areas, differentiation of the curriculum for academic versus vocational studies was not a major thrust of the early twentieth century reformers. The trend was toward a practical approach to the study of science for all.

But some forces did act to separate academic and vocational education. The 1917 Vocational Education Act, also known as the Smith–Hughes Act, was specifically intended to promote vocational education in the public schools. The act separated vocational and academic study by limiting the amount of academic instruction that students in the vocational program received. In addition, the salaries of vocational teachers could be covered by the appropriation but not the salaries of academic teachers. Later versions of the act, the Carl D. Perkins Vocational and Applied Technology Act of 1984 (P.L. 98–524) and the Carl D. Perkins Act of 1998 (also known as Perkins III), eventually moved vocational education toward a greater integration of academic and vocational content.

The Comprehensive High School and Aptitude Testing as Democratizing Influences

The "comprehensive high school" was first proposed in the USA by the Commission on the Reorganization of Secondary Education in 1918 as a way to help democratize education. In contrast to the vocational education movement, which in its early form tended to separate academic study from vocational study, the comprehensive high school offered, under one roof, a broad range of academic and vocational programs for students with differing career goals. The comprehensive high school was meant to unify society by having all students, regardless of their academic or occupational goals, studying together and thereby developing mutual respect for each other. As late as 1959, James B. Conant, in his book *The American High School Today* (1959), praised the comprehensive high school that had become so popular during the first half of the twentieth century. Although criticized later for its policies of tracking and academic segregation (Angus and Mirel 1999), in Conant's time, the comprehensive high school was seen as a democratizing institution because it was thought to soften the distinctions between those planning to go to college and those entering the world of work.

Sorting students into the different tracks was often accomplished by means of standardized tests so that students most suited for each course of study could be identified on the basis of their ability. There were also efforts to use aptitude testing to place students in different levels for different subjects so that students would not be locked into a particular ability track. According to John Gardner, in such a system, "A pupil might be in the top group in one subject and not in another. Thus there is no over-all sorting out of youngsters into separate 'tracks' or programs or levels" (1961, p. 116).

Aptitude testing also enabled colleges to admit students on the basis of entrance exam scores rather than on the schools they graduated from or the social standing of their parents. Conant, as president of Harvard University from 1933 to 1953, introduced aptitude testing into the college's admissions process so that students could be selected more accurately on the basis of their intellectual promise. Whether in academia, industry, or civil service job selection, aptitude tests were being viewed by the society as the fairest and most democratic way to provide individuals with opportunities best matched to their abilities.

World War II and the Search for Science Talent

For most of the first half of the twentieth century, there was little, if any, pressure to use the sorting mechanisms in place in schools to increase the number of technically trained workers in the country, to improve the quality of the technical workforce, or to find ways to attract students to study science. World War II, however, created severe shortages of technical personnel, and these shortages came to be ever more closely linked to national security. As an indication of the drain of science talent during the war, there were 375,000 science majors enrolled in college in the 1940–1941 school year; by 1944–1945, that number was just 200,000. There were 41,000 college science faculty members in 1940–1941, but only 36,000 in 1945–1946 (President's Scientific Research Board 1947, Vol. 4). In response to the need for more technically trained personnel, President Truman created the Scientific Research Board in 1946 to study and report on the country's research and development activities and science training programs.

To assist in assessing the quality of science education at all levels, the Board asked the American Association for the Advancement of Science (AAAS) to conduct a study and issue a report on the effectiveness of science education in the schools. Their report, "The Present Effectiveness of Our Schools in the Training of Scientists," provided a balanced view of the importance of science education in society by emphasizing not only the training of future scientists, but also the importance of the public's understanding of science. The report discussed the need to encourage students with talent in mathematics and science to prepare for work in science fields, early identification of science talent through standardized testing of incoming college students, provision of scholarships to ensure that all talented students had a chance to attend college, and ways to improve the general education of the nonscience student.

General education for the nonscience student also received attention because of Conant's report, *General Education in a Free Society*: *Report of the Harvard Committee* (1945), which in science emphasized the importance of "basic concepts, the nature of the scientific enterprise, the historical development of the subject, its great literature, [and] its interrelationships with other areas of interest and activity" (pp. 220–221). The AAAS Cooperative Committee on the Teaching of Science and Mathematics went one step further and recommended that this integrated and conceptual approach to science teaching was appropriate not only for the nonscientist, but should be made part of the training of the science specialist as well (President's Scientific Research Board 1947, Vol. 4, p. 143), another example of efforts to bring the education of scientist and nonscientist together.

In the postwar years (1945–1955), tensions with the Soviet Union led to even greater concerns about national security and the need to use the schools to locate and train future scientists and engineers. But, throughout the war and postwar years, the country was not yet prepared to give wholesale preferential treatment to the gifted and talented or to create special courses for them as ways to increase the number of technical personnel. Even though some in the policy community supported the idea that special efforts were needed to attract science talent (Brandwein 1955; US Office of Education 1953), there were few suggestions that actually described what science courses would look like that would be more appropriate for the talented student. Most proposals were intended to encourage talented students to study the science courses that currently existed.

The Sputnik Challenge

National attitudes toward science education and the schools changed with the launch of the earth-orbiting satellite *Sputnik* by the Soviet Union in 1957. Suddenly, the technological challenge from abroad was no longer an abstract possibility but a reality, as was the apparent technological lead the Soviet Union had on the USA. US policymakers were quick to draw a connection between technological development and education, which complicated the debate about how to meet the security needs of the country and at the same time provide equitably for the education of all citizens. The National Defense Education Act (NDEA) was signed into law on September 2, 1958, to support the "fullest development of the mental resources and technical skills of its young men and women…" (NDEA 1958, p. 3). The act was an effort to increase the number of talented students who would go into science, mathematics, and foreign language careers.

The launch of *Sputnik* also gave new impetus to those who had been arguing that the US educational system was not challenging or rigorous enough, and it boosted interest in special programs for talented students. But, as before, these proposals were not without controversy. Gardner in his 1961 book *Excellence: Can We Be Equal and Excellent Too?* noted the ambivalence of policymakers and the US public toward special treatment of gifted students, in part because, as Gardner put it: "Children who are not gifted—and parents who do not have gifted children—are in the great majority" (p. 115).

It is not that there were no new programs for gifted students. In biology education, for example, the Gifted Student Committee of BSCS (Biological Sciences Curriculum Study) was created to examine the nature of giftedness and creativity in science and the environments that would foster creative work in the secondary school, prepare summaries of promising programs for the development of able students in biology, and develop a collection of research problems in biology for gifted students (Hurd 1961, p. 150). For the most part, though, the intent of the curriculum reforms in the post-*Sputnik* era was to raise the intellectual bar for *all* students, just as practical education was seen as valuable for all students earlier in the century. The issue at hand was "science and education for national defense" (Hurd 1961, p. 108), and the best way to accomplish that was to create quality education for all students. Thus, the goal of science for all again characterized US education policy, even in the face of the obvious need to recruit and train special talent. To emphasize the idea that science was important for all students, the Committee on Educational Policies at the National Research Council said in its 1958 report: "Whether the student eventually works in agriculture, industry, government, business, commerce, education, arts or sciences, he is likely to need some part of a changing body of scientific knowledge in his own work" (as cited in Hurd 1961, p. 132).

Nevertheless, even though policymakers talked about the value of the new courses for all, in fact the courses that were created during this period of curriculum reform tended to be geared more toward the academically able student, both in terms of their conceptual difficulty and the theoretical, rather than applied, nature of the content. Subsequent analyses of the courses concluded that they were too difficult for the typical high school student because of their theoretical sophistication and abstract nature, and the courses were not motivating enough because the science was not related to the practical interests of students or the role of science in everyday life (Hurd 1970). The lesson to be learned from this period of reform is that any effort to create a common experience for all requires that attention must be paid to the nature of the experiences that will make them suitable for all.

From the 1960s to the Present: The Era of Civil Rights

As was true in the first half of the twentieth century, virtually every policy document written in the past 50 years addresses the importance of science for all, not just for those preparing for science careers. This can be seen in the language used in *A Nation at Risk*, the 1983 report of the National Commission on Excellence in Education; in *Educating Americans for the 21st Century*, the 1983 report of the National Science Board of the National Science Foundation (NSF); in *Science for All Americans*, a vision of science literacy for all published in 1989 by Project 2061 of the American Association for the Advancement of Science; and in *Rising Above the Gathering Storm*, a 2007 report of the National Academy of Science; among others. But, beginning with the civil rights movement of the 1960s, "science for all" also took on another dimension. In addition to arguing that the public at large and not just future scientists should understand science, policymakers began to explicitly press the point that race, class, gender, and disability should not limit who studies science, who becomes a scientist, or the quality of education those students receive.

This emphasis on race, class, gender, and disability did not occur at once. Efforts had begun decades earlier, were codified into law during the era of civil rights legislation, and then required constant vigilance in subsequent years to move toward greater equity for all, both in terms of opportunity and outcomes. For example, school segregation on the basis of race was declared unconstitutional in *Brown v. Board of Education* in 1954, although *de facto* segregation continued throughout the country for decades. The Civil Rights Act of 1964 prohibited discrimination in voting, education, and the use of public facilities on the basis of race, color, religion, and national origin, and it provided the government with the powers to enforce desegregation by barring the use of federal funds for segregated programs and schools. The bill also included provisions outlawing sex discrimination in hiring. In 1966, the National Organization for Women (NOW) was created to fight for full equality between the sexes. In 1972, Title IX of the Education Amendments of 1972 was passed. The act says that no person in the USA shall be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving federal financial assistance on the basis of sex. Then, in 1973, Congress passed Section 504 of the Vocational Rehabilitation Act, which barred discrimination against people with disabilities. Regulations for implementation of the act were signed by the Secretary of Health, Education, and Welfare in 1977 (Pfeiffer 2002).

During the early years of the civil rights movement, energies were focused on legal battles and enforcement of laws involving large-scale issues such as school desegregation. Very little attention was paid to inequalities due to race, gender, or disability at the curricular level. But over time, science educators became more and more aware of the discriminatory practices that kept women, minority group students, and students with disabilities from studying science and having careers in science. For example, the *Science and Engineering Equal Opportunities Act* of 1980 made it clear that such inequities had existed and still existed. The bill, amended in 1985 and 2002 to add language regarding persons with disabilities and substituting the term "engineering" for "technology" states:

> [I]t is the policy of the United States to encourage men and women, equally, of all ethnic, racial, and economic backgrounds, including persons with disabilities … to have equal opportunity in education, training, and employment in scientific and engineering fields, and thereby to promote scientific and engineering literacy and the full use of the human resources of the Nation in science and engineering. (p. 1)

It is significant that the act is justified primarily in terms of the development of human resources ("the full use of the human resources of the Nation"), not on moral grounds of justice and fairness for all. In fact, with few exceptions, there is little mention of equity as a moral issue in policy documents.

As part of the *Science and Engineering Equal Opportunities Act of* 1980, every 2 years, NSF publishes a report titled *Women, Minorities, and Persons with Disabilities in Science and Engineering* (http://www.nsf.gov/statistics/wmpd/). The reports provide statistics on the progress being made in the participation of the various groups of students in science and engineering from elementary school through postdoctoral careers. By highlighting the obvious disparities that have persisted, the reports keep the equity agenda in front of the public.

That disparities continue to exist is evident from the data. For example, in a study conducted for the Spencer Foundation, Anne MacLachlan (2005) notes:

> In 1980, when the Science and Engineering Equal Opportunities Act was passed, underrepresented minorities, African Americans, American Indians, Chicanos and Hispanics were 2% of US doctorates granted in physical science, 2.5% in engineering. In 1990 the percentages were 3.4% and 3.6% respectively. (p. 1)

Slow progress in meeting the goals identified in the *Science and Engineering Equal Opportunities Act* prompted NSF to commission Jeanne Oakes of the RAND Corporation to study educational policies that created disparities within the educational system, in particular the use of separate tracks for students in science and mathematics courses. In two reports (1990a, 1990b), Oakes concluded that the practice of tracking and ability grouping limited opportunities for many students to learn science and mathematics and pursue careers in science. In her review of these reports, Sharon Lynch (2010) says:

> Grouping practices in the elementary and middle school grades affected children who had been clustered in "low-ability classes" for years on end. By the time these students reached high school, their science education experiences were strikingly different from their peers

in high track classes, with markedly different expectations for achievement, access to resources, and chances of having competent science teachers. (p. 309)

Although ability grouping may have been seen as a way to provide both future scientists and nonscientists with courses that were appropriate to their interests and abilities during the first half of the twentieth century, by the 1980s it was clear that this practice had led to diminished opportunities for large segments of the population.

A Call for Excellence and Common Culture

In 1983, the National Commission on Excellence in Education (NCEE) issued its report, *A Nation at Risk.* Reminiscent of the recommendations of the Committee of Ten in the 1890s and of the curriculum reformers of the 1950s and 1960s for increased conceptual rigor, the NCEE recommended a return to a more academic focus and more disciplined effort on the part of all students. They said that students in the USA needed to be better educated and highly motivated if they were to compete successfully with international competitors. The new raw materials of international commerce were knowledge, learning, information, and skilled intelligence.

The NCEE also pointed to the importance of a high level of common understanding in a free and diverse democratic society. The common culture argument had been raised before, most prominently by Ernest Boyer and Arthur Levine (1981) just prior to the publication of *A Nation at Risk* in their *A Quest for Common Learning*. Boyer and Levine acknowledged that past efforts to present a “common culture” in educational programs had not addressed the *diversity* of that common culture and concluded that “this nation is not one culture but many” (p. 21), but yet “our future well-being, and perhaps even our survival, may depend on whether students understand the reality of interdependence” (p. 22). The NCEE (1983) reflected a similar inclusive approach: “The twin goals of equity and high-quality schooling have profound and practical meaning for our economy and society, and we cannot permit one to yield to the other either in principle or in practice” (p. 13).

This same spirit of a quality education for all is echoed in *Educating Americans for the 21st Century* (National Science Board 1983). Because US national security and economic health depended on its human resource development, a commitment to academic excellence would place the USA on a firm economic footing in its competition with other countries. The NCEE addressed the excellence–equity distinction in the context of human resource development by saying: “While increasing our concern for the most talented, we must now also attend to the need for early and sustained stimulation and preparation for all students so that we do not unwittingly exclude potential talent…” (p. x).

“Science for all” was also a prominent theme of *Science for All Americans,* the 1989 publication of Project 2061 of the American Association for the Advancement of Science, which describes what all citizens should know in science to be considered science literate. The authors of *Science for All Americans* also focused on the "common core" argument, making it clear that a recommended core applied to all students:

> The set of recommendations constitutes a common core of learning in science, mathematics, and technology for all young people, regardless of their social circumstances and career aspirations. In particular, the recommendations pertain to those who in the past have largely been bypassed in science and mathematics education: ethnic and language minorities and girls. (p. xviii)

The Economic Argument

It was the economic argument for raising academic standards for all students, however, not the common culture argument, that soon became the major justification for ensuring access to science education for all students regardless of race, gender, or disability. For example, on April 18, 1991, President George H. W. Bush released *AMERICA 2000: An Education Strategy* (US Department of Education 1991), which described a plan for moving the nation toward a set of national goals and linked American economic competitiveness to "educating everyone among us, regardless of background or disability" (p. 2).

Then, on March 31, 1994, President Clinton signed the *Goals* 2000*: Educate America Act*. The act featured eight goals centered on educating workers for productive employment, with special reference to competition in international trade. The purpose of the act was to support new initiatives to ensure educational opportunity for all students so that they would be prepared to succeed in the world of work and in civic participation.

Also in 1994, President Clinton signed the *Improving America's Schools Act* (IASA), which was a reauthorization of the original *Elementary and Secondary Education Act* of 1965 (ESEA), first enacted as part of President Johnson's War on Poverty and intended to improve education for disadvantaged children in poor areas. IASA laid the foundation for what was later to become the *No Child Left Behind Act* of 2001 (NCLB). Under IASA, each state had to: (1) develop challenging content standards for what students should know in mathematics and language arts; (2) develop performance standards representing three levels of proficiency for each of those content standards—partially proficient, proficient, and advanced; (3) develop and implement assessments aligned with the content and performance standards in at least mathematics and language arts at the third through fifth, sixth through ninth, and tenth through twelfth grade spans; (4) use the same standards and assessment system to measure Title I students as the state uses to measure the performance of all other students; and (5) use performance standards to establish a benchmark for improvement referred to as "adequate yearly progress" (AYP). All schools were to show continuous progress or face possible consequences, such as having to offer supplemental services and school choice options to students or replacing the existing staff.

In one of the few references to equity as a moral issue in any of the policy documents that appeared during this time period, the act's statement of policy says: "The Congress declares it to be the policy of the United States that a high-quality education for all individuals and a fair and equal opportunity to obtain that education are a societal good, are a *moral imperative* (italics added), and improve the life of every individual, because the quality of our individual lives ultimately depends on the quality of the lives of others" (*Improving America's Schools Act* 1994). The act also acknowledges the persistent achievement gap among various groups in society and calls for improvements in Title I and other federally funded programs aimed at closing that gap.

At the signing of the landmark *Americans with Disabilities Act* (ADA) on July 26, 1990, President George H. W. Bush also acknowledged the moral responsibility we have to enable Americans with disabilities to contribute their efforts and their talents to the nation:

> The ADA is a dramatic renewal not only for those with disabilities but for all of us, because along with the precious privilege of being an American comes a sacred duty to ensure that every other American's rights are also guaranteed. (Bush 1990, p. 1)

But more often than not, rather than arguing on the basis of common culture or moral imperative, policymakers have used the nation's technical personnel needs and economic competitiveness as the primary argument in support of improved educational opportunity for underrepresented groups. For example, in *Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,* the National Academies' Committee on Prospering in the Global Economy of the 21st Century, says:

> …in the long run, the United States might not have enough scientists and engineers to meet its national goals if the number of domestic students from all demographic groups, including women and students from underrepresented groups, does not increase in proportion to our nation's need for them. (National Academy of Sciences 2007, p. 166)

No Child Left Behind (NCLB)

Perhaps, the most aggressive legislation to date for ensuring opportunity for all students was NCLB. NCLB requires states to build assessment systems to track the achievement of students in their state against a common set of state-defined standards. By 2005–2006, states were required to test individual students annually in reading and mathematics between grades 3 and 8 using statewide tests, and to test students at least once during grades 10 through 12. By 2007–2008, students had to be tested in science at three grade bands. States were also required to administer the mathematics and reading tests of the National Assessment of Educational Progress (NAEP) every 2 years to a sample of students in grades 4 and 8. NCLB mandates that the data reported to the public must be disaggregated by the following subgroups: economically disadvantaged students, students from major racial and ethnic groups, students with disabilities, and limited English proficiency students (US Department of Education 2008, p. 24). The goal of NCLB was to have all students be proficient in reading and mathematics by 2014. Failure to make adequate progress toward meeting these goals results in various actions intended to help a school improve. In addition to technical assistance, staff changes, and the possibility of private or state takeover of the failing school, students in schools that do not meet their target goals are able to transfer to another school or use their Title I funds to pay for tutoring or other supplemental services.

Although well intentioned as a vehicle for focusing national attention on the performance of all students and for motivating school districts to direct resources toward those students most in need of assistance, there have also been unintended negative consequences of the NCLB legislation, which Sherry Southerland so convincingly argues in the next chapter of this volume. Similarly, Nancy Brickhouse notes in her chapter the limitations of standards-setting as a way to improve science education for all, even though this has been the dominant policy approach over the past two decades.

By early 2012, separate bills to overhaul ESEA had been passed by the House Committee on Education and the Workforce and by the Senate Committee on Health, Education, Labor and Pensions. As of May 2012, none of these bills had been considered by the full House or Senate, nor is it likely that any reauthorizing legislation will pass before the 2012 presidential election. Nevertheless, it is hoped that when modifications to ESEA are finally made they will reflect a spirit of bipatisanship, address the concerns that have been raised about the limitations of NCLB, and support the ongoing efforts to achieve educational equity and excellence for all.

Conclusion

There is no question that the equity theme has been prominent in science education policy for more than a hundred years. Prior to the civil rights era, "science for all" referred to science for both citizenship and technical career preparation. Following the era of civil rights legislation, there was a much greater recognition of the significant disparities in both opportunity and outcome for various subgroups of students within the population. The arguments for reducing those disparities due to race, ethnicity, gender, and disability as well as arguments for raising standards for all were often economic in nature. The argument was that talent had to be found wherever it could, not just among students who traditionally pursued high-level technical careers. Along with a concern for equity, there has also been an unwavering commitment to excellence, and in most policy statements, it is clear that high standards are meant for all students.

Today, the policy goal in science education is clearly one of excellence for all. But there are challenges in meeting that goal. In reality, the society does not expect everyone to achieve the same outcomes. In a meritocracy, vast differences in accomplishment are inevitable. There is no way to create identical outcomes in a meritocracy because someone will always be more naturally gifted in a specific area or work harder than others. We have come to believe that the best way to achieve an equitable system for all is to provide all students with the opportunity to succeed to their fullest potential in whatever area they wish to pursue their talent, along with high expectations for all and incentives and resources for all to achieve their full potentials. Although there are limits to what can be accomplished simply by establishing standards, many policymakers believe that enforceable high standards for all students are important so that students are not short-changed by themselves or by others.

But as Gardner said in 1961 and is still true today: "One of the obstacles to the full development of talent in our society is that we still have not achieved full equality of opportunity" (p. 38). There are many examples of that lack of fairness, and many of them involve educational resources that are not provided equitably to students. Lynch (2010) identifies a number of key areas in which resources are still unequal, including access to quality teachers, availability of specialized facilities and materials, and instructional technology, especially out of school. Also, *America's Lab Report*, the National Academies' study of science laboratories in schools, notes that less adequate laboratory facilities are more likely to be found in schools with higher concentrations of minority students and in schools with higher concentrations of students eligible for reduced-price meals (National Research Council 2005).

For the nation to achieve the goal of science for all, it is important that resource allocation be made more equitable, particularly in the quality of teachers that students have. Two things might make that more likely. The first is to keep data on the participation and performance of various subgroups of students in front of the public. If the public sees the wide disparities that continue to exist for different groups of students, they may be more likely to see the injustices in our present system. For this reason, it is important that the reauthorization of ESEA require that performance data continue to be disaggregated by subgroups as it currently is under NCLB. This does not mean that the same kinds of tests that were used under NCLB have to be used in the future. Those tests were often too narrow in their focus and led, especially in low-performing schools, to uninspired teaching. But whatever metrics are used, we need to know how subgroups of the population are doing.

The second is that it may be time that we begin to discuss equity not just as an economic necessity but as a moral imperative as well. As John Rawls (1971) said in his *Theory of Justice*: "Justice is the first virtue of social institutions, as truth is to systems of thought. …Each person possesses an inviolability founded on justice that even the welfare of society as a whole cannot override" (p. 3). To Rawls, this meant both the freedom to pursue personal goals and the opportunities to succeed. There is no question that most individuals within this society do see equity as an issue of basic fairness. But in public policy, policymakers seem more comfortable talking about the economic benefits of a broadened work force than about basic justice. It is certainly not uncomplicated how the twin goals of excellence and equity are best achieved in a democratic society, but it is important to realize that the commitment to equity must be based on something more permanent than simply the search for talent to support the nation's economic competitiveness. Perhaps, a focus on equity as a moral issue would lead to more persistent efforts to achieve equity and, therefore, to more consistent and more effective policies and outcomes.

What insights and understandings do the theoretical and methodological lenses used in this scholarship enable and constrain? By examining the evolution of relevant policy over time, the historical approach taken in this chapter allows the reader to place equity in science education within the larger social, economic, and national security contexts of the nation during major historical events and eras (e.g., World War II, the Cold War, the civil rights movement). This enables the reader to appreciate the full range of factors that can influence science education policy at any given time and the tensions and challenges that can result when principles collide with practical needs. In addition, by focusing on policy at various levels—federal, state, local, professional, disciplinary—the reader can begin to understand the complex nature of policymaking in science education.

But, with the focus strictly on policy, what this account does not provide (and cannot provide given the limits of space) is insight into how policies have actually played out in the classroom for specific groups of students. A critically important question to ask is how effective these policies have been and what impact they have had on the wide diversity of students in schools. It is one thing to espouse an equity agenda, but implementation efforts supported by adequate funding are also essential. This chapter does not examine efforts at implementation, the support or resistance by various stakeholders, the adequacy of legislative appropriations to support equity policy, or policy analyses that have examined the effectiveness of these efforts.

How can the ideas in this chapter be used to inform research, practice, and policy? Educators often tend to be ahistorical, choosing to operate in the moment, as if every idea is new, but an understanding of history is an important way to broaden one's perspective in all areas of scholarship and policymaking. This chapter distills important lessons about education policy from key periods in the nation's history when science was in the foreground. It also documents the continuing struggle to provide equitable opportunities to all students, and highlights factors that make the education of all students in science particularly challenging. The continued and steadfast support for an equity agenda among policymakers gives us reason to be optimistic, yet the failure to fully realize our goals demonstrates that we cannot be satisfied with talk alone. Practical steps are needed to give all students an opportunity to succeed to their fullest.

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Chapter 2
Is It Possible to Teach "Science for All" in a Climate of Accountability? Educational Policy and the Equitable Teaching of Science

Sherry A. Southerland

Teachers, students, and other members of the educational system find themselves in another period of change. In 2010, the nation embarked on yet another reformulation of federal education policy with the proposed reauthorization of the *Elementary and Secondary Education Act* (ESEA, formerly known as *No Child Left Behind)*; this contentious proposal continues to be debated in 2011. At the same time, a set of prominent multistate standards was proposed in the form of Common Core State Standards in language arts and mathematics, and a new science education framework proposed by the National Research Council (NRC) provides an overarching vision of what it means for K-12 students to be proficient in science in an effort to inform the design of the Next Generation Science Standards. Given this period of flux, it seems wise to reflect on how the last wave of national policy as embodied in the *No Child Left Behind* (NCLB) Act of 2001 legislation interacted with science education reform efforts (Duschl et al. 2007) to influence the science teaching and learning of nonmainstream learners, as well as to look forward to changes proposed to this legislation.

As has been described by George DeBoer in Chap. 1 in this volume, one of the original goals of the ESEA was to reduce the achievement gap for children living in poverty. The ESEA was first enacted in 1965 under President Lyndon B. Johnson as part of a package of programs known as the "Great Society" designed to combat poverty (Klein 2010). Over the years, that intent to focus on the needs of underserved students has been retained. Indeed, one of the goals of NCLB, as ESEA was renamed during the second Bush administration, was to reduce the achievement gap seen in students of color, students in poverty, and English language learners when compared to their White, middle-class, and native-speakers-of-English counterparts.

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As described by James Kim and Gail Sunderman (2005), the accountability provisions of NCLB were "intended to close the achievement gap between nonmainstream and nonminority students and between disadvantaged children and their more advantaged peers" (p. 3). Likewise, a central goal of the science education reform efforts was to support the development of scientific literacy for "all students." As described by the American Association for the Advancement of Science (AAAS 1989), "The world has changed in such a way that science literacy has become necessary for everyone, not just a privileged few: science education will have to change to make that possible" (p. xvi).

As will be argued in this chapter, despite the seeming resonance in goals between the federal efforts to change education and the work of those engaged in science education reform, on the one hand, and the powerful influence of high-stakes assessments on instructional decision-making, on the other hand, the achievement gaps between mainstream and nonmainstream learners remain. But if each state has such assessments and if the practices engendered by science educators are effective in supporting *science for all*, it is essential to understand why achievement gaps for nonmainstream learners remain if we are to move forward.

Nonmainstream Students, NCLB, and Science Education Reform

As has been described elsewhere in this book, the student makeup of the USA is rapidly changing. Demographers suggest that by 2035, students of color will be the numerical majority in the United States (Banks et al. 2005). The number of English language learners in our schools has more than doubled from 1985 to 1995 and is continuing to increase (Villegas and Lucas 2002). Accompanying this demographic upheaval, the USA has the highest rate of children living in poverty of any of the Western democratic nations.

These trends become worrisome when one considers the success of our educational system with nonmainstream students. National Assessment of Educational Progress (NAEP) results indicate that students on the free or reduced price lunch program underperform compared to students who are not, and achievement gaps for African American and Hispanic students are so large that the twelfth-grade achievement levels for these students are comparable to the eighth-grade achievement levels for White and Asian American students (National Center for Education Statistics NCES 2010). However, there have been gains in the course-taking patterns of students in various demographic groups. In recent years, more African American, Latino/a, and Native American students are taking 2 years of high school science in addition to chemistry and physics, although they still lag behind their White and Asian American counterparts (National Science Foundation 2009). More students of color are pursuing STEM degrees, but long-term gaps persist when comparing the STEM majors of students of color with those of White and Asian American students (National Science Board 2010).

The achievement gap that exists in science is echoed in many other content areas (Kim and Sunderman 2005), and in 2001, these gaps provided a needed rationale for the reauthorization of the ESEA as NCLB (Kantor and Lowe 2006). NCLB was a national policy focusing on student achievement, academic standards for all students specifying knowledge and skills for mastery, and student achievement testing as a means of monitoring the effect of reforms (McDonnell et al. 1997). NCLB introduced a new era of test-based accountability to American public schools, augmented by broad jurisdiction over public schools. As described by Randall Penfield and Okhee Lee (2010), the theory of action underlying NCLB depends on the required reporting of test scores in core subjects, holding schools accountable for adequate progress (known as Adequate Yearly Progress [AYP]) of all students, with the prospect of sanctions when AYP is not met. These sanctions are meant to motivate schools and districts to allocate resources to allow all groups of students to meet the established levels of progress.

At its outset, NCLB was heralded by diverse political groups, in part because it was based on the notion of accountability of schools to be measured by the administration of statewide assessments. But as importantly, NCLB required the disaggregation of students' test scores for the following groups: "economically disadvantaged students, students from major racial and ethnic groups, students with disabilities, and students with limited English proficiencies" (NCLB 2001, Sec. 1111 [2Cv]). It was hoped that the close examination of student achievement across different categories of students would provide the means and motivation for reforming schools that fail to help all students achieve (Supovitz 2009).

One of the central features of NCLB was the use of AYP to require that students from the various demographic groups meet the same academic standards. This requirement of meeting AYP or facing sanctions was understood to be the central mechanism for closing achievement gaps between mainstream and nonmainstream learners (Marx and Harris 2006), who in the past have been "segregated by low expectations" (NCLB 2001). The attention paid to the performance of groups of students was a fundamental innovation of NCLB, as it required schools, districts, and states to attend to the achievement of nonmainstream students—prohibiting stakeholders from "washing out" the performance of students in these groups through averaging them in with the scores of mainstream students. When it was first proposed, this emphasis on measuring the achievement of all students, and not simply reporting means taken from an entire population of a school, was heralded as potentially revolutionary. Where NCLB legislation differs from earlier attempts by both the first Bush and Clinton administrations, it further raised academic standards and carried with it increased accountability for achievement results. It was hoped that this more fine-grained analysis, combined with a uniform (within a state) annually measurable objective, would create strong incentives to motivate teachers, schools, and policymakers to understand different patterns of student achievement with the aim of reallocating resources to improve the learning of various groups of students. If AYP was not met for specific groups of students within a school, they were to be provided with the right to transfer to another school or to gain access to additional resources, such as tutoring. Given this emphasis on the disaggregation of data to describe the achievement of different groups of students, NCLB gave the appearance of requiring the equality of educational opportunities (Kantor and Lowe 2006). This attention to the achievement of specific groups of students was something many educators, educational researchers, and politicians from very diverse groups embraced.

At the time of this writing, ESEA is again being considered for reauthorization. As described by Klein (2010), through the Blueprint for Reform and the Race to the Top (RttT) grant competition, the Obama administration seeks to address critiques of the earlier NCLB, and the bulk of the attention has been focused on changes at the school level. To address complaints that the NCLB law does not make a clear distinction between schools that are consistently struggling to raise the achievement of all their students and schools that are having trouble only with particular student groups, the Obama administration is seeking to differentiate interventions for schools that have varying difficulty in meeting the law's goals. For schools that are not successful in supporting student growth for all subgroups identified in the original NCLB, there are four intervention models, including a *transformational model* (replaces the principal, strengthens staff, requires the use of research-based intervention strategies, provides increased learning time, and implements new governance), a *turnaround model* (like the transformational model, replaces the principal as well as no more than 50% of staff), a *restart model* (converts or closes and reopens a school under the management of an effective charter operator), and a *school closure model* (closes the school and allows the former students to attend another higher performing school).

As described by Klein (2010), the ESEA renewal plan seeks to survey teachers to provide information about the school's working conditions and school climate. Schools would be required to report on factors such as teacher turnover, teacher absenteeism, and the number of novice teachers working in a school. The plan will require states to make sure their most effective teachers are distributed equitably among high- and low-poverty schools. States will be directed to develop a definition of "an effective teacher" that relies at least partially on student outcomes, and establish systems for linking students' achievement to their teachers and school leaders.

Yet another proposition in the Blueprint is the effort to ensure that all states have comparable and rigorous standards for students. The proposed new ESEA blueprint dissolves NCLB's 2014 deadline by which all students are to be proficient in reading and mathematics. In its place, under the proposed revision to NCLB, states are to be given time to adopt new college- and career-ready standards and to set performance targets against those new standards (Klein 2010).

Many see NCLB and its proposed revisions as clear directions for the reform of the educational system. As science educators, then, it seems wise to examine how these current and future efforts support or contrast with those proposed by science educators. Given the audience for this text, I will not belabor the point by offering a description of the organizing goals of these reforms (see the DeBoer discussion in this volume) or the central foci of the most recent efforts at science education reforms (for a full description of the foci, see Southerland et al. 2007). However, it is instructive to examine how the reform efforts within science education differ from those of the more encompassing effort of NCLB and ESEA. Science education reform can be characterized by a strong emphasis on specific practices in science teaching (NRC 2000); the recognition of different forms of student learning (currently recognized as strands of science proficiencies) (Duschl et al. 2007); and the realization that student learning is a complex process that depends on what the learner already knows as well as the habits of mind, ways of knowing, and cultural frameworks students bring into the classroom. Science educators recognize the complexity of both science teaching and learning.

Science teacher educators recognize that the new emphasis on teaching science to *all* students is by no means a straightforward proposal and requires a new understanding on the part of many teachers (Lynch 2000). Thus, another central focus of the reform efforts in science education is that of equitable science teaching. To understand equitable science teaching, it is useful to contrast it with equality in science teaching. Sharon Lynch and others (Lee and Luykx 2006) describe that as teachers we must move past the notion of equal science instruction to that of equitable science instruction. This means that teachers should hold the same goals for all our students, but given understandings provided by learning theory, teachers must recognize that the path to those goals may vary from student to student based on his/her specific strengths, knowledge, and abilities. The goal of equitable science instruction requires teachers to learn about their students' lives, cultures, expectations, and languages. In turn, this knowledge should inform day-by-day, moment-to-moment instructional decision-making.

As we compare NCLB and science education reform, it is clear that NCLB is relatively mute on theories of learning and descriptions of useful teaching practices. Instead, the theory of action of NCLB relies largely in providing motivation for school systems, teachers, and students to succeed on the accountability measures (Penfield and Lee 2010). Indeed, many politicians, policymakers, and members of the general public understand such extrinsic motivation to be essential to change behaviors associated with schooling. In contrast, the reform efforts undertaken by science education rely predominately on intrinsic motivation, and the overall theory of action underlying our work is that if teachers (and administrators) are led to understand what it means to be proficient in science, if they recognize the support students require to develop these proficiencies, and if they are exposed to a suite of potentially effective teaching practices, they will choose to employ such practices. It is through these intrinsic paths that we seek to change how students learn science.

So, we have two very different avenues for reform "playing out" at the same time and often in the same classrooms. These reforms have very similar goals on the surface but are posited on different assumptions. These differences in assumptions lead to challenges in achieving commonly sought goals in part due to their empowerment of different agents of change. The extrinsic motivation on which NCLB is predicated encourages and emboldens the efforts of actors that exist primarily outside of the science classroom, including state and district level administrators, and privileges the quantitative measures of testing. Although the original NCLB does give attention to the critical role of the teacher in closing achievement gaps, the reality of its implementation has remained steadily focused on high-stakes assessments and AYP scores, thus necessitating sometimes near obsessive focus by these external actors on external measures. The intrinsic motivation of science education reform seeks to tap into the cognitive and affective power of teachers as agents of change within the science classroom. Through empowering teachers to become adept in their professional craft, understanding the complexities of learning in a classroom and the multitude of ways it can be demonstrated (particularly unique for nonmainstream students), science educators support teachers in going beyond NCLB assessments as the sole indicators of their students' science knowledge. The resulting efforts from these different directions engender a complicated conversation, where both sides may argue for the same goal but follow drastically different pathways to achieve that goal.

Influence of NCLB on the Science Learning of Nonmainstream Students

Under the guidelines of NCLB, each state developed its own science standards and assessments for these standards, and it is difficult to summarize the results of all states. However, to inform this discussion, student performance in two large and diverse states (Florida and Texas) are examined. Data from the Florida Department of Education website (2010) demonstrate that student performance on state NCLB measures for science has steadily increased since 2003. It is important to note, however, it was not until 2006–2007 that science scores counted in AYP considerations for schools in Florida. Thus, it can be argued that schools did not "take the test" seriously until 2006. However, even in 2010, these scores did not factor into student promotion or graduation, so it can be further argued that the test is still not "taken seriously" on an individual level—thus this analysis will include all available data for science.

Between 2003 and 2010, the percentage of all fifth-grade White students who scored at or above the mastery level on state science assessments increased by 24%. Over the same period, the percentage of Hispanic students increased by 22%, and the percentage of Black students increased by 17%. However the achievement gap, that is the difference between the percentage of White students who scored at or above the mastery level and that of Hispanic students or Black students, remained remarkably constant. In 2010, the achievement gap between White and Hispanic students was 21% and between White and African American students was 36%, almost echoing the gaps seen in 2003. The situation is more stark for English language learners. Between 2003 and 2010, the percentage of English language learners scoring at a proficient level in the fifth grade increased by 8%, but in 2010, the gap between the number of White students and English language learners scoring at proficient or higher was 47%. Similar trends are found at the eighth- and eleventh-grade levels.

In Texas, another large and diverse state, student performance on state NCLB measures for science has steadily increased since 2003 (Texas Education Agency 2010), although it is interesting to note that these scores are not used in AYP determinations for schools. Between 2003 and 2010, the percentage of all fifth-grade White students who met state science standards increased by 40%. Over the same period, the percentage of Hispanic students meeting state standards increased by 58%, and the percentage of African American students increased by 17%. Correspondingly, the achievement gaps narrowed for nonmainstream student groups. In 2010, the achievement gap between White and Hispanic students was 11% and between White and African American students was 15%, a reduction from 2003s gaps of 29% for Hispanic students and 33% for African American students. Between 2003 and 2010, the percentage of "Limited English Proficient students" (the term employed by the state of Texas) taking the English version of the test meeting Texas state science standards increased by a remarkable 62%, and in 2010, the achievement gap between White students and Limited English Proficient students on this test was 23%. The picture is less promising when one examines the results of the Spanish version of the exam. Only 6% of all students taking this version of the test met state standards in 2003, increasing to only 9% in 2008. These figures are clearly lower than the 72% of proficiency seen for Limited English Proficient students who opted to take the English version of the exam.

A comparison of Florida and Texas NCLB measures for science reveals an improvement in all students' performance. However, it is important to note that even in 2010, after NCLB included a focus on science (although with varying degrees of inclusion in AYP), mainstream students continue to outperform nonmainstream students in science. However, in Texas where students experienced far more success overall on the assessment, achievement gaps between mainstream and nonmainstream students seem to be narrowing.

Given the very different nature of NCLB assessments and ways of categorizing students based on these assessments across the states, it is necessary to examine more uniform measures to gain an understanding of the influence of NCLB on students' science performance. Since 1996, the NAEP has been used to assess the science abilities of students in grades 4, 8, and 12, using a scale of 0–300 for each grade (NCES 2010). The national average for fourth-grade science score showed a small increase from 147 in 1996 to 151 in 2005. However, during that time period, there was no change in the eighth-grade score, and the twelfth-grade score actually decreased. White students scored higher than Black or Hispanic students at all three grades in 2005. Reflecting the increase shown in the aggregated fourth-grade data, average scores were higher consistently for White, Black, Hispanic, and Asian/Pacific Islander students in 2005 than in 1996. At grade 8, the average score for Black students was higher in 2005 than in 1996, but the scores did not measurably change for other racial/ethnic groups. At grade 12, the scores remained stable for all racial/ethnic groups between 1996 and 2005.

Possible Reasons for Continued Gaps

NAEP results do provide one avenue to describe how students' science knowledge is shaped in the context of NCLB, although analysis of more recent data is needed. The NAEP results and analysis of science performance across all 50 states conducted by Battelle Technology Partnership Practice (2009) (which takes into account NAEP, ACT, and Advanced Placement exams) suggest that the early years of NCLB did not increase students' science knowledge overall, nor did they allow for a significant shift in the science learning of nonmainstream students (something that does contradict the findings of both Florida and Texas). This discussion speaks to the need for more common measures of accountability to allow a more national portrait of student learning (something the Common Core Standards and RttT promise), as it is possible that a state's standardized assessments are more sensitive to change than the long-employed NAEP. Although for some groups the achievement gap in science seems to be closing based on the Florida and Texas data, given the continued presence of achievement gaps in both these states as well as the more static NAEP results and the variety of indicators described by the Battelle Technology Partnership Practice (2009), it seems that the patterns of science teaching and learning that emerged in reaction to NCLB were not as supportive for nonmainstream learners as hoped: the achievement gaps remain.

It is important to recognize here that "nonmainstream learners" are not a monolithic group. As the results of Florida and Texas suggest, when compared to White students, African American students typically experience a larger gap than Latino/a students. But more marked is the gap between mainstream students and English language learners. In both Florida and Texas, English language learners are the least successful on state science assessments. In an examination of Florida's high-stakes science assessments for 24,251 elementary students, Maerten-Rivera et al. (2010) found that a student's ESOL status had the greatest effect on science assessments, compared to gender, ethnicity, and socioeconomic status. Thus, as we examine the research that speaks to the effect of NCLB on students' science learning, we must take particular care to identify which group of nonmainstream students is the target of discussion. In this section, we'll explore the research that directly speaks to possible reasons for science achievement gaps, including the structure of NCLB policy, instructional decisions focused on short-term assessment gains, negative consequences for teachers and teacher attrition, and the structure of NCLB assessments.

Structure of NCLB Policy

It could be argued that one reason for continued achievement gaps can be found in the very structure of the NCLB "rollout." Administrators have urged teachers to focus on school subjects that are at the core of AYP to the exclusion of others, and this tendency is particularly acute at high-needs schools in order to help more students achieve at grade level in reading and mathematics (Lee et al. 2008). The early years of NCLB focused on reading and mathematics, science scores were not originally factored into AYP, and once science was included in AYP, it was weighted less than reading and mathematics. Because of these factors, under NCLB attention to science was extremely limited.

Instructional Decisions Focused on Short-Term Assessment Gains

A second possible reason for the continued achievement gaps for nonmainstream learners may be found in the instructional decisions driven by the high-stakes nature of the assessments. As science began to be factored into AYP scores for schools and began to gain importance in the views of administrators and teachers, instructional time sometimes increased but with unanticipated results. Saka et al. (2009) describe that in the face of upcoming assessments of science, teachers in schools which served a high percentage of nonmainstream learners were often required to devote class time to test “prep” activities that largely reinforce science vocabulary in their courses. Such reviews occurred regardless of the content of the course. In a chemistry course, for instance, teachers were required to use class time to review life and physical science in the weeks before the test. Practice tests that mimic the style of question employed on the state’s NCLB assessments are commonly used to familiarize students with the format of the test. Thus, in the context of NCLB, when science is addressed in a high-needs setting, it is often done so in a way that ignores much of the research on effective practice so that science is trivialized (Settlage and Meadows 2002), and reform-minded practices such as inquiry are avoided because of the time and energy they require (Shaver et al. 2007). Buxton (2006) describes that teachers working in high-needs elementary schools serving a predominately Black student population rarely taught science partially due to limited administrator support for science, and when it was taught, science instruction consisted of reading and answering science questions. Given NCLB, decision-making about science instruction is often structured around high-stakes assessment (Lee and Buxton 2010), and science teaching in high-needs settings is designed to familiarize students with the structure and content of the test (Saka et al. 2009).

A growing body of research describes that reform-based instruction can be effective in supporting the science learning of students (Schneider et al. 2002), but there is continued concern that practices (such as inquiry, argumentation) may be more effective for mainstream learners than students of color, students living in poverty (Calabrese Barton 2003), and students from diverse cultures and languages (Lee and Fradd 1998). However, recent work suggests that reform-minded practices such as inquiry can be supportive of the learning of both middle-class and working-class students when inquiry is enacted by a prepared practitioner (Kanter and Konstantopoulos 2010).

While NCLB does bring more attention and energy to the teaching of science, this activity often is accomplished to the exclusion of reform-based teaching practices despite evidence that speaks to their effectiveness (Pringle and Carrier Martin 2005). Southerland et al. (2007) describe that the broad scope of the current standards, the limited time in the classroom, the need for “quick improvements” for AYP, and the often singular focus on low-level science concepts characteristic of NCLB assessments interact to prohibit teachers’ use of reform-minded science instruction in the classroom. Thus, in the context of NCLB, inquiry-based, student-centered instruction described in the science education reforms is often de-emphasized in favor of rapid "coverage" of the broad scope of science described in the state standards, both in elementary (Upadhyay 2009) and secondary schools (Saka et al. 2009).

Negative Consequences for Science Teachers

A third possible reason for the continued achievement gaps has to do with the negative consequences NCLB has for teachers in high-needs schools. One aspect of NCLB is its emphasis on highly qualified teachers, with the theory of action that a qualified teacher would be more effective in supporting student science learning. To be considered highly qualified, teachers must have (a) a bachelor's degree, (b) full state certification or licensure, and (c) proof that they know each subject they teach (such as a content degree or successful completion of a state designed content test) (NCLB 2001). However, only 25% of all elementary teachers view themselves as well qualified to teach science (Weiss et al. 2001). In middle and high schools, teacher attrition makes it unlikely that all schools are able to locate and maintain highly qualified science teachers (Marx and Harris 2006). Although the limited number of science teachers is often attributed to the lack of teacher production, the problem is one not of teacher production but teacher attrition. Richard Ingersoll and David Perda (2010) suggest that this attrition is greater in schools with limited resources (which influence new teacher support, salary, student discipline, administrative effectiveness, and instructional supplies); schools serving large percentages of nonmainstream learners often fall into this category. Indeed, Peter Tuerk (2005) examined the distribution of teachers in Virginia and found that students who attended higher-poverty schools were less likely to be taught by highly qualified teachers.

Despite its intensions, NCLB legislation has had particularly negative consequences for science teachers working in high-needs settings. John Settlage and Lee Meadows (2002) describe that national and state educational policies have diminished teachers' sense of professionalism, jeopardized teachers' relationships with students, and caused them to adopt a "triage" mentality—in which teachers are asked to focus their efforts on those students whose scores showed the potential for increase at the expense of less promising students. Annis Shaver and her colleagues (2007), too, support this description of the loss of teacher authority and professionalism as they feel forced to focus on test preparation, often without being allowed to provide accommodations for their English language learners during the assessments. Teachers in high-needs schools experience a loss of agency concerning the success of their students (Crocco and Costingan 2007). This loss of agency becomes tangible when examining the science teaching practices in high-needs settings. For instance, the teachers responding to the survey conducted by Rose Pringle and Sarah Carrier Martin (2005) describe that scripted lessons, which have become a common reaction to high-stakes measures, prevent them from responding to their students' particular needs in science. Likewise, pacing guides also short-circuit teacher decision-making, and district progress monitoring results in even more time being devoted to the assessment of science instead of the teaching of science. For schools that have not met AYP, as is often the case in high-needs schools, instructional changes that focus on the structure of the assessment rather than understanding of the discipline have become common, exacerbating the loss of teacher morale (Finnigan and Gross 2007) and teacher attrition. NCLB is based on the theory of action that to avoid sanctions, schools and school districts reallocate resources to allow all groups of students to meet basic proficiencies (Penfield and Lee 2010). In science, however, the opposite seems to be occurring, with the result of NCLB causing the loss of a valuable resource: qualified teachers.

Structure of NCLB Assessments

The last of the four factors contributing to continued achievement gaps between mainstream and nonmainstream students in science can be found in the nature of the assessments themselves. As described by Maerten-Rivera et al. (2010) in their study of the predictors of elementary students' scores in one state's high-stakes science assessments, students' abilities in reading and mathematics did have an effect on their science achievement. Interestingly, reading had a significantly larger effect than mathematics, suggesting that verbal ability contributes more to science achievement as it is currently measured. This trend becomes particularly stark for ESOL students. As previously described, ESOL students continue to lag behind all demographic groups in science, which is not surprising given the documented interactions between reading and verbal ability and science achievement.

The interaction between reading ability and students' NCLB assessment can be partially explained by the fact that states' NCLB science assessments are developed for native speakers of English using items with a high level of linguistic complexity (Penfield and Lee 2010). It is not at all clear that such assessments can yield valid scores for any student with limited verbal abilities in English. Abedi (2004) describes that the validity of high-stakes assessment is much higher for English-speaking students than for English language learners. The limited validity of assessments for ESOL students helps to explain the vast achievement gap found between ESOL students and English-speaking peers. In addition to their linguistic complexity, because states' NCLB assessments are designed by and for mainstream students, there is also a question as to the degree to which nonmainstream students' cultural background influences their responses. Penfield et al. (2009) examined science assessments in terms of their differential item functioning (DIF) for different groups of learners. (DIF is a measure of the degree to which an item is biased to allow for a higher success rate for some groups of students in comparison to others.) These researchers found DIF effects were attributed to the cultural and linguistic properties of specific items, resulting in lower scores for a wide range of nonmainstream students. This work suggests that success on NCLB assessments may be due more to students' degree of cultural congruence with the assessment than to their science understandings.

Understanding the Paradox: Negative Consequences of NCLB

It is paradoxical that the ESEA was created to address the educational needs of underserved children, yet the system created by the latest instantiation of ESEA—that is NCLB—has serious flaws, particularly in supporting the learning of the very nonmainstream learners it is designed to aid. Kim and Sunderman (2005), in their analysis of student data from six different states, found that schools that made federal AYP had smaller percentages of Latino/a and low-income students, and almost all the schools that failed to make AYP had three or more student subgroup accountability targets. Maerten-Rivera and colleagues's (2010) work in science reveals a similar pattern that in schools functioning in the context of NCLB, "small differences add up," as nonmainstream learners, particularly learners that fall into more than one "nonmainstream category," (p. 21) are failing to become proficient in science.

The research presented in this chapter suggests that NCLB carries with it negative consequences for schools serving nonmainstream learners. How can we understand this paradox? As Jonathan Supovitz (2009) describes, and the research described earlier bears out, high-stakes assessments have been used to leverage change in the educational system in the USA. To allow for this change, such assessments are thought to motivate teachers and administrators to shape their instructional practices to align with high-stakes assessments. However, given the lack of guidance on what effective instruction should and could look like (as is the case of NCLB), the changes they motivate are often superficial alterations to "cover" content and preparation to mesh with the format of the test rather than call for any substantive alterations in how science is taught and learned. Too, the information provided by the assessments has limited utility in guiding instruction, as the results are often shared well after the school year has ended; are not linked to local instructional practice; and fail to provide much descriptive information of student thinking. While NCLB policy is designed to bring about an alignment in the system among assessment, curriculum, and classroom practices, from the research presented here, it is clear that it is the high-stakes assessment aspect of the policy that holds the most sway. That is, high-stakes assessments make remarkably fast inroads into instructional decision-making. But if each state has such assessments, why then does the achievement gap in science remain?

In an earlier discussion of NLCB policy's influence on science teaching and learning, I (along with colleagues) invoked Larry Cuban's (1988) idea of first-order and second-order changes in education (Southerland et al. 2007). First-order changes include small changes to existing practices to increase the effectiveness and efficiency of current teaching practices (e.g., changing texts, tutoring sessions, block scheduling). Second-order changes are designed to transform the fundamental patterns of teaching and subsequently learning (e.g., use of student-centered instruction in lieu of lecture, varying instructional activities based on the knowledge and needs of the learner). Second-order changes are more radical as they contradict and overturn the structures and rules that constitute traditional schooling. Such changes require fundamental changes in both teacher thinking and teaching practices.

NCLB calls for a first-order change, as it simply requires changes in schools without identifying corresponding goals for science learning, or describing how teaching and learning science must be different. Given the expectations of rapid changes (year to year) with the very tangible specter of reduced funding or loss of autonomy, school districts, administrators, and teachers are forced to take the most expedient and efficient routes to increasing students’ test scores, that is, first-order changes such as test preparation, vocabulary drills, teaching “triage,” and “stealing” time from other subjects to devote to science. These first-order changes require a huge investment of resources including time, money, and energy—from a system already hard pressed for each of these. Because of the enormous influence of NCLB assessments in the absence of any accompanying guidance of the sort of teaching and learning that should be the target of teachers’ efforts, school systems channel all their energies to these first-order changes, leaving no resources available to change the way in which science is taught and learned.

While the first-order nature of NCLB actions has been mixed for mainstream learners, this situation is more uniformly negative for nonmainstream learners. NCLB presupposes that holding schools or districts accountable for these achievement gaps through punitive funding policies will allow for enhanced learning for all students. However, given limited time, funding, and lack of coherent vision of science teaching and learning in NLCB policy, an unintended consequence of this legislation is a new embrace of an old concept—a deficit view of multiculturalism. Due to poor alignment among components of the educational system (content standards, teaching practices, and assessments), nonmainstream learners can be seen as “bringing down” a school’s success—a view that does not allow teachers to validate and use the cultural and linguistic resources of nonmainstream students as the foundations of teaching. Given the misalignment of this system, within NCLB, educators tend to perceive student diversity as a barrier to overcome rather than as a resource to capitalize on. Although NCLB does focus on achievement gaps of particular demographics groups, it does not provide schools with the resources (e.g., funding, time, professional development) or vision necessary to meet the accountability demands it imposes. This misalignment of the system has particularly negative consequences for nonmainstream students (Lee and Luykx 2006).

Comments on Methodology

The argument I constructed for this contribution drew upon a wide range of research. This research employed a broad spectrum of methodologies, from the qualitative (interviews, ethnographies) to quantitative (surveys, large scale quasi-experimental comparisons, factor analyses), to even policy and more historical analyses. This use of a broad spectrum of methods is a characteristic of policy research, as the central focus is to shed as much light as possible on a topic. Such methodological pluralism is important not just for its power of enlightenment but also for its power of persuasion (rhetorical power). Researchers must be aware of the research methods embraced by the communities to which they seek to speak, and employ those methods (as well as others) if their work is to inform communities other than our own.

Implications for Science Education Research, Practice, and Policy

Although it is unclear how well current high-stakes assessments measure mainstream OR nonmainstream students' "walking around knowledge of science" (Brickhouse 2006), it is clear that they have become a fixture of the American educational system as such assessments serve as tangible evidence politicians use to demonstrate that they can shape education before they again run for office. But as Jonathan Supovitz (2009) describes, within NCLB policy, "reform itself has become confused with the instrument used to measure it. While the testing system can reveal serious educational problems, these problems cannot be fixed by reforming the assessment system alone" (p. 222). Too, improving student success in science cannot be accomplished by simply changing a teaching practice or a shift in policies (Wood et al. 2006). Instead, I argue that the next generation of researchers in science education, particularly those interested in issues of equity and diversity, should take great care to describe how the current misaligned environment of accountability "bears down on even the best teachers" to make reform-minded practice a near impossibility (Carlone et al. 2010) and actively share these descriptions in a compelling manner in an effort to inform policy. Science educators and science teachers must persuade policymakers and the general public of the need for a complete realignment of the educational system, one that ties assessments with a vision of productive science teaching and learning, *if* the assessments that are embraced by politicians, policymakers, and voters are to catalyze second-order changes. Clearly, such fundamental second-order changes are needed if we are to help all students, particularly nonmainstream students, become proficient in science.

We recognize the power of high-stakes assessments in aligning or misaligning the educational system. The work of science education researchers must extend past our common pathways of traditional scholarship, and we must expend our efforts to give the features of the misaligned system the attention they require. The production of assessments cannot be left to testing companies and individual states; instead, science education researchers and teachers must become more actively involved. Many of the resources of the science education community will be needed if we are to "get this right" so that these assessments can serve as adequate proxies for "walking around knowledge of science" (Brickhouse 2006) or can measure students' "rich science knowledge" as described in the national reforms (Marx and Harris 2006). If the system is to be aligned in a way to support the learning of ALL students, we must consider not only the degree to which these assessments measure students' varied strands of science proficiencies (Duschl et al. 2007), but also the degree to which these assessments are culturally and linguistically biased. Our educational system can be no more effective in supporting the science learning for students from diverse backgrounds than the assessments are in reflecting all students' science knowledge and abilities. Clearly, this is no small task, and given current economic conditions in most states, it seems imperative that the resources of states as well as the academic community will be necessary to develop assessments up to the task (as might be realized in the Common Core Standards Initiative). But to be effective, these assessments must be designed and evaluated to the degree they serve as useful proxies of science knowledge and abilities of ALL students, particularly diverse groups of nonmainstream learners.

In addition, if national educational policy is to be effective in instigating and supporting real changes in the way science is taught and learned, it must go beyond high-stakes assessments to include not only high-stakes teaching goals and practices, but as Brickhouse describes in this volume, attention must be paid to the resources necessary to allow for and support these goals and practices. It is only through the alignment of the complete system that a second-order change can be achieved. If we are to build an educational system in which all groups of learners have access to science, professional development must be part of that system. This professional development should focus on the way in which science teaching can be adapted to capitalize on the knowledge and abilities that diverse groups of students bring with them into the science class. If policy is to be effective for fundamental reform, a second-order change that allows all students the opportunity to excel in science, that policy must carry with it the vision, time, and expertise necessary in supporting truly equitable science instruction.

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Chapter 3
Conceptions of Inequality in the Era of Bush/Obama

Nancy W. Brickhouse

> Whether it's fighting poverty, strengthening the economy or promoting opportunity, education is the common thread. It is the civil rights issue of our generation and it is the one sure path to a more equal, fair and just society. (Arne Duncan, US Secretary of Education, December 8, 2008)

Educational inequality is not news to educational researchers. What is new, however, is that since the implementation of the No Child Left Behind Act (NCLB), achievement gaps have been front page news. While many question the strategies used to drive today's education reform, others recognize the value of what reformers are trying to achieve – the improvement of STEM education, particularly for students in schools in underserved communities. However, the explanations for the causes of this educational inequality vary widely, as do the solutions.

Concerns about equality in access to education are driving the agenda of the US Department of Education – a reform that is backed by $4.35 billion in Race-to-the-Top (RttT) funds awarded to states that adopt the new Common Core Standards, commit to developing reward systems for educators that depend in part on growth in student achievement, create new routes for the preparation of high-quality teachers/leaders, employ new incentives for the best educators to teach in the highest needs schools, develop new data systems and expertise in how to make good decisions based on these data, and take bold steps to turnaround persistently low-performing schools by changing the way they are staffed. Eleven states (Delaware, Florida, Georgia, Hawaii, Maryland, Massachusetts, New York, North Carolina, Ohio, Rhode Island, and Tennessee) plus the District of Columbia have been awarded RttT grant money.

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These reforms are not only incentivized by RttT grants, but the policy changes required by these grants are also driving legislative and regulatory changes across all 50 states and much of the rest of the funding of the US Department of Education supports these reforms. Meeting the demands of these reforms in many states requires legislative and/or regulatory changes that will likely remain in place even in those states that did receive the RttT award, and these changes will likely remain long after the 4 years of grant funds are spent.

Furthermore, many of the same initiatives supported by US DOE are also supported by very large private foundations, such as Gates, Walton, and Broad. The amount of money flowing into US public schools through private foundations is unprecedented, and because the commitments of these foundations are well aligned with those of US DOE, the impact of these private foundations strengthens the financial and political power of US DOE.

One element of the current RttT reform requires the adoption of new Common Core Standards in mathematics and English/language arts. This initiative has also been taken up by some of our nation's most distinguished mathematicians, scientists, educators, scholars, business leaders, and public officials as it relates specifically to STEM education. *The Opportunity Equation*, supported by the Carnegie Corporation of New York and the Institute for Advanced Studies (Commission on Science and Mathematics Education 2010), claims that "the United States must mobilize for excellence in mathematics and science education so that all students – not just a select few, or those fortunate enough to attend certain schools – achieve much higher levels of math and science learning" (p. 1). The educational goals promulgated in this document demand far more than the procedural skills and factual knowledge that are often the bread and butter of science and math curricula. They demand that we gauge success by the ability of our youth "to analyze problems, imagine solutions, and bring productive new ideas into being" (p. 1). In other words, according to the authors of *The Opportunity Equation*, the challenge in math and science education is to embrace both equality and excellence – and to achieve this they call for new standards that are "fewer, higher, clearer" with aligned assessments, new models for schools to provide the challenging curriculum, and a research agenda that will inform these changes. In science education, the Carnegie Corporation then provided support to ACHIEVE to write the actual standards. The development of a conceptual framework and standards involved partnerships with the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), the Association of State Science Supervisors (ASSS), the National Governor's Association (NGA), and the Council of State School Officers (CSSO). In July 2010, the Board on Science Education at the National Academy of Sciences released a draft of the conceptual framework for the new standards for science and (explicitly, for the first time) engineering.

These initiatives articulated in *The Opportunity Equation* and those supported by US DOE complement each other in some ways. For example, RttT awards demand the adoption of the Common Core Standards in mathematics and English/language arts. However, in other ways, there are tensions between *The Opportunity Equation* and education reforms supported by RttT grants in terms of where they locate sources of inequality and how they propose educational inequality is to be alleviated.

In this chapter, I will analyze conceptions of inequality embedded in these two reforms (i.e., RttT funds and standards-based reform in science called the Next Generation Science Standards), as well as conceptions of inequality typically expressed and shared by science educators, as articulated in the chapters of this volume. Here, I will describe the claims of standards-based reform as a strategy of alleviating educational inequality, and how the arguments put forth in *The Opportunity Equation* cohere with these claims. Whereas the education reform of US DOE, as articulated in the RttT requirements, incorporate some of the ideas promulgated by standards-based reform, they also incorporate many of the ideas of those who argue that the source of educational inequality can be addressed with a more open-market approach to educational services. Finally, I will discuss the scholarship of many of the authors in this book, who more typically argue that the sources of educational inequality are, at least, in part epistemological, thus questioning the possibility that standards and markets alone will be effective in achieving desired goals of educational equality in STEM education.

Conceptions of Inequality in Standards-Based Reform

1990s Conceptions of Standards-Based Reform

The argument for the potential of standards-based reform to address inequalities in student access to science education rests on the belief that the most fundamental source of inequality is in the educational system itself, and the fact that there is too much variability in the quality of the educational system, leading to a predictable abundance of opportunity in privileged communities and a lack of opportunity for individuals and communities that have been underserved. This is why there is an unequal distribution of opportunities to learn science:

> Schools are organized around the idea of providing distinct learning opportunities in multiple academic disciplines. Yet, in the United States the opportunities to learn this academic content are not equally distributed among districts, schools, classrooms, or students. The unequal distribution stems primarily from the structure of the American educational system…. This form of variability in OTL (opportunity to learn) is designed into the system, and reflects a conscious decision to sort children and provide them with different opportunities. (Schmidt and Maier 2009, pp. 541, 551)

Thus, systematically implementing rigorous, coherent, and uniform expectations for all children is viewed by some researchers and policymakers as key to addressing inequalities in access to science education. Standards are the foundation that must be in place in order to reduce the variability in the quality of the enacted curriculum, instruction, and assessments.

This variability in opportunity to learn is also due in part to the fact that in the USA, the authority and responsibility for education lies with the states and local districts (Cohen and Moffitt 2010). Since the federal government has no authority over the curriculum in US schools, determining who should have the authority to write national standards is a contentious matter. When the National Science Education Standards (National Committee on Science Education Standards and Assessment, National Research Council 1996) were written, professional teaching organizations such as the NSTA collaborated with scientists on their development. The controversy that erupted in 1994 over alleged political bias in the history standards crippled the movement for voluntary national standards (Ravitch 2010). President Clinton as well as governors throughout the country distanced themselves from the national standards.

Since the 1996 standards were voluntary and controversial, the extent to which they influenced state standards varied a great deal. Furthermore, although all textbook publishers claimed alignment with the standards, there was neither a set of curricular materials specifically designed to facilitate the teaching and learning of the standards, nor a system of assessment that could be used by educators to judge how well students were learning the content of the standards. In some states, standards were written with little influence by the national standards. In other states, although rigorous standards were written, follow-through was so weak that classroom practices were not changed and learning did not improve. The poor leverage that the national standards had on classroom practice held across school subjects. Thus, it is perhaps not too surprising that a National Center for Educational Statistics study shows no relationship between high-quality standards and mathematics achievement (Bandeira et al. 2009). Standards that are written, yet have no influence over the curriculum or assessment, are simply irrelevant. It is the policy coherence that comes with the alignment of standards, curricula, and assessments that gives potential power to standards as a lever for reform (Furhman 1993).

It is not only possible for standards to be impotent in affecting classroom instruction, but they can also be harmful. When standards are low or encourage superficial coverage rather than deep learning, they can be destructive by creating an image of meaningful learning that is illusory. The 1996 National Science Education Standards were considerably weakened when NCLB was enacted in 2001, providing incentives for schools to spend time and other resources on English/language arts and mathematics, rather than science (Marx and Harris 2006). While NCLB required states to write standards in English/language arts, math, and science, it also strongly incentivized low standards by punishing schools with large numbers of students who did not meet the standards in mathematics and English/language arts. Furthermore, if standards are merely translated into a testing system that holds children, teachers, and schools accountable to narrow, low-level skills, test scores could improve while the overall quality of education declines (Brickhouse 2006).

Influence of Standards-Based Reform in Contemporary Initiatives

While the history of standards-based reform should provide good reasons for caution, some educators argue that standards-based reform has not been successful because it has not been implemented vigorously. Thus, the current wave of reform using standards as the foundation uses different strategies. With regard to English/language arts and math, rather than professional organizations taking the lead, the National Governor's Association, the Council of Chief State School Officers, and ACHIEVE formed a partnership to push forward with national standards in English/language arts and math. While these groups may not have the same kind of professional, content-based expertise as organizations like the National Council of Teachers of Mathematics (NCTM), governors have considerable authority over education in their home states. Furthermore, many of the governors have signed on to enforcing the use of the new Common Core Standards in English/language arts and math.

In the case of science, *The Opportunity Equation* called for a revision of national standards in STEM. Recognizing the need for content experts, the Carnegie Corporation made an award to the National Academy of Sciences to write the frameworks document for science standards, and to ACHIEVE to write the actual standards. While professional organizations did not lead the revision of the new standards, NSTA, the AAAS, and the ASSS were heavily involved.

While there are many individuals and organizations that continue to support standards-based reform, the argument has been most powerfully articulated in *The Opportunity Equation* (Commission on Science and Mathematics Education 2010):

> Common standards would be a strong platform upon which to build a more effective instructional infrastructure for American math and science education: educators, along with schools, districts, and states in which they work, would be able to concentrate on how math and science are taught and on how much students are learning rather than on what to teach. Common standards would provide the framework for a widespread, national conversation about how educators can best help students in all groups – from struggling to advanced – to master academically rigorous content and acquire essential skills. They would provide a similar framework for the preparation of future teachers. (p. xx)

These common standards would not only provide a framework for curriculum, assessment, and teacher education that would be national in scope, they would also provide a framework for research that would facilitate the work of researchers who desire their research to have greater impact on the practices of science education. In particular, as researchers examine the implementation of the standards over time and in different contexts, the standards, as well as the curriculum, assessments, and professional development programs that support them, could undergo continuous improvement. The authors of *The Opportunity Equation* call for research and development in policy relevant to changing the educational system and making our young people "STEM-capable" when they leave high school. In particular, they call for funding for research to develop better assessments and data management systems, to develop educational practices in support of new standards, to better understand what students need to know and be able to do to be STEM-capable, to assess the effectiveness of science and mathematics teacher recruitment strategies as well as systems of professional development, and to develop data systems to track the success of graduates of science teacher education programs. In sum, they are calling for a massive research and development effort in science education that is directly related to important policy issues.

This argument for standards speaks directly to issues of equality simply because children and youth of color and from low-income communities often depend on schools to provide access to academic subjects such as science. While there are certainly strong examples of children and youth from underserved communities finding resources from within their families and communities that can provide them with access to scientific practices (Bell et al. 2009), it is less clear that these informal practices can provide them with what they need to be successful in rigorous, academic science. Furthermore, these resources are not distributed in ways that make them accessible to all children. For example, Nancy Brickhouse and Jennifer Potter (2001) documented how a parent with strong computing skills provided a home environment that was relatively rich in computing opportunities compared to other families without this knowledge. Similarly, parents with college degrees in engineering were more likely to discuss conflicting scientific claims with their children than parents with college degrees in the humanities (Valle 2007). When learning is left to the private sphere, inequality can grow considerably simply because wealthy parents and communities may have the means of providing their children with access to technologies and resources that often are unattainable in poor communities (Collins and Halverson 2009). In other words, opportunities to learn science in informal settings also are distributed inequitably. Some youth must rely on the science offered in school more than others.

Yet, the schools that children from underserved communities attend are least likely to have the kind of curriculum, instruction, and professional development infrastructure that is needed for teachers to be successful science teachers and for students to be successful science learners. As David Cohen and Susan Moffitt (2010) note, it is clear that a major failing of standards-based reform and NCLB is that reformers overlooked the weak capability of schools to implement the changes needed to improve achievement. This is especially the case in schools serving large numbers of children from high-poverty communities. Cohen and Moffitt state, "The policy aims of equality and excellence collided with weak capability, limited policy instruments, and very unequal access to educational resources, to create unprecedented incompetence in educational practice" (p. 192). Furthermore, high-poverty schools not only had the weakest capability to change, but they also embodied the largest distance between goals and practice.

Cohen and Moffitt (2010) also argue that the cases of successful schools working in challenging communities are similar in that they focus their efforts on working inside schools to build an infrastructure of strong curricula and professional development to support the school staff. Examples include the Knowledge is Power Program (http://www.kipp.org/) and Success for All (http://www.successforall.net/index.html). Similarly, researchers in systemic reform have argued for innovations that take into account the alignment of policy demands with curriculum, assessment, and teacher professional development (Goetz et al. 1995). Rather than replacing teachers whose students are not scoring well on achievement tests, these reformers argue for working with the staff in the school to help them become effective teachers.

In essence, for advocates of new standards, the argument is that strong standards provide the basis for building an infrastructure to support the ambitious teaching and learning of science – and that it is precisely what is most needed in high-needs schools to support the science learning of children from diverse backgrounds. This infrastructure would provide all children/youth with opportunities to learn science by reducing variability in opportunity to learn science across and within schools. In other words, since inequality is conceived as a structural problem, its solution is also structural in nature.

The most significant practical challenge to this approach to improving access to science education in the USA is that the authority for education is decentralized and policies are often incoherent or contradictory. The articulation and enactment of the standards must not only drive curriculum development, professional development, and assessment, it must also be taken up by state and (sometimes) city governments and local school boards. Standards-based reform assumes that there is an educational system, when in fact there are many systems with policies in place that are often contradictory and incoherent.

Conceptions of Inequality in Market-Based Reform

Although present-day education reforms have strong, bipartisan support, the ideological roots of NCLB and its successors have been traced to Barry Goldwater conservatism that emphasizes "individualism, self-reliance, economic liberty, social mobility, and entrepreneurship" (Hess and McGuinn 2002, p. 78). Every individual has the right to pursue his/her dreams without government interference. NCLB is a response to the charge that there is not a level playing field because some Americans receive a substandard education. Elimination of the achievement gap makes American capitalism a fair game.

The argument for the potential of market-based reforms to address inequality in student access to science education rests on the belief that the fundamental source of inequality is the fact that students in poor urban and rural schools must attend schools operated by the government. The government is a monopoly. Monopolies breed mediocrity. Market forces are a force only for wealthy families who can choose their neighborhoods and thus their children's schools or they can opt for private ones. It is when all schools are subjected to the market forces of choice that they become both innovative and efficient. If students in underserved communities had schools that were free of government regulation and union protectionism, achievement would improve without increased costs. Charter schools and school choice programs are not intended to completely replace traditional schools. They are instead intended to insert competition into the system so that all schools will get better. Those schools that perform poorly are to be replaced by high-performing ones. Policymakers who support these market-based reforms may recognize the need for a strong infrastructure to support teaching, but they believe that the way of getting it is by introducing new competitive programs that will be more innovative because they operate independently of the existing bureaucratic system.

These market-based reforms have had profound effects on education, in general, and science education, in particular, and have attracted unprecedented resources from private foundations: Gates, Broad, Walton, and Carnegie Corporation. Many of the reforms embedded in the requirements for RttT grants are premised on the notion that competition will improve the schools. These grants provide large sums of money to high-needs schools – with vendors bidding on contracts to teach school staff about data-driven decision-making or to turn around persistently low-performing schools. In Ohio and Tennessee, Battelle, a nonprofit science and technology company, in partnership with the Gates Foundation, designed the strategy for science education in the RttT grant application.

More significantly, perhaps, RttT grants support states in attracting new programs for teacher preparation. No state that relies solely on traditional programs in universities to prepare teachers is eligible for a RttT grant. Teacher quality is seen, in business terms, as a human capital challenge. Thus, some of the most successful alternate routes programs, such as Teach for America (TFA), have developed marketing strategies that have been successful in recruiting highly talented candidates into teaching, thereby making the program prestigious and capable of attracting millions of dollars in public and private funding. Furthermore, TFA and other alternative providers of teacher preparation specifically target high-needs schools – and most of them prepare science teachers.

The rationale for multiple routes to certification is similar to the argument for charter schools and school choice programs. By introducing competing teacher education programs into the educational landscape, traditional university-based teacher preparation programs will have to improve. Unlike former US Secretary of Education Rod Paige, who famously quipped that he would like to "blow up Ed Schools," Arne Duncan, in his addresses at both the University of Virginia and at Teachers College in 2009, embraced and criticized university-based teacher education. Recognizing that the nation needs more teachers and that universities prepare the majority of new teachers, he would prefer that education schools be reformed rather than "blown up." His strategy for achieving the reform of education schools is by inserting competition from additional teacher preparation programs. It is ironic that many science educators teaching in traditional science teacher preparation programs have devoted our careers to doing research on issues of inequality in access to science, yet we are not seen as having viable solutions for teacher preparation. In fact, many of these alternative programs that focus on developing teachers for high-needs schools completely bypass university-based teacher education.

For example, TFA prepares science teachers by placing them all in high-needs schools following a 5-week summer boot-camp. Corp members take courses while teaching in order to become fully certified. TFA is a highly competitive program – attracting excellent candidates from many of the most prestigious universities in the country. TFA corp members commit to teach for 2 years, after which a few stay but most leave. For example, in New York City, approximately 45% of TFA teachers are in the first or second year (Kane et al. 2008). Studies of the effectiveness of TFA corp members generally use student achievement in evaluating the success of the teachers. The most rigorous study of TFA science teachers concludes that at the high school level, TFA corp members' students score higher on end-of-year exams than the students of a comparison group of teachers (Xu et al. 2009).

While these studies comparing the relative effectiveness of science teachers are informative regarding the relative achievement of students taught by teachers in different teacher preparation pathways, to some degree they also miss the point. The rationale for multiple pathways into teaching is that they add competition to the system that will force all programs to either get better or to go out of business. The challenge for those with faith in these market-based reforms is that teacher education programs rarely close and there is no reason to believe that the invisible hand of the market would close down programs based on quality.

Conceptions of Inequality as Epistemological

While education reformers appear to be driven primarily by standards-based and market-based arguments, science education researchers often adopt a different view of the sources of inequality as deeply cultural and epistemological. Although many, if not most, science education researchers would likely recognize the inequality of access and outcome in science education and the ways in which our educational system have failed to serve all children equally well, many have also argued that this analysis does not go far enough. There are also epistemological matters related to the sciences as disciplines that pose additional barriers for students' access to science.

Researchers studying the relationship between everyday activity and learning have shown that learning is embedded in sociocultural contexts that shape knowledge in culturally specific ways (Rogoff and Lave 1984). The fact that the scientific knowledge taught in school was generated in very different contexts than the ones in which many students live explains at least in part why access to science is incredibly challenging. The contexts in which scientists work can be conceived of as a culture since there are many values and repertoires of practice that scientists hold in common (Bell et al. 2009). In many traditional school settings, the values and repertoires of practice are stereotyped in ways that exaggerate the specialness of scientific practices and reinforce an elite scientific brand.

From this perspective, the solutions that are advocated for by standards-based reform will never be sufficient in addressing inequality in science learning. Providing equality in opportunity to learn alone will not be successful because it fails to recognize the epistemological and cultural dimensions of science and school science that must be mediated in order to provide access to science for all.

Thus, science education researchers have examined the ways in which the knowledge and practices of children and youth in their homes and communities overlap in important ways with the practices of scientists. Repertoires of practice, developed in the everyday lives of children and youth, can then be leveraged for the development of more complex skills (Bell et al. 2009). Thus, Angela Calabrese Barton, Edna Tan, and Anne Rivet (2008) have designed after-school science programs for urban girls to provide a hybrid third space that exists in the interstices of youth culture and science and results in learning science subject matter in ways that are integrated with the values and practices of youth culture. Similarly, Ann Rosebery and Cynthia Ballenger (2008) describe ways of reaching out to children who are English language learners by allowing students to use diverse language practices and life experiences to understand scientific phenomena.

This emphasis on science as a repertoire of practices is significant for advancing equality goals because the conceptual distance between what children and youth do in their everyday lives and what happens in school science is minimized. Observing nature, judging scientific expertise, and communicating information are all practices that occur in the everyday lives of ordinary people. They are as well highly relevant to the everyday work of scientists in the generation of scientific knowledge. Thus, the draft frameworks of the National Science/Engineering standards released for comment in July 2010 that shifted away from an emphasis on science as inquiry to science as a repertoire of practices has the potential of guiding the creation of curricula in ways that will draw upon the values, experiences, and knowledge that resonate with students.

While researchers have documented compelling cases in which curricula that address the problem of the epistemological distance between learners and science can enhance science learning, the next step for researchers is to consider how such curricular reforms can be brought to scale (Lee and Buxton 2010). How can this research begin to address the problems of inequality at a systems level so that the impact is broad and sustainable?

What These Lens Enable and Constrain in Our Scholarship

These three conceptions of inequality are neither mutually exclusive nor entirely complete. Individual researchers and policymakers often recognize that the sources of inequality are multiple and that all or some combination of these strategies for promoting equality have merit. In addition, there are other conceptions of inequality not discussed here, for example, that the source of inequality resides in individual capability. What is significant about the first two conceptions of inequality – standards-based reform and market-based reform – is that although the conceptions of inequality are rarely explicitly articulated, they are shaping powerfully the reform agenda of US DOE. The third – epistemological or cultural conceptions – is important because of its prominence in the science education community, as illustrated in this volume.

The challenge for us as science education researchers is to give more consideration to shaping our research agenda in ways that will enable our research to be read and valued by those who shape actual educational policies and practices. In the past, science education researchers holding an epistemological conception of inequality have attempted to shape practice by making the research accessible to teacher educators and by infusing the knowledge gained about teaching science for social justice in our own teacher education programs. One limitation of this strategy, however, is that the number of new science teachers prepared by research institutions is relatively small. Furthermore, while there is research that shows how teachers and teacher candidates make use of these research findings, this research is small in scale and has never garnered the attention of policymakers.

We should also acknowledge the tensions that exist between these conceptions of inequality and the ways they lead to different conclusions concerning the alleviation of inequality. The concern with the standards-based approach to addressing inequality is that it is a one size fits all approach that does not account for the diversity of students in our schools and the communities they serve. In a similar manner, the concern with the market-based approach to addressing inequality is it requires faith that the free market will either build an infrastructure to support science learning for all or that such an infrastructure is not necessary. Furthermore, although many science education researchers focus on epistemological or cultural conceptions of inequality, they would also agree that there are large structural barriers to students' access to science education.

What Is the "So What" for New Scholars Interested in Equality and Diversity?

While much has been accomplished in creating a research base in science education for "bringing in the outsiders" (Brickhouse 2011), the next step involves addressing the challenge of linking with policy and practice to enable improvement in the educational system. This work must be done if our ambitions to make science truly accessible for all are to be realized.

There are enormous opportunities for researchers interested in equality and diversity to carry out policy-related research. As new policies intended to alleviate educational inequality are implemented, researchers should be prepared to study the effects of these new policies on teaching and learning science. Do policies designed to distribute equitably opportunities to learn science actually have that effect? Do new pathways for the preparation of science teachers improve student access to high-quality science teaching? Do science-themed charter schools address inequalities in science learning?

Researchers could also work across the conceptual frameworks and examine the tension between what should be the same for all students (e.g., common core standards), and what local variations could be put in place to leverage the repertoires of practice students bring to school (e.g., cultural practices). We need research that illuminates the potential of common core standards, highly qualified teachers, and strong systems of curriculum and assessment in alleviating inequalities in access to science. How can we take what we have learned about student success in science, particularly successful science students living in low-income communities, and integrate these opportunities for science learning into large educational systems that have substantial impact? There are tremendous opportunities for young scholars to build on the scholarship in this volume, yet to also design research that speaks to policymakers who are currently influenced by ideas of systemic and market-based reform.

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Chapter 4
International Response for Part I: Bridging the Gaps Between Policy and Practice on Equity for Science Education Reforms

Mei-Hung Chiu

The three chapters in *Science Education Policy*—by George DeBoer, Sherry Southerland, and Nancy Brickhouse—discuss the influences of and relationship between policy and practice on equity for science education reforms in the USA. DeBoer's chapter provides a comprehensive review of the evolution of relevant policies in science education from a historical perspective. Southerland draws on data of nonmainstream students' performance scores to show the influences of the No Child Left Behind (NCLB) Act and concludes that without precise and proven interventions, achievement gaps in the USA will persist leaving generations of young people underserved. Finally, Brickhouse describes how federal legislation has failed to incorporate cultural and epistemological views of equity. While policies to promote equity and excellence exist, legislation like NCLB has not positively influenced science education reform because it has overlooked the inability of most schools across the country to effectively implement reform efforts.

Using the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis method proposed by the Stanford Research Institute, I highlight the key issues addressed by the authors of these three chapters. First, they all agree that the great strength of equity policies is their ability to call attention to issues of excellence and equity. Second, weaknesses exist in the limited generalizability of available performance data, and the misallocation of funds to schools for narrowing performance gaps between mainstream and nonmainstream students. Third, there are opportunities to bridge performance gaps if science educators vehemently advocate for improved teacher professional development programs and improved communication among researchers, federal policymakers, local legislators, and regulatory authorities. Finally, competition between schools in terms of student achievement

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may actually contribute to performance gaps, and "teaching to the test" may only produce more pressure for both teachers and students.

The authors take different paths in their analyses of present-day gaps in equity science education. DeBoer argues that it is important to continue to provide students with the opportunity to succeed to their fullest potential regardless of their race, gender, language, or socioeconomic status. Therefore, tension between economic necessity, personal goals, and the opportunity to succeed exists. On the other hand, Southerland points out the need to carefully and critically examine the impact of policy on student learning, and draws on analysis of national assessments (e.g., NAEP) over a period of time to show the continuous gaps in learning outcomes of nonmainstream students. She further describes a strong need to realign the educational system with high-stakes assessment for productive teaching and learning. Alternatively, Brickhouse argues that politicians have overlooked the low capacity of schools to implement current reforms, and emphasizes an emerging need for cultural and epistemological viewpoints that value and appreciate the different learning backgrounds that students bring into the classroom. As a result, learners' personal experiences in their daily lives, a perspective currently not valued in educational settings, would be welcomed in formal school science. Brickhouse further proposes that there is a desperate need to provide a basic infrastructure for teaching and learning, and that inadequate awareness of cultural and language effects hinders successful reform implementation.

Next, I will briefly discuss the relationship between equity and policy by answering three key questions. Based on this discussion, I will draw some conclusions as to WHAT SCIENCE EDUCATORS CAN DO to make a difference leading to equity of learning opportunities in science education.

Question 1: What Are the Major Trends of the Policies on Equity in Science Education?

As illustrated in DeBoer's chapter, researchers and educators often tend to be *ahistorical* in choosing ideas and operationalizing these ideas as if they were new and innovative. Despite "science for all" being pushed by politicians, it is contested whether any true gains have been achieved. I demarcate policy development into four categories related to when influential events occurred: Induction Period (before 1950), Latent Period (1950–1980), Incubation Period (1981–2000), and Emerging Period (2001–2020) (see Fig. 4.1).

During the Induction Period (before 1950), "science for all" referred to science for both citizenship and technical career preparation in its literal meaning. During the Latent Period (1950–1980), the launching of *Sputnik* by the Soviet Union in 1957 generated a major momentum to catalyze the movement of science education reforms in the USA. Reforms during this period, however, had little positive impact on disadvantaged students. DeBoer argues that "little attention was paid explicitly to inequalities due to race, gender, or disability at the curricular level." During the Incubation Period (1981–2000), many influential documents and proactive actions

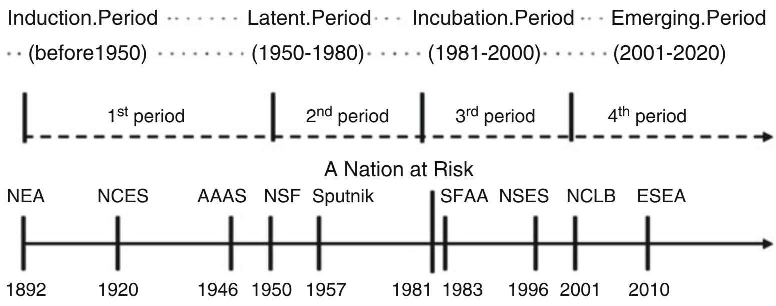

Fig. 4.1 Developmental periods of policies related to science education

were taken. For instance, *A Nation at Risk* published by the National Commission on Excellence in Education (1983) and *Science for All Americans* published by the American Association for the Advancement of Science (1989) focused on a "common core" argument for all students regardless of their social circumstances, races, and career aspirations. The fourth period, the Emerging Period (2001–2020), is related to accountability for opportunity, excellence, and equity. The intention of NCLB was to empower teachers and principals and to provide resources for improving student achievement. However, according to the report *Broadening Participation in America's Science and Engineering Workforce* (National Science Foundation 2005), despite measurable gains, progress has been slow and uneven across underrepresented groups in various science and engineering fields.

Question 2: How Do These Chapters Address Similar Issues that Might Be Encountered by International Scholars and School Science Teachers?

In 1996, US policymakers for the first time announced that science education should have standards for content teaching, assessment, teacher education, and science education programs. The *National Science Education Standards* (NSES) (National Research Council 1996) came to play a central role in textbook writing, program design, and research themes.

As a science educator from Asia—with most of the top-performing countries/regions in international student assessment in science and mathematics, such as PISA and TIMSS—I was astonished at first glance by the decreasing flexibility in teaching the curriculum in the USA and by the policies for teaching science in a more standardized and rigid format. However, my second thought about the NSES was more positive as I realized the value there is in having these standards as guidelines for school systems to help ensure equity in learning. It is a way to control the quality of education by eliminating variability in the quality of the educational systems. This has been explicitly addressed, too, in Brickhouse's chapter, "Standards are the foundation that must be in place in order to reduce the variability in the quality of the enacted curriculum, instruction, and assessments."

One of the explanations for Asian students (including those from Taiwan, Singapore, Hong Kong, Japan, and Korea) outperforming their counterparts in the Western countries is the standardized curriculum guidelines/content and high-stakes entrance examinations in these Asian countries/regions. As stated earlier, there is a need to have standards for science education if US students want to lead the world in their science and mathematics performance. The attributes of the standards of the curriculum could ensure the baseline of students' literacy in science at different grades; however, the high-stakes entrance examinations might shift the value of education from "teaching for learning" to "teaching for testing." This movement toward educational standards has also taken place in several other countries such as Germany (e.g., Nentwig and Schanze 2007). If the content and assessment for learning science are well designed and of high quality, this might avoid the paradoxical situation faced by Asian countries/regions where there is a tradeoff between students' high performance and their low motivation in learning science. Students of the top-performing Asian countries/regions in TIMSS and PISA except Singapore have low motivation and interest in learning science under the high pressure from entrance examinations, parents, and teachers (Chiu 2009). Therefore, one of the challenges that Asian countries must confront is how to avoid these counterproductive teaching situations that twist educational goals. Outcomes of the international student assessment studies could better inform such policymaking (Yore et al. 2010).

What can the USA learn from the experiences of Asian countries/regions about test-based reforms? I doubt whether the national Standards could solve the problems that the US educational system is facing and provide learning opportunities for the majority of US students in schools. Also, I wonder if test-based accountability is the right direction for the US educational system, which is based on a liberal market approach.

How could science educators in the USA evaluate the effectiveness of educational policies in terms of students' scores on national assessments (i.e., NAEP)? Did NCLB bridge the achievement gap between different races, genders, and groups in large cities? Several statistics might provide some background of the impacts of NCLB. First, as examples drawn from the statistics in Southerland's chapter show, the data indicate that eighth-grade students in the USA showed improvement for all racial/ethnic groups between 1996 and 2005. Second, Black students were the only racial/ethnic group to make significant gains, although all the students scored increasingly higher. However, gaps in scores between White and Black students remained.

I further examined eighth-grade students' science achievement in NAEP 2009 (National Center for Education Statistics 2011) that revealed a lower performance by Black students (mean = 128) and Hispanic students (mean = 131) when compared with the average science score for the nation (mean = 159) and an even lower performance when compared with that of White students (mean = 161) and Asian/Pacific Islander students (mean = 159).

Apparently, achievement gaps still remain as described above. The existence of disparities in students' science performance is not a surprise to many science educators in the USA and internationally. However, my questions are: (1) Are we expecting "all students" to achieve the same learning outcomes? (2) Should science educators tolerate such large gaps in achievement across different groups, and if not, what could we do to diminish these gaps? A tradeoff consequence might happen when the students' academic performance is the major accountability for effectiveness of school administration. (3) Are we ready to sacrifice students' interest in learning science and embrace teaching for testing? We might find the answers in these three chapters which approach these questions from different perspectives and provide possible solutions to bridge the gaps among students. The above discussion might also provide some warnings regarding restructuring the school learning climate.

"Science for all" is not a new slogan in science education. Promoting citizens' literacy in science to increase the country's competitive edge in the global economy is now an emerging need for many countries. In the USA, NCLB was intended to increase student performance with a test-based accountability approach for narrowing the achievement gaps between different demographic groups of students. But in reality, instead of achieving its goals, it has brought with it a potential risk of teaching for testing as in Asian countries/regions. In the literature, we find many publications discussing what should be taught in terms of "science" content in a curriculum but few discuss the different levels of proficiency of student learning. What scientific literacy should all citizens have? Also, few studies emphasize the meaning of "all," even though different races, genders, and demographic groups are mentioned in discussing equal opportunities and resources for student learning. What is still missing? What should we have done and in what areas have we not made enough effort?

I asked earlier, are we expecting "all students" to achieve the same learning outcomes? The answer is, of course, no. Theoretically, it is an ideal aim for education. Practically, it is unrealistic. In practice, we should scaffold students, elicit their potential, and direct their learning to where their talents and their interests lie.

Question 3: What Issues or Actions Need to Be Considered to Achieve Equity?

I will discuss three perspectives on educational reforms for promoting equity and excellence to draw conclusions in this commentary as follows:

Importance of Teacher Preparation in Educational Reform

In moving from inquiry learning to learning science as a practice, a number of issues—in teacher preparation, socioeconomic status, resources for promoting this new reform, researchers and school teachers, and policymakers—are interwoven. But if we set student outcomes in an explicit manner, teachers should be well equipped with knowledge for teaching. If the traditional universities or teacher training institutes cannot prepare high-quality science teachers in alignment with the goals of educational reforms, they should collaborate with professional organizations and private corporations to provide science teachers with in-service and pre-service teacher professional development programs. In particular, the states or the federal government of the USA or of other countries/regions should understand the key elements for strengthening the quality of education and for appropriately allocating resources for science education. This is obviously not a new concept, but adding evidence-based decision-making might open a new avenue for shaping an innovative and useful infrastructure for school systems. Curriculum, assessment, instruction, and teacher professional development could be aligned to effectively achieve educational equity. High expectations from parents and teachers have the potential to improve educational practice in schools. Therefore, efforts should be focused on changing the attitudes and expectations of parents and teachers toward their children and toward finding a balance in expectations between performance and interest in science learning. Also, it is important to provide attractive salaries and conduct evaluations of science teachers to maintain a high quality of teaching in schools.

Let me take Finland, the leading country in PISA (Lavonen and Laaksonen 2009), as an example. There are no predefined learning outcomes in the national-level curriculum, but the aims and goals set for teaching and learning are explicitly stated in the outline of the school curriculum. Lavonen et al. (2011) attributed the teachers' autonomy and power over decision-making to this decentralized design, which is related to increasing the quality of teaching and learning in physics in Finland. The most important element in the system is that education authorities and national-level education policymakers trust teachers and their professionalism. Mutual trust also exists between teachers and parents (Lavonen et al. 2011). From my observation and experience, without extrinsic (e.g., salaries, awards, and particularly respect) and intrinsic motivation (e.g., personal values and self-esteem), science teachers are reluctant to make changes in their teaching. Therefore, how to keep the high quality of science teachers and elicit their self-motivated attitudes has become a big challenge in science education.

Necessity of Conducting Policy-Related Research to Provide Evidence of Effectiveness of Policies

As Lee and Buxton (2010) suggested, an emerging task for educational reform is to investigate how policies change educational systems over time and how such curricular reforms can be brought to scale that meet the learning needs of diverse groups of students. Therefore, if science educators want to make a difference in educational reforms, we should focus on evidence-based policymaking (Segone 2010), conduct policy-related research (such as longitudinal studies), and speak to policymakers to convey our ideas of reforming school systems with consideration for equity. In addition, the outcomes of an assessment analysis should be clearly disseminated to the public, parents, superintendents, school principals, teachers, and students for them to understand the educational reforms and to develop a consensus of the educational vision for the country or region, and all stakeholders in science education have to put their efforts and thoughts into actions for implementing the reforms.

Essential Actions Taken for Communication Between Researchers and Policymakers

As mentioned above, science educators should pay substantial attention to establishing alignment among the standards, assessment, and classroom instruction for a successful reform in science education. All stakeholders should be aware of such an alignment and support the implementation of the reforms. I have similar thought as Southerland that an emerging call for a complete realignment among standards, assessment, and instruction should be the center of attention of science education researchers, policymakers, and teachers as well as politicians. Although from my experiences and observations, in many cases, researchers are either lacking interest and intention or eloquent skills needed to persuade politicians to make changes, science educators should still make our voices heard when we speak about equity in science education to the politicians and policymakers who have the authority to make changes that influence students' lives.

Figure 4.2 summarizes the major components in evaluating the effectiveness of reform programs and the impacts of policies on these programs. As discussed in these three chapters, these elements are intertwined. In terms of the impact of a policy, one must decide how long until the intended effects of the policy are measureable so as to avoid making changes or evaluations too soon.

Concluding Remarks

To conclude, I would like to refer to two Chinese proverbs from Confucian conceptions of learning to echo the ideas of NCLB. They are: "to provide education for all students without discrimination" (youxiaowulei or 有教無類 in Chinese) and "to teach students in accordance with their individual differences" (yincaishijiao or 因材施教 in Chinese). The first one is mainly about equity and the second one is mainly about teaching students according to their abilities. As Kahle (2009) stated, the minimum standards do not promote equity. Of course, they do not guarantee excellence either. Not only do schools have the responsibility to provide students with equal opportunities to learn, but they also need to provide them with possibilities to excel.

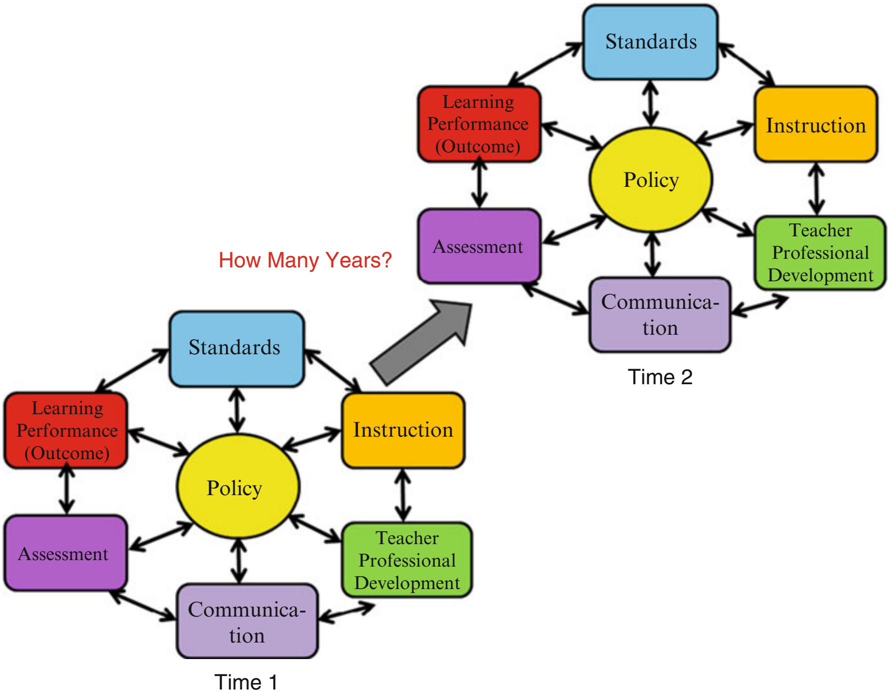

Fig. 4.2 Components related to implementation of policies in science education reforms

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Part II
Introduction: Globalization

Julie A. Bianchini (Lead Editor) and Valarie L. Akerson (Co-editor)

The world's people are growing more connected.

> Increasingly globalisation, conceived of as the geopolitics of cultural formations interpenetrated with economic globalism, and based in the dialectical relationship of the universal and the particular, is becoming the macro-level set of forces shaping the conditions for and being expressed within education. (Carter and Dediwalage 2010, pp. 275–276)

There is little research in science education, however, that investigates the ways globalization shapes the processes of teaching and learning in either local or global contexts (Martin 2010). The authors of this part contribute to this nascent field of study by using the lens of globalization both to reframe persistent inequities in science education and to recommend changes in policy, teacher education, and instructional practices needed to engage and educate all students in science.

To introduce this part on globalization in science education, I suggest several common themes for readers to consider as they examine each chapter in detail; I do not provide summaries of chapters' arguments. One such crosscutting theme is the persistence of inequities in science education across different levels of scale, or to use Sonya Martin, Beth Wassell, and Kathryn Scantlebury's framing, across macro, meso, and micro levels. Alejandro Gallard Martínez, for example, argues that our shrinking world brings into bold relief the ways science education on a global, or macro, scale continues to serve the privileged few and ignore the needs of the disenfranchised majority. Martin, Wassell, and Scantlebury move across all three

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levels of scale – global trends in e|im|migration, the experiences of language minority and English language learners in US schools, and the challenges faced by local teachers and learners in the science classrooms of Philadelphia – to call for changes in policy, science teacher education, and teacher practices needed to ensure the academic success of LM/ELL students. At the micro level of the classroom, Bhaskar Upadhyay examines connections elementary students make between science concepts, such as earthquakes and nutrition, and global injustices, such as the inequitable distribution of resources and disparities in the status of different kinds of knowledge systems.

A second theme that emerged from my reading of these three chapters is the continued importance of the local: Attention to globalization and to the ways it should inform science education do not mean that national, regional, and local concerns fade away. Gallard Martínez argues against equating globalization with sameness, promoting one global village at the expense of local cultures and contexts, and thus providing all students the same (Western) science education. Upadhyay draws from the works of Sandra Harding (1998) and David Turnbull (1997) to emphasize that all knowledge is situated in specific local conditions and cultural practices. He discusses at length the arguments made by Mia, a Hmong student originally from Thailand, during a small group activity on planting strawberries: Mia asserted that her method for planting strawberries, drawn from her knowledge and experiences planting strawberries with her parents at home, was just as valid and useful as the "official" method printed on the package of strawberry seeds.

These chapters also highlight a third theme: the need to attend to complexity. Martin and colleagues highlight the negative consequences for students when a teacher ignores the complexity of their lives. They open their chapter with a vignette from one of the science classrooms in their study. A science teacher had grouped three "Asian" students together with the expectation that they could help one another; the teacher was unaware that these students were of different ethnicities, spoke different first languages, and were born in different parts of the world. Gallard Martínez underscores the limitations of science education research that examines the processes of teaching and learning in isolation from larger contexts. He uses the notion of a holon, an entity that exists in its own right but is at the same time inseparable from a larger system, to emphasize that researchers must examine the complex interplay of science education with social, economic, and political forces. It is important to note that this call to attend to complexity is not new. Feminist scholars of science make the same argument: They warn against the tendency in science and society to privilege uniformity over difference – to search for commonalities rather than to investigate variation. This valuing of complexity by feminist scholars – of identifying and attempting to make sense of difference – was eloquently described by Evelyn Fox Keller (1985) in her biography of plant geneticist Barbara McClintock.

Lyn Carter concludes Part II by looking across the three chapters both to compare the ways globalization has informed US versus Australian science education and to discuss key challenges in using the lens of globalization to research science teaching and learning. In particular, Carter identifies two challenges to using globalization to inform research that center around the construct itself – a construct I admit I knew little about before I began editing this volume. Carter warns against assuming the term globalization has only one definition. Indeed, she explains, in detail, her definition of globalization differs in multiple ways from chapter author Upadhyay. Science education researchers must make explicit the ways different definitions of globalization inform and constrain the problems they pose, the kinds of arguments they craft, and the insights they generate into the processes of teaching and learning science for all students. Carter also underscores the need to avoid globalization becoming a popular term tacked onto existing research projects. If science educators are to take globalization seriously, they must be willing to move beyond traditional theoretical frames and kinds of research analyses. They must use the lens of globalization to reenvision the landscape of science education and to identify new theories and methods to improve science education.

Taken together, these chapters and response suggest ways globalization – if thoroughly understood and thoughtfully addressed – can help us move closer to a science education for all students. They also identify questions in need of further discussion and study. For example, what should be the purposes and goals of science teaching and learning in the age of globalization? How can we as science education researchers help ensure science literacy for all children in our own country as well as in countries around the globe? How might issues of globalization inform notions of equity, diversity, and social justice in science curriculum and instruction? How should global and local perspectives be presented in a particular science classroom so as to resonate with and support students' diverse communities, cultures, and interests? As stated above, globalization in science education is an emerging area of research; the authors included here have contributed important insights to this conversation.

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Chapter 5
The Imperative of Context in the Age of Globalization in Creating Equity in Science Education

Alejandro J. Gallard Martínez

Overview

Globalization, what a forceful word! On the one hand, it is a word that can conjure up images of one big happy family working together to eliminate poverty and misery through boundless economic opportunity for all under the rubric of a massive global culture. On the other hand, this word can conjure up images of illiteracy, gender inequality, poverty, and human despair. "Why has globalization—a force that has brought so much good—become so controversial?" (Stiglitz 2003, p. 4). According to Joseph Stiglitz (2003), the promise of poverty reduction has not materialized as "a growing divide between the haves and the have-nots has left increasing numbers in the third world in dire poverty, living on less than a dollar a day" (p. 5). For education, in general, and for science education, in particular, this dichotomy results in the advancement of human capital in one part of the world and a serious lack of education among the less fortunate in the world. The most critical factor in this chapter is the understanding that all actions are context-driven and are mitigated by complex systems of influences from within and beyond the social landscapes leading to visible and invisible tensions.

In this chapter, I argue that education alone cannot be successful in improving the human condition in a globalized world because education is an integral part of globalization that is inextricably intertwined within the contexts in which it is enacted. By this, I mean that factors such as poverty, racism, classism, sexism, and inequitable attention to social justice issues and differential access to social and economic resources influence all facets of education, regardless of geographic locations. The aforementioned factors should not be considered an exhaustive list; rather, I use them

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to underscore the notion that any effort to understand the impact of past, present, and future education and development efforts are hollow if context and its associated sociohistorical legacy are not an integral part of the research.

Second, my chapter addresses interrelated and intertwined factors that influence "in situ" phenomena. All actions when enacted are influential impacts, which can be implicit as well as explicit, that include holons, habitus, and cultural capital. Third, I will provide my definition of globalization and its positive and negative effects on improving equity regarding social justice issues, which influence the teaching and learning of science. Finally, I will discuss the role and function of education and schooling and conclude with the revisiting of the imperative of context in improving the human condition. Unless a tension is created between what one wants to accomplish and the reality within which it needs to be accomplished, there cannot be an effective and equitable solution to advancing the purging of poverty and social injustice.

My perspective, addressed above, provides a framework for this theoretical chapter and efforts to improve the teaching and learning of science in the age of globalization. My theoretical position has been shaped by many years of experience working with national education policymakers and local teachers in multiple countries, including the USA.

Contextual Factors of Globalization

One of my favorite Latin phrases is "in situ" because it serves as a reminder that all phenomena when enacted are influenced and that influences can be implicit as well as explicit as they unfold. "In situ" is a phrase that is contextually defined because one can never separate a moment from the context within which it takes place. This is why I begin this section by defining and discussing the terms holons, habitus, and cultural capital as developed by Pierre Bourdieu (1977).

Holons

Categories such as class, culture, economics, gender, native language, country of origin, and race are called holons (Koestler 1967). Arthur Koestler argues that an individual can be a holon as well as a nation. "More generally, the term 'holon' may be applied to any stable biological or social sub-whole which displays rule-governed behavior and/or Gestalt-constancy" (p. 341). In the past, I have used this framework to argue that systems of education are holons, in particular, social holons, that exist in their own right but are at the same time inseparable from a system (Gallard Martínez 2009). "In social behaviour [theory], the canon of a social holon represents not only constraints imposed on its actions, but also embodies maxims of conduct, moral imperatives and systems of value" (Koestler 1967, p. 344).

This means that holons may be part of one system and yet can belong in part to other systems but are always contextualized. A country's education system is not isolated from but is both a part of and apart from the cultural, economic, political, and sociological frameworks of that country. These same education systems are in turn not isolated from the cultural, economic, political, and sociological frameworks that drive the world. In terms of globalization, another way of thinking about this is that "humans are not self-contained, insulated, or isolated beings, but are situated in grander social, cultural, and ecological systems" (Davis et al. 2008, p. 7). Such "parts and wholes in an absolute sense do not exist in the domain of life" (Koestler 1967, p. 341). This is to argue that poverty, as an example, is not isolated from the issue of social injustice that, in turn, is not isolated from classism.

I argue that students can be part of the social holon of education from a global perspective, an individual country's standpoint, or their individual selves. This worldwide, country, and individual connectedness can be referred to as nested structures (Davis and Sumara 2006) or what I refer to as a spider's web (Gallard Martínez 2009). Holons, nested structures, and spider webs are the conglomerations of mitigating forces that I will talk about later in this chapter. My interest in presenting this argument is not to offer solutions but to bring attention to the notion that teaching and learning, whether in general or specific to science education, is a holon and, as such, cannot be presented as being isolated from the influences of society. An implication of this idea is that education researchers, in general, and science education researchers, in particular, when offering solutions or ideas, need to make explicit the complexity of the context, which gives rise to the tensions in which a solution or method has to occur.

For the purpose of this chapter, the point is that mitigating forces serve to underscore the complexity of globalization, education in a globalized world, and specifically, the teaching and learning of science that has as an end goal scientific literacy for all. Inherent to this undertaking are tensions across intent, function, and outcomes for a few or for all. In other words, poverty cannot be resolved until a system of equitable distribution of resources is in place. For example, a country's intent may be to eliminate poverty, with an underlying function of reducing state spending on human welfare in order to invest in other areas. The immediate tension is one between intent and function of eliminating poverty and the unequal distribution of resources, which influences outcomes. The outcome will always be the same unless opportunities for equitable access to resources are created for all.

Globalization

I agree with the definition of globalization by Stiglitz (2003), which I use to frame my thinking about the concept of globalization.

> Fundamentally, it is the closer integration of the countries and peoples of the world which has been brought about by the enormous reduction of costs of transportation and communication, and the breaking down of artificial barriers to the flows of goods, services, capital, knowledge, and, (to a lesser extent), people across borders. (p. 9)

In my search for understanding the concept and function of globalization, I have found this definition to be consistent with those of Lyn Carter and Ranjith Dediwalage (2010) and Kenneth Tobin (2011). I see the function of globalization as being rooted in economics and selected stakeholders that enact its politicization: the International Monetary Fund (IMF), World Bank, and World Trade Organization (WTO) (Stiglitz 2003) as they play a major role in funding education throughout the world. I am not discarding multinational corporations but I am underscoring that, from a financial perspective, they play a major role in the distribution of resources in the world. Globalization in political and economic terms implies a function of education and schooling as political and/or economic endeavors. This infers that there are class, cultural, economic, political, and sociological differences among individuals that are defined and perhaps perpetuated by how globalization influences the positive or negative outcomes associated with the function of schooling. Like education, the whole notion of globalization is a social holon because it is driven by the influences of the IMF, World Bank, WTO, and multinational corporations, which politically and economically define the grand schemes of nations.

Positive Effects of Globalization

Continuing with a holistic view of the process of globalization, the United Nations has played a significant role in the elimination of diseases, poverty, and social injustices. For example, the Millennium Development Goals of the United Nations have contributed positively toward the alleviation of poverty and hunger, the universalization of education, the reduction of gender inequality, the improvement of child and maternal health, the combating of HIV/AIDS, the fomenting of environmental sustainability, and the encouraging of the development of global partnerships (United Nations 2010). Another positive example is that in Africa, from 2000 to 2007, primary school enrollments increased from 58% to 74% (Sachs 2010). Other examples of positive outcomes are that international trade markets have opened up; standards of living have increased as well as longevity and access to global knowledge.

These positive outcomes are reinforced by Stiglitz:

> Foreign aid, another aspect of the globalized world, for all its faults still has brought benefits to millions, often in ways that have almost gone unnoticed: guerillas in the Philippines were provided jobs by a World Bank-financed project as they laid down their arms; irrigation projects have more than doubled the incomes of farmers lucky enough to get water; education projects have brought literacy to the rural areas; in a few countries AIDs projects have helped contain the spread of this deadly disease. (2003, p. 5)

Yes, the actions of the United Nations and other such agencies to improve human conditions, when viewed in the absence of the context in which they are enacted, are very positive. But looking at the process of globalization in a holistic view, one immediately understands that, in spite of these commendable efforts, poverty, social injustice, and unequal distribution of resources still exist because these and other mitigating circumstances define the context within which these actions take place. Unless the context is reshaped, the improvement of the human condition will be limited.

Mitigating Forces

Returning to the idea of contextual mitigating forces such as the serious lack of education, gender inequality, and poverty among the less fortunate in our world in economically stressed nations, bear with me as I describe in greater detail some of these factors. They are important to consider because they provide a graphic picture of conditions (mitigating forces) that create a tension between the positive intents of globalization and the realities that exist in which globalization is enacted. For example,

- The top 1% of the world's richest people earn as much as the poorest 57%.
- In the 1990s, average per-capita income growth was less than 3% in 125 developing and transition countries, and was negative in 54 countries.
- During the 1990s, the share of people living in extreme poverty fell from 30% to 23%. But as world population increased, the number fell only by 123 million, and if booming China is left out, the number actually increased by 28 million.
- Of the over six billion people in the world, at least 1.2 billion do not have access to safe drinking water.
- More than 2.4 billion people do not have proper sanitation facilities, and more than 2.2 million people die each year from diseases caused by polluted water and filthy sanitation conditions.
- Two thirds of the world's 876 million illiterates are women.
- About 80% of economically active women in sub-Saharan Africa and South Asia work in agriculture.
- The annual dairy subsidy in the EU amounts to $913 per cow per year; EU's aid to Africa is $8 per African per year (Food 4 Africa n.d., p. 1).

If I take any of the facts stated above and focus on science education, I can ask, "What do I care about scientific literacy when I am hungry?" If my cynicism has not been noted yet, please let me make it clear that I view globalization, in its current form of actualization, as an effort to globalize hegemonic practices and that globalization as a concept ignores the world's sociocultural context in which globalization is enacted. This includes the erasure of scientific illiteracy as an experience to understand everyday life for the sake of making a nation's students number one in the world of standardized tests, and thus, achieving economic and political objectives but not improving the human condition. More explicitly, this implies educating for jobs that do not yet exist but will emerge tomorrow by framing the function of education, in general, and by implication, science education, in particular, along economic lines. In other words, individualization, which is local, versus standardization, which is global, creates a polarity that defines these tensions in current educational systems. As long as education and its function is defined by standardized tests and the lack of identification of human needs within the existing context to achieve economic and political gratification, the results will always be at the expense of the majority and for the benefit of the few.

The Economics of Education and Society

Is education and, by extension, science literacy a commodity or are they both publicly provided social goods? The answer lies in how one chooses to frame this question. For example, under the auspices of the neoliberals, a teacher's autonomy has been taken away and placed into the hands of bureaucrats and "hence, the neoliberal emphasis on universal standards, national curriculum and testing" (Giroux 1994, p. 158). Neoliberals are those who believe in standardized testing to demonstrate learning without considering the contexts within which education systems operate to include the learner as "there is little sense of the powerful role that schools play in maintaining and sustaining certain relations of dominance" (Giroux 1994, p. 159). This notion is reinforced by Rick Ayers (2009) who states that:

> In the hands of the neoliberals, the schools are less about learning and more about certification, the blessing of those who can afford it with a piece of paper that says they are qualified to hold the more privileged positions in society. Education is not seen as a public good—it is a private benefit that can be purchased in the marketplace. It's a system for handing down privileges to the next generation while masking as a meritocracy. Them what has, gets.

Neoconservatives are more about controlling education and "…argue from the ideological perspective of functionalism; that is, they believe that the role of education is to promote those human capacities in students that enable them to adapt to existing social forms such as schools, the state, and the workplace" (Giroux 1994, p. 158). They are strong on controlling teachers and strong on marginalizing oppositional democratic forces such as local elected democracies, trade unions, critical educators, and critical students. Moreover, neoconservatism aids in the formation of a state strong on enforcing the neoliberalization of schools and society (Hill 2006, p. 13).

Regardless of whether one looks at schooling and education through a neoliberal or neoconservative lens, the bottom line is that the way education and schooling have been enacted in society has not only created differing classes but perpetuated the gap between the haves and have-nots. The framing function of education and schooling fits very neatly with some, the privileged, and not with the rest, the disenfranchised.

I choose neither lens of neoliberal or neoconservative in looking at education and schooling. Having said this, I do however think that in either focus there is a "sanitization" of society from both a sociohistorical and sociocultural sense that promotes a deidentification of society, which, in turn, promotes a very simplistic view of the same. Another way of looking at this is that there is a decontextualization of people's needs and aspirations, which creates a skewed and incomplete view of reality. What is missing is the story of the struggle necessary for many people to meet their needs and fulfill their aspirations. As a consequence, there is a cost to those who are disenfranchised from equitable participation in education and, by extension, society. They are disenfranchised because of their class, culture, economic situation, gender, language, race, and/or religion and the parallel hegemonic practices, which cannot and should not be ignored. You may take my repetitiveness as being redundant, but we have abundant examples of scholars who have made a career of pointing out that in education and schooling and science education, disenfranchisement does take place but it seems to fall on deaf ears. The works of some researchers from multicultural education, science education, sociology, and urban education all have one thing in common: They bring to the attention of the education community the existence of cultural, economic, political, and sociological factors that teachers, in general, and science teachers, in particular, are dealing with in the ways they know best—to embrace, ignore, or put on hold. Precisely, these are factors that both the neoliberals and neoconservatives deny as being influential. What concerns me is that there is a glossing over and, at times, a complete disregard of the implications of their ideas by other scholars and policymakers, which is that all contextual factors, whether positive or not, found in culture and society are inseparable from one another and impact education, which is part of both.

I take this idea one step further and argue that culture and society are inseparable from globalization, education and schooling, classrooms, and, in particular, science classrooms. If contextual factors are ignored, this results in a decomplexification of a very complex set of relationships. As a consequence, a surface picture is painted and the breadth and depth of the connections between and among mitigating forces to achieve equitable education for all are ignored. For example, academic gains that have been made among Latinos/as in the USA (e.g., Richard Fry 2010) have been reported. What is missing from this discussion is explicit recognition of the very societal prejudices and other contextual factors that had to be overcome by successful Latinos/as and could not be overcome by the unsuccessful Latinos/as and whether these contextual factors still exist in society and in what form. Regarding globalization, Stiglitz (2003) provides a striking example of making explicit the mitigating social forces of the river blindness disease: "Even where river blindness has been eliminated, poverty endures – this despite all the good intentions…" (p. 24).

In science education in the USA, there is an emphasis on getting more underrepresented people into the sciences. The intent is noble but the emphasis should be on understanding why some people are overwhelmingly represented and others are not by raising the questions necessary to make explicit how and why students are culturally, economically, and politically sifted in science classrooms. Returning to the river blindness disease example and the example of Latinos/as, eliminating disease is great, having people succeed is also great, but it does not help anyone if they then starve to death or are disenfranchised from active participation in society.

The Notions of Capital and Habitus

Pierre Bourdieu (1977) and his notion of capital articulate the idea that there are differences in a society in the educational achievement a given social class can attain. According to Bourdieu, there are three types of capital: cultural, economic, and social. In this discourse, I am interested in cultural capital because

> …it is the product of education, which Bourdieu also often refers to as an 'academic market', and exists in distinct forms: connected to individuals in their general educated character – accent, dispositions, learning etc.; connected to objects – books, qualifications, machines, dictionaries, etc.; and connected to institutions – places of learning, universities, libraries, etc. (Grenfell and James 1998, p. 21)

In addition to the notion of cultural capital, I find it important to understand a second construct of Bourdieu: habitus, in general, and habitus in an educational setting, in particular. While cultural capital is perhaps the most familiar of Bourdieu's concepts to sociologists of education, it is actually part of a larger model of social action, which includes habitus. Habitus is one's orientation toward the world, and is largely based on one's class position (Dumais 2006, p. 84). In other words, it is "… an acquired system of generative schemes objectively adjusted to the particular conditions in which it is constituted" (Bourdieu 1977, p. 95). It is what students learn from home (conditions of class) and bring into the classroom (a site of power struggle between students and teachers).

According to Bourdieu (1997), the acquisition of habitus and cultural capital is acquired at birth:

> The initial accumulation of cultural capital, the precondition for the fast, easy accumulation of every kind of useful cultural capital, starts at the outset without delay, without wasted time, only for the offspring of families endowed with strong cultural capital; in this case, the accumulation period covers the whole period of socialization. (p. 49)

The relationship of this idea to globalization and the function of education and schooling in a globalized world are that students who have the correct habitus and, as such, the correct cultural capital will be able to get a much higher rate of return on their education investment than those who do not. This is because they continuously accumulate and cash-in "correctness" as they go through their academic and professional lives, perhaps becoming one of the gatekeepers of "correctness." On the other hand, people who are not born with the correct habitus and cultural capital have to first rid themselves of who they are and then recreate themselves into what the hegemonic forces say they should be. They are hampered by not being born into the "correct" cultural and socioeconomic environments and, as such, must accumulate "correctness" before they can start taking maximum advantage of any capital acquired. This is precisely what I mean when I argue that students who do not possess "correctness" cannot equitably participate in society.

Applying this idea of "correctness" to the teaching and learning of science, in general, and the development of scientific literacy, in particular, is that some students enter a science classroom with the "correct" habitus and cultural capital and, thus, immediately start to accumulate more cultural capital in the form of scientific literacy and reaffirm their habitus, which is part of their identity. Scientific literacy for these students becomes a tool for more successful participation in society. Can the same be said for disenfranchised students throughout the world? I believe no for two reasons. The first is that an achievement gap is not only a measure of "learning" but is also a representation of the distance between disenfranchised students' cultural capital and habitus and the "correct" cultural capital and habitus. The second reason for my belief is that even if these students achieve the same level of scientific literacy as the "haves," it will not happen until they become one of "them" that scientific literacy will become a useful tool. "Correctness" then has everything to do with issues such as class, culture, gender, language, race, and/or religion and, I would dare add, the power tension between Eastern and Western science.

Role and Function of Education and Schooling

What should be the role of schooling, and by implication, the function of education in a capitalist society is a question posed by Samuel Bowles and Herbert Gintis (2002). If globalization means to socialize students to become future workers in a global economy at the expense of the development of existing local cultural capital, then two additional questions need to be asked: First, is there a predetermined universal set of cultural and cognitive indicators that are used by the hegemonic forces as filters to determine one's participation in a globalized world? Second, does the function of education as determined by policymakers and educators in a globalized world include these same filters and, if so, are they enacted implicitly or explicitly in a school setting? Regardless of how one chooses to answer these two questions, my argument throughout this chapter is that what must be made explicit are contextual factors, which shape human conditions and vary from place to place. But should it not behoove the power brokers to make contextual mitigating circumstances on a local, national, and/or worldwide basis explicit? The answer is no because the hegemonic stakeholders are interested in maintaining economic and political control.

A genesis for the above two questions lies in Martin Carnoy and Henry Levin's (1985) observation: "On the whole, members of racial minorities and low-income groups are less likely to do well in school, and they are also less likely to do well in the job market" (p. 1). Carnoy and Levin add, "The educational system is not an instrument of the capitalist class. It is the product of conflict between the dominant and the dominated" (p. 50). Even though the authors are referring to the USA, I believe that the reality of who succeeds and who fails is a worldwide phenomenon. I argue this because the reality is that the gatekeepers control the equitable distribution of resources including formal knowledge. In other words, does academic success and failure speak to the reproduction of labor relations or to something else such as inequitable distribution of resources that reinforces class differences on a local, national, and/or worldwide basis (Bowles and Gintis 1976)? Depending on one's socioeconomic status, there are advantages and disadvantages to what Basil

Bernstein (1975) refers to as the hidden pedagogy, which is framed by a function of education, and which serves as the reservoir of values that strengthen the divide between the lower social class and the privileged class.

Examples of hidden pedagogy in the USA, which have an economic and political framing function of education, are policy documents such as the No Child Left Behind Act of 2001 (NCLB 2001) and Science for All Americans (AAAS 1989). If one invokes the terms cultural capital and habitus and uses them as a framework to understand the implications of these two sets of policies, then it seems that at least two aspects need to be made explicit. The first is to ask, What is the function of any education policy document when we talk about globalization? Another way of asking this is, What is the connection between education policy documents and society – culturally, economically, politically, and socioeconomically? The second question is to ask, What are the cultural boundaries that frame the development and eventual enactment of any education policy efforts, in general, and science education, in particular?

Both these questions become critical because as the American Psychological Association (APA) recognized in 2002, there is an importance in understanding that society is not enacted in a societal vacuum. APA criticized "…the profession of psychology as being culture-bound and potentially biased toward racial/ethnic minorities, women, and gay men and lesbians" (Sue 2004, p. 762). Can the same criticism be made of teaching and learning, in general, and science education, in particular, when one uses a definition of globalization that is framed by economics and politics and that promotes sameness in purpose and structure internationally? The answer is yes, if those who "have" are the ones who define the norms of the "have-nots" culturally, economically, and politically. In the teaching and learning of science, Western science preempts Eastern science and this preemption was created along paradigmatic lines.

Globalization does not mean sameness. At a session during the European Science Education Research Association (ESERA) annual conference, it was stated that "…many participants called for uniformity in the defining of culture and there appeared to be consensus that culture should carefully be defined" (Tobin 2009, p. 756). Let us assume that the comments of the conference participants about making the definition of culture uniform are sincere, although perhaps naïve, in wanting to help the field of science education. How would a common definition of culture advance the field of science education, particularly if one uses globalization as a framework for analysis? Other than trying to simplify or mechanize and, consequently, deny the complexities that permeate all acts of education, I can see no advantage to using a common definition of culture to understand the processes of teaching and learning science unless all students' cultural capital and habitus reflect the same academic level culturally, economically, and politically. What I do see in enacting this recommendation is a possible usurping of "me," my identity, which means ignoring the multiple ways that students act, interpret, and enact in the larger world, in general, and in science classrooms, in particular.

How would one definition of culture be reached? Immediately, a power struggle will take place between those who wield cultural, economic, and political clout and those who do not possess the same type of clout. Will the disenfranchised—whether researchers, teachers, or students—get an opportunity to participate in constructing a common definition of culture on equitable footing? The answer for disenfranchised populations is no because there is an undeniable hegemonic line drawn in the sand. On one side of the line, there are those who perpetuate acts of imperialism and colonialism, resulting in further disenfranchisement of those on the other side. Some examples include learning English at the expense of a mother tongue, or in many nations, the difference in quality between a public and private school education.

On the other side of the line, those who are part of the power circle of privilege and domination, consistent with the notion that globalization invokes sameness, view identity, culture, and the freedom to include one's mother tongue as issues that are more than likely inconsequential, confusing, or personal quirks. What about those whose cultures and identities are not part of the inner circle or part of the elite? How do they perceive these issues? How important are their identities and cultural experiences to them and to society-at-large in an education system nested within globalization efforts? The answers to these questions are, indeed, complex and, thus, illusive. Yet, they should serve as a reminder that in order to enact education as a worldwide phenomenon or under the umbrella of globalization, there are critical and meaningful differences among us that should not be subsumed by a one size fits all mentality. I find this to be particularly true of science classrooms and the teaching and learning that occur within the same. What I suspect is part of the driving force behind a one size fits all mentality is the lack of fit between recognizing and understanding how each and every pedagogical act is influenced by a complete host of contextual factors, which is what I have referred to as mitigating forces.

Revisiting the Imperative of Context

In a dialogue between Letch Witkowski and Henry Giroux, Witkowski made the following observation:

> There are a lot of forms of oppression and symbolic violence, which are hidden within sometimes very soft, very gentle methods of manipulation in human interactions. Therefore it seems to me that the idea of struggle must take into consideration this particular aspect of hidden confrontation, which actually takes place. (Giroux 1994, p. 156)

It is Giroux's response that led me to reconsider how I use the word "context."

> But what has often happened in the late twentieth century, as Antonio Gramsci brilliantly pointed out, is that people often find themselves positioned within forms of knowledge, institutional structures, and social relationships that have a "creeping or quiet" kind of hegemony about them. The forms of domination they produce and sustain are not so obvious, they're not so clear. (p. 157)

I asked myself how much am I hiding by using the word context, and how much are other researchers and theoreticians hiding by using the same word? From a theoretical perspective, we need to keep in mind and understand that making explicit the interconnectedness of influences is critical. Inquiry learning in many US science classrooms that have high numbers of students who cannot communicate in English can never be successful if science teachers cannot communicate with all of their students. From a mitigating contextual lens, it is not only students who have to learn the dominant language but also teachers who have to communicate with the students in their language(s). Similarly, science education as a global phenomenon can never be successful as long as only Western science is the reigning king or queen of scientific inquiry. Scientific literacy for all can never be achieved as long as some citizens can culturally, economically, and politically take full advantage while others cannot. No, I am not trying to paint a Fabian society. Things are not equitable. I understand that they are not, which is precisely my point. Yet, the picture that many science education researchers paint and that policymakers use for decision-making is lacking how inequities manifest themselves and influence all pedagogical acts in the teaching and learning of science. The inability or the lack of willingness to make explicit the multiple cultural, economic, and political mitigating forces behind any data reported, teaching method suggested, or policy formulated is the largest constraint that exists in getting a deep understanding of how inequity manifests itself in society and in a science classroom regardless of geographic location.

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Chapter 6
Frameworks for Examining the Intersections of Race, Ethnicity, Class, and Gender on English Language Learners in K-12 Science Education in the USA

Sonya N. Martin, Beth Wassell, and Kathryn Scantlebury

> After observing one section of the biology class for a week, I [Sonya] approached the biology teacher and student teacher about the table of three Asian students seated at the back of the classroom. I had sat with the students for one week, observing their interactions with one another while engaging in small group activities focused on understanding the function of different cell organelles. It had come to my attention that the two male students in the group did not speak the same first language, making English their only common language. The third student was a native English speaker and did not speak a second language at home. When I asked the biology teacher why she had grouped the three students in this way, she indicated she believed they could all "talk to and help one another in their own language." Upon sharing with the teacher that two of the boys were Vietnamese and Cambodian and did not speak the same language and that the third boy was Chinese American and only spoke English, she expressed surprise, noting she did not really know what [ethnicity] "any of [her] students are." (January 2010, *Field Notes and Interviews, High School Biology Teacher, Philadelphia*)

According to the Census Bureau's 2008 *American Community Survey*, there are nearly 38 million foreign-born immigrants residing in the United States of America (USA), representing about 12.5% of the total population. The children of immigrants in the USA represent the fastest growing student population in K-12 classrooms,

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and the majority of these are language minority and/or English language learner (LM/ELL) students.[1] The vignette above provides an example of some of the inherent social, linguistic, and pedagogical structures in science classrooms that can inhibit ELL students' agency as learners (Wassell et al. 2010). Currently, researchers know little about the learning needs, achievements, or problems of LM/ELL students and their families, especially with regard to science education. As science education researchers, we conduct research on K-12 school science experiences to improve teaching and learning for LM/ELL students. Because we recognize that multiple factors, such as gender, race, ethnicity, class, religion, country of origin, native language, and school experiences in the country of origin, collectively shape student and teacher experiences, we contend that researchers should use comprehensive measures for making sense of the ways in which these categories intersect in the classroom.

In our work, we argue that through the use of two complementary theoretical frameworks, intersectionality and cultural sociology, researchers can gain multifaceted understandings about the challenges teachers face in trying to meet science content standards while supporting the learning needs of LM/ELL students. In the sections that follow, we briefly describe how we are utilizing these frameworks to expand our understanding of the complexities of the teachers' and students' individual experiences in school science. In an effort to illustrate some of the challenges facing researchers examining these issues, we draw from some preliminary findings from research conducted as part of our work with in-service middle school science and English as second language (ESL) teachers[2] and their students in two urban K-8 schools.

Integrating Frameworks to Expand Levels of Analyses

Because our research is grounded within a sociocultural theoretical framework (Sewell 1992), we emphasize the dialectical relationship between the individual and the collective in our utilization of intersectionality as an analytical tool.

[1] In the United States, the term language minority (LM) is used to describe students who live in homes where a language other than English is the primary language spoken. English language learners (ELLs) are language minorities who have been identified as having limited proficiency with spoken and written English. Both LM and ELL students are often constructed as cultural "others" in K-12 schools in the USA. In this chapter, we use the term LM/ELL to refer to all students who may benefit from English language supports in schools and who may be challenged as learners as a result of their limited English language proficiency. We recognize that there are major differences in the needs and experiences of ELL and LM students, yet for the purposes of this chapter, we contend that both groups need additional supports in classrooms to make science academic language comprehensible and to meet science standards. In addition, we acknowledge that there is also a need for research to be conducted on the experiences of students who speak a nonstandard dialect of English (e.g., African American Vernacular English or Southern American English) who can also be disadvantaged in school science in the USA by their limited proficiency in standard American English, especially in speaking and writing.

[2] National Science Foundation (NSF) HRD 1036637. *G-SPELL Gender and Science Proficiency for English Language Learners.*

As such, we view the individual|collective[3] as inseparable, meaning we cannot look at the individual without considering the collective and the relationship of the individual to, and with, others. To that end, it is critical to examine the impact of globalization and migration on individuals and groups of people (a collective), especially in the context of education, including science education. We see intersectionality (McCall 2005) as being a complementary methodological and analytical framework to cultural sociology, especially when considering how global trends in migration inform teacher and student experiences in K-12 school science in the United States. Intersectionality provides a powerful lens with which to contextualize the complexity of issues science education researchers must contend with when attempting to draw generalizable conclusions about immigrant students' needs and science learning experiences. And as such, it enables researchers to problematize the consequences of the simultaneous interaction of systems of oppression, such as gender/gender identity, race, ethnicity, religion, class, sexual orientation, nationality, and language.

For example, currently, LM/ELL students are typically characterized in the research literature using broad labels, such as "English language learner" or "Asian" or "Hispanic," with little attention paid to the complexity of the multiple yet intersecting aspects within their identities. Without the ability to disaggregate data based on differences in languages spoken, gender, race, ethnicity, religion, etc., it is difficult for researchers to gain a comprehensive understanding of the challenges faced by LM/ELL students and their teachers in the context of K-12 school science. Research in science education that utilizes sociocultural theoretical frameworks for data collection, analysis, and interpretation highlights and shows the importance of taking into consideration the multiple categories of students' identities.

However, to better illustrate the complexities of teachers' and students' individual experiences in school science from the perspective of intersectionality, we also need to understand the effects of globalization at different levels of analysis, namely the macro, meso, and micro levels. In doing so, we can contextualize our research and highlight some of the significant challenges faced by science teachers with regard to knowing and understanding their students as learners. We begin this chapter by offering the reader macro, meso, and micro level perspectives from which we can examine the impact of global migration patterns on K-12 science education in the USA.

[3] We placed the Sheffer stroke (|) between two words or a prefix and a word to indicate the existence of the various states of being (on either side of the Sheffer stroke) as constituting a whole. The Sheffer stroke is used to denote a both|and relationship between two concepts as a way to help conceptualize the complexity of the relationship.

Global Trends in E|im|migration[4] at the Macro Level

There is a growing body of literature examining the impact of globalization on economics and politics (Clothey et al. 2010), and research is beginning to emerge discussing the implications of globalization on education, specifically its impact on K-12 science classrooms (Carter 2008), science teacher education (Richardson Bruna 2010), and/or science education research (Martin 2010). Being able to make sense of the ways in which immigration trends to the USA are being shaped by macro level forces allows researchers and educators to better understand the impact on the regions to which people are migrating, including the neighborhoods where the children in these families are learning school science. In our consideration of the dialectic relationship between the individual and the collective, in the following section, we provide a brief introduction to global migration patterns (that is, a macro level analysis of groups of people moving within countries and around the world) to better understand the impact of migration in the context of globalization in K-12 education in the USA. Herein, we provide a brief description of internal and international migration patterns in East and Southeast Asia[5] and Latin America[6] to provide some historical context for the immigration patterns of people to the USA over the last century since these regions currently serve as the largest providers of e|im|migrant students to K-12 schools in the USA.

In recent decades, there have been unprecedented numbers of people migrating, both within a given country and from country to country, in search of labor opportunities. Worldwide, there are currently an estimated 214 million international

[4] Just as we introduced the concept of the dialectic relationship between the individual and the collective, we also use the Sheffer stroke to indicate that the process of leaving one's homeland for another country as a migrant is complex. The term e|im|migrant recognizes that immigrants to a new country are simultaneously emigrants from their native country. We prefer this term as one that is more inclusive of the complex nature of migration and because the term "immigrant" often has a negative connotation in the new country. The Sheffer stroke enables us to represent the act of emigrating from a host country, migrating to a new country, and becoming or being an immigrant in a new country.

[5] For the purpose of our research, we define East Asia as the region including the countries of Hong Kong, Japan, Macau, Mongolia, People's Republic of China, Republic of China (Taiwan), and the Republic of Korea. We define Southeastern Asia as the region including the countries of Brunei, Burma (Myanmar), Cambodia, East Timor (Timor-Leste), Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. Our research of the literature focused on East Asia, Southeast Asia, and Latin American regions.

[6] In our research, we use the term Latin America to refer to regions in the Americas where the Spanish or Portuguese languages are spoken, namely Mexico, most of Central and South America, as well as the Caribbean, Cuba, the Dominican Republic, and Puerto Rico. When referring to student groups in this chapter, we use the term Latino/a instead of Hispanic to be inclusive of students who may identify culturally/racially/ethnically as being Latino/a but who do not speak Spanish (e.g., Brazilians speak Portuguese and can be characterized as Latinos/as but could not be classified as Hispanic). When we use the term Hispanic, it is in reference to terminology utilized by the US Census Bureau.

migrants, who represent just over 3% of the global workforce (International Organization for Migration [IOM] 2010). Migration patterns include both the internal movement of people within the borders of a country and the movement of people across borders of adjacent countries or countries that are geographically distant. Internal migratory flows can be diverse and complex in terms of duration (seasonal or permanent), composition (e.g., women only, children only, or only ethnic minorities), and direction of flow (e.g., rural to rural, rural to urban, or urban to urban). In many developing and developed countries, the majority of international migration occurs as border migration, meaning individuals cross from one developing nation to another for short-term work, such as from one country to another in Southeast Asia, or from developing to developed nations, such as from Mexico to the United States (World Migration Report [WMR] 2008).

Currently, the largest human migration trend involves internal movement of people from rural to urban centers. Some examples from East and Southeast Asian countries that have seen significant rural to urban migration include the People's Republic of China, Mongolia, Cambodia, and the Republic of Korea. In China alone, there are more than 150 million Chinese migrant workers (WMR 2008). The migration pattern in China is described as circular because migrants move from rural areas to find work in garment and industrial factories in the cities and then return to the countryside (for many, only once per year) to visit their families. Researchers estimate around 70% of these Chinese migrants are between the ages of 16 and 35 and will spend years, or even decades, in this circular migration pattern before returning home to retire (WMR 2008).

Cambodia is another example of a country with a large internal migrant population. In recent years in Cambodia, there has been a sharp increase in rural-urban migration, about 35% of the population, including many young girls and women who seek work as unskilled labor in garment factories, as domestic help, or as sex workers (WMR 2008). Other regions, including Latin America, have different migration patterns. Faced with dwindling rural populations, urban-urban migration patterns in this region have steadily increased since the 1980s. For example, in Mexico between 1995 and 2000, nearly 70% of all internal migration was between urban areas. Some regions in Latin America have lost large portions of their population to external migration. Some countries in Latin America have more than one-tenth of their population living abroad as e|im|migrants (WMR 2008).

In the context of K-12 education, research examining the experiences of families with children who are e|im|migrating (both legally and illegally) to and from other countries may offer findings that have important implications for educational policy and teacher practice in both the host and sending countries. Much of the research on immigration to the USA has focused on understanding the processes of assimilation and enculturation of e|im|migrants into American society. Many accounts of individual e|im|migrants' experiences in the USA at the turn of the twentieth century have been construed by historians as being representative of the experience of the collective group, regardless of race, ethnicity, gender, class, etc. As a result, research into these historical accounts may provide some general understandings about the plight of subgroups of European immigrants, such as the "Irish" or the "Italians," but there are few accounts of the experiences of individuals who comprise these larger groups, such as unmarried Irish women who e|im|migrated as indentured servants at the turn of the last century. Findings from studies such as these speak to the need for educational researchers to consider the impact of migration and globalization not only on large groups of people at the macro level but also at the meso and micro levels as well. The importance of recognizing and appreciating the experiences of individual e|im|migrants and members of ethnic subgroups is emerging as a significant area of research within many fields of global study.

Technological advances in communications, including widespread access to the Internet and mobile phones, offer today's e|im|migrants close interaction with their family and friends, regardless of where they live. These tools are contributing to the establishment of transnational global networks that support circular, cross-border migration patterns (Portes 2001). Thus, unlike any time in the past, people are migrating to new lands but are maintaining familial relationships, economic ties, and national allegiance to their sending countries. As a result of improved communications and transnational networks, when people e|im|migrate from one country or region to another, they can more easily locate and develop concentrated communities within new host countries. For example, in the United States, Mexican-born e|im|migrants account for about 30% of all foreign-born immigrants, and many of these migrants reside in large homogeneous Mexican American communities. Over the last decade, researchers have studied such communities to understand how "global villages" help e|im|migrants find jobs and accommodations, circulate goods and services, and gain access to social and economic information (Vertovec 1999).

These communities and migration patterns have important implications for K-12 education systems as the children of these families are more likely to remain immersed in both their native culture and language while also being asked to assimilate the host country's cultural norms and language. Natalia Martínez-León and Patrick Smith's (2003) recent study examining the assimilation and enculturation processes for *retornados*, transnational migrant families, and children who move to and from New York City and Puebla, Mexico, found this circular migration pattern had a significant impact not only on student learning but also on the teachers and communities in the New York City and Puebla schools. Their study revealed that teachers in the receiving schools in Mexico did not have the necessary resources to support the further development and maintenance of English language skills of the transnational learners, especially at the elementary school level where English instruction was absent. Additional research highlights the difficulties faced by immigrant children as science learners in classrooms where teachers have limited language resources, other than English (Richardson Bruna and Vann 2007). Building on this work in a more recent study, Katherine Richardson Bruna (2010) explored more closely the challenges Mexican transnational children face as science learners when their teachers fail to inquire about prior educational histories. Richardson Bruna argued that if teachers hold a limited grasp of the socio/historical/political/cultural context of global forces that impact the lives of transnational e|im|migrants, then they remain ill equipped to recognize and value the science educational experiences children bring with them from schools in their native countries and from their encounters with science in their everyday lives.

Such findings not only make clear the need for teachers to acknowledge the importance of e|im|migrants' experiences as individuals but also demonstrate a need for educational research utilizing intersectionality and cultural sociology as theoretical lenses so researchers can better understand and explain how migration is affecting science teaching and learning from the perspective of both individuals and collective groups of people. In the following sections, we focus our analysis from the macro level perspective to examine demographic trends in the USA to illustrate at the meso level how K-12 education in the USA is being impacted by e|im|migration of individuals from the regions previously discussed in this chapter, namely East Asia and Latin America.

A Meso Level Analysis: Who Are ELLs and What Challenges Do They Face in the USA?

Nearly half of all ELL students in the USA are native born, including the children of immigrant and/or refugee parents, Native Americans, and US Latinos/as (Capps et al. 2005). Almost three-quarters of all foreign-born ELLs have resided in the USA for less than 5 years (31% for less than a year and another 41% for 1–4 years), and many of the remaining long-term ELL students are still not English proficient (Garcia et al. 2008). US ELL students speak more than 460 languages; however, Spanish is spoken by 75% of all ELL students (Kindler 2002). After Spanish, the second most common language is Mandarin Chinese (4.4%) (Migration Information Source [MIS] 2008). Fifty-five percent of e|im|migrants who have lived in the USA for more than 40 years speak a language other than English at home (Singer et al. 2008). Of those who arrived in the USA since the 1990s, 82% speak a language other than English at home. Country of origin plays a significant role in determining English language proficiency as well. Nearly two-thirds of e|im|migrants from Mexico and more than one-half of e|im|migrants from Southeast Asia report not speaking English well or at all. Only about one-quarter of e|im|migrants from the rest of Asia report not speaking English well or at all.

To compound the challenges facing ELL students, approximately 91% of all ELL students live in metropolitan areas (Fix and Passel 2003). More than half (53%) attend schools where more than 30% of their peers are also ELL students. More than 75% of ELL students live in poverty. However, the actual rate may be significantly higher since not all poor families provide the requisite documentation to receive subsidized school lunches; in some cases, this is a result of residing in the country illegally (Zehler et al. 2003). Thus, a majority of ELL students deal with the complex issues associated with urban schools, such as larger enrollments and class sizes, racial and ethnic diversity, student poverty, health problems, and school violence (Noguera 2003). In addition, teachers in urban schools often hold provisional, emergency, or temporary certification; are teaching out of field; and have less academic preparation than their colleagues in suburban schools (Ingersoll 2007).

The USA is a monolingual society; thus, language is a significant factor in a child's schooling experience and in determining an individual's status as "other."

Schools and teachers often support monolingualism as a norm by ignoring linguistic diversity. Cultural adjustment, social exclusion resulting from migration, and linguistic barriers are distinct to ELL students and profoundly intertwined with the process of migration (Louie 2005). Compounding these challenges is the perception that the cultural and linguistic backgrounds of ELL students are not advantageous for their academic success in US schools (Vang 2005). In addition, ELL students and their parents lack the knowledge to successfully negotiate the US educational system (Louie 2005). Further, ELL students' lack of access to and proficiency in English – the dominant language in the USA and the language used in school – negatively affects their ability to gain new content knowledge. Estimates for the time it takes learners to acquire academic English range from 4 to 7 years (Butler et al. 2000) to 10 years for students with weak native language literacy levels (Collier 1987). While learning English, ELL students must also master standards-based content-area learning outcomes and do "double the work" as they study to obtain language proficiency and academic content knowledge (Short and Fitzsimmons 2007). This is particularly problematic when students come to the USA during their middle and high school years, with 6 or fewer years to gain English proficiency and learn the requisite standards in science and other academic subjects to graduate.

These issues may account for the 42% dropout rate for ELL students from school, a number that is significantly higher than that of native English-speaking students (10.5%) (August and Hakuta 1997). Moreover, states with the highest immigration rates and population growth have the highest dropout rates for ELL and minority students (Fine et al. 2007). Furthermore, teachers often hold deficit views of ELL students' abilities (Sacks and Watnick 2006). Fewer than 3% of teachers instructing ELLs have a degree in teaching English to speakers of other languages (TESOL) or bilingual education (National Center for Education Statistics [NCES] 1997).

Unfortunately, none of these reported data is especially helpful for researchers interested in examining the challenges facing individuals who are broadly characterized by labels like "Asian" or "Latino/a." Details and factors such as students' migration experiences, family situation, reason for migrating, or future goals have important implications for teaching and learning in K-12 schools. However, if researchers continue to only adopt macro and meso level perspectives from which to examine the experiences of individuals within these broad groups of people, then it is difficult to imagine how teachers serving these students will be supported to understand the varying needs of the science learners in their classrooms.

In the following section, we share some initial findings from our ongoing NSF-funded study involving LM/ELL students and their science and ESL teachers to offer a micro level perspective of how migration is impacting urban middle school science classrooms in a large urban center in the northeastern United States. By examining micro level migration patterns to the Philadelphia metropolitan area, we are better able to draw connections between international migration patterns and the impact on individual teachers, students, and communities in local contexts. Building from this section, we conclude this chapter by raising some questions related to policy, teacher practice, and science teacher education, which we find critical for promoting the academic success of these growing subpopulations of students in both the USA and in other countries around the world.

Immigration Trends in Philadelphia: A Micro Perspective

Philadelphia's e|im|migrant populations have followed national trends with significant growth in the last 20 years; e|im|migrants now account for 9% of the city's population (Singer et al. 2008). Since the 1970s, Philadelphia has experienced several distinct waves of e|im|migration, both of refugees from Southeast Asia (Vietnam, Cambodia, Laos, and Indonesia), Eastern Europe (the former Soviet states), and Africa (especially Liberia), and of voluntary e|im|migrants from Korea, China, India, Mexico, and the Caribbean Islands (Welcoming Center for New Pennsylvanians [WCNP] 2009). Singer and colleagues (2008) noted that geographical areas in Philadelphia that historically were strongly identified with White European e|im|migrants were now home to great ethnic diversity with a population characterized as Asian (39%), Latin American and Caribbean (28%), White European (23%), and African (8%). The researchers also found that 55% of e|im|migrants age 5 years and older in Philadelphia spoke English "less than very well."

Seen as a viable way to stem population flight from urban centers, cities like Philadelphia have instituted several initiatives to bring e|im|migrants to live and work in the city. Philadelphia's e|im|migrants from Asian and Latin American countries have settled in ethnic enclaves, which are neighborhoods or sections of neighborhoods that are culturally distinct from the surrounding areas in that there are businesses (grocery, clothing, and music stores), restaurants, and places of worship used primarily by the ethnic minorities within that community and catering to specific cultural and language needs. More than 56% of Philadelphia's Chinatown residents, for example, are foreign born from China, while immigrants from Indonesia, Hong Kong, Vietnam, and Guyana comprise about 5% each of the total foreign-born population. Other neighborhoods, such as South Philadelphia, make up the commercial center of a "new Asia-town," catering to Vietnamese, Cambodian, Indonesian, and Laotian refugees. The large numbers of Latino/a e|im|migrants from Mexico and Central and South America reside in the "heart of Mexico."

This growth in the e|im|migrant population in Philadelphia has significantly impacted the demographics of neighborhood schools. For example, the population of Latino/a students at one neighborhood elementary school has more than doubled from 13% in 2003, to 23% in 2008 (School District of Philadelphia [SDP] 2009), to 32.4% in 2010 (SDP 2011). As a result, teachers are increasingly called upon to support ELL students and their families. However, currently, there is little published research focused on providing useful science-specific teaching strategies to help support teachers and the students and families in these changing communities. In an effort to address the learning needs of specific ethnic subgroups involved with the recent waves of e|im|migration to the Philadelphia region, we are conducting a longitudinal research study focusing on two school communities with large populations of LM/ELL students.

In the following sections, we share some findings examining the educational achievement of students within the ethnic subgroups that are most prevalent in Philadelphia urban schools and that are the focus of our research study. These findings provide a context for further exploration of individual LM/ELL students in

Philadelphia and illustrate the need for research combining intersectionality and multiple levels of analysis using cultural sociology as we seek to understand how not only race but also ethnicity, gender, and language proficiency shape the experiences of individual students and groups of students in school and science.

Situating Our Research: Southeast Asian and Latino/a Students in the USA

Overshadowed by the model minority myth that stereotypes all Asian American students as academically successful (Lee 1996), the needs of Southeast Asian American students, particularly ELL students, are often overlooked. Following Spanish, the second and third most spoken languages of ELL students across the USA are Vietnamese and Hmong. Both groups are represented in Philadelphia, which has the third largest Vietnamese e|im|migrant population on the east coast and the fourth largest Cambodian population in the USA (WCNP 2009). Southeast Asians from Cambodia, Laos, and Vietnam are the largest group of refugees in the USA. As recent refugees, many Southeast Asians have no formal education or have not developed literacy skills in their native language due to lack of opportunities for education in war-torn countries and while living in refugee camps prior to resettlement in host countries. For example, in the United States, many Southeast Asian American adults 25 years and older have only a high school degree, and a significant number have no formal schooling, including 27% of Cambodian Americans, 45% of Hmong Americans, 23% of Lao Americans, and 8% of Vietnamese Americans (Ngo 2006). These data represent both immigrants and US-born Southeast Asian Americans.

Latino/a students fair even worse than Southeast Asian students in US schools. Dropout rates for Latino/a students in the USA are significantly higher than for other ethnic groups. Forty percent of Mexican e|im|migrant youth, the largest subgroup of Latinos/as, who arrive in the US between the ages of 16 and 19 drop out of school. Latino/a youth who are born in the USA and who attend US schools for longer periods than those who have e|im|migrated to the USA have a dropout rate of 20%, compared with 8% for non-Hispanic White students (Morse 2005). Additionally, the native-born and e|im|migrant Latino/a population accounted for half of the nation's growth between 2000 and 2006 (US Census Bureau 2006). And native and e|im|migrant Latinos/as represent the single fastest growing ethnic group in Philadelphia (WCNP 2009).

We believe it is significant that much of the national data available to researchers for analysis of educational trends among students of different ethnic groups does not provide information about e|im|migrant status or language proficiency. In our own study, we are examining the educational experiences of students from different ethnic groups with greater attention paid to intersecting sites of oppression, including proficiency in native and English languages. We believe it is critical that we explore the intersections among ethnicity, class, and language proficiency if we are to understand who these students and their families are and what challenges they face in the community and in the schools.

In our review of the educational research addressing school science experiences of students identified as native born or e|im|migrant Latinos/as, we found no research examining student experience in relation to country of origin, class, region, or language. However, meso level analyses of demographic data describing the current wave of Mexican immigrants to South Philadelphia reveal important findings with regard to differences in the native languages spoken by groups who are e|im|migrating from Mexico. While Spanish is the national language spoken across Mexico, many of the new e|im|migrants to Philadelphia come from central and southwestern Mexico, including the regions of Puebla, Veracruz, and Oaxaca (Saverino 2007). In these regions, large percentages of the population are indigenous peoples who communicate primarily in dialects other than Spanish, such as Nahuan or Nahuatl, which is a language descended from the Aztecs (Pedraza 1996). Providing Spanish language support for families and children in these school communities may be of little help; because the type of demographic information being collected by school and government agencies is rarely disaggregated with enough detail, including language and ethnicity, many of these students are labeled as being "Mexican" and, thus, are assumed to speak Spanish.

This is another example of why it is important for researchers to be able to account for the ethnic and linguistic diversity of e|im|migrants in the US K-12 education system. For students and their families who are e|im|migrating from Asia, Southeast Asia, and Africa, some may speak a primary dialect within their ethnic community or region, a secondary dialect (often a national language) for government and official transactions, and additional dialects necessary for trade and business among members of different regions. Thus, in some K-12 classrooms, science teachers may need to support students who are acquiring English as a third or fourth language, and many of these students may not be literate in any of these languages, including their first language.

Using Intersectionality to Improve Science Teaching for LM/ELL Students

From the normative perspective, intersectionality seeks to unravel the ways in which multiple marginalizations of race, class, gender, or e|im|migration at the individual and institutional levels create social and political stratifications, and thus, requires a multi-method research approach that is attuned to examining the interactions of these different categories (Hancock 2007). Most educational research depicts diverse groups of students using broad labels, such as "English language learner," "Asian," or "Hispanic," without attending to the multiple factors, including gender, race, ethnicity, class, religion, country of origin, native language, and school experiences in the country of origin, that all collectively shape student and teacher experiences at the local levels. The use of such labels is ubiquitous in K-12 classrooms, as is illustrated in the vignette presented at the beginning of this chapter. In that situation, the teacher assumed that all three Asian students spoke the same language and could provide language support for each other during cooperative science learning activities. This vignette illustrates the possibilities for using intersectionality in K-12 science classrooms as it demonstrates the need for teachers to think critically about the categories represented in their students' identities. Herein, we introduce how we use intersectionality in our research with science and ESL teachers to help teachers better understand their students by applying intersectionality to the introductory vignette for analysis. Building from this analysis, we offer implications for teacher practice in the context of this science classroom.

Intercategorical complexity uses analytical categories to examine relationships between social groups and specifically focuses on inequities and how those inequities exist in multiple and, at times, conflicting aspects. Leslie McCall (2005) proposed three categories – anticategorical, intercategorical, and intracategorical – to understand intersectionality. Anticategorical complexity deconstructs social categories. In our work, we have found that the use of anticategorical complexity provides opportunities for teachers to deconstruct the social categories tacitly assigned to their students. For example, in the opening vignette, the teacher had made broad assumptions about her students' ethnicities, languages, and learning needs based on her perception of their race as a pan-Asian unifying construct. By using anticategorical complexity to examine the students' ethnicities and languages, this teacher could have provided the students a culturally responsive instruction that would meet each student's specific needs by taking into consideration their individual ethnicities, languages, and other social categories. Further, she could have considered the students' cultural differences when learning science, based on their gender, class, and/or religious beliefs.

When using intercategorical complexity as a strategy for intersectionality, teachers and researchers can examine how power dynamics, social location, and other social categories shape identity (Shields 2008). For example, a female student who is ethnically Vietnamese and born in the USA would have a different personal narrative than a recently immigrated male student who is ethnically Chinese but was born and raised until early adolescence in Cambodia. The female student may have good English language skills, but her family may rely on her to provide care for younger siblings, which could prevent her from excelling academically. The male student may be an excellent science student, but his limited English proficiency could prevent teachers from uncovering his expertise. Further, providing childcare to younger siblings is often not expected from a boy, less so in some cultures than others. By engaging in more meaningful interactions with students, parents, and community members (in this case, monks in the local temple and leaders from different ethnic civic organizations in the neighborhood), teachers and administrators at this school can begin to appreciate the experiences of individual students and their families that will enable them to better connect with their students as learners and to their experiences with school and science, which will provide them opportunities to understand individual, family, and community expectations for school, in general, and science learning, in particular.

Another example of categories that can be used is intracategorical complexity, where the teacher (researcher) focuses on groups that exist in the boundaries between categories and, as such, are often ignored. For example, using intracategorical complexity, a teacher begins with one category, such as gender, and then examines the similarities and differences within other categories, such as language proficiency level, race, ethnicity, immigration status, and science learning. From here, we may question, how are a student's science experiences ameliorated by the other categories? From this perspective, we would recognize that a student's prior science learning experience would be an important dimension that could contribute to his or her social location in the science class. One of the students in this vignette lived for several years in a refugee camp where he received no formal education, but he engaged in many different scientific investigations as his family was encouraged to grow their own vegetables for consumption. This required a lot of experimentation as the soil, seed, and weather conditions were unfamiliar to them at the camp. However, unless teachers engage their students to learn about their prior science learning (formal and informal) either in Cambodia, the refugee camp, or in other science classes once in the USA, then teachers cannot begin to draw on their students' knowledge of science.

So far in this chapter, we have highlighted some findings from macro level research that we find have limited potential to inform practice or policy at the meso (local) level, in communities and schools, or at the micro level, as interactions between teachers and students. We argue that only if researchers begin to make connections at the macro and meso levels between complex processes, like globalization and migration, can they begin to understand the micro interactions that occur between teachers and LM/ELL students in the science classroom. Because intersectionality asks that we acknowledge that an individual's social identity influences her or his beliefs about and experiences of gender, class, race, and ethnicity, we believe that by engaging intersectionality in the analysis of students' lives, researchers and teachers can begin to contest the social boundaries and categories that shape a student's opportunities for learning. If teachers are able to challenge the terms currently used to describe their students (e.g., immigrant, language minority, English language learner, female, male, Cambodian, or Chinese), they will be better positioned to question the implications of these labels for their students' experiences in school and science. For example, teachers could begin to consider what cultural practices could enhance and restrain their students' science learning and question how might those practices vary because of a student's gender, ethnicity, or native language. They might also consider how learning within science, a discipline focused on the observation of the natural world and the use of symbolic language, might help students obtain academic success in other subjects. Further, teachers might think about how a student's achievement in science could be impacted by native language proficiency or consider the degree to which the native language is utilized within the symbolic language used in science.

The examples we have shared in this section are meant to highlight the need for teachers to understand the sociohistorical context of the global forces impacting their students' e|im|migration experiences from their home country and to their new country. We caution that teachers must also avoid generalized understandings about students' based on these intersections by acknowledging the fluidity represented in students' multifaceted, highly individual identities. However, until teachers begin paying attention to the intersections of these different categories, they will continue to be limited in their abilities to support students as individual science learners. In the following section, we consider additional implications for policy, research, and teacher education and even offer examples of transformative research being implemented by teacher researchers at the classroom level.

Implications

As a result of globalization, student populations in countries all around the world will continue to become more diverse. In order to better understand the issues and interactions between these students, their teachers, and school science, we need more powerful tools with which to analyze data that can tell us more about individual and social phenomena and in more complex ways. Using intersectionality as a framework provides researchers and teachers the opportunity to learn about the complex ways that instructional methods, modes of communication, and cultural practices in classrooms either support or constrain science learning for diverse students. If researchers are to generate findings that have important implications for policy, research, and teacher practice with regard to the growing LM/ELL student population in US K-12 schools, we believe they must employ new and different methodologies and theoretical frameworks so that they can better understand the complex relationship between globalization and e|im|migration at global levels and the resulting impacts on school environments at local levels. Fostering more meso and micro level research on LM/ELL students is warranted, especially studies that illustrate the complexities that exist within groups of students and that complicate the conclusions drawn by data gathered using broad labels such as "Asian" or "Latino/a."

Research that emphasizes the science learning needs of LM/ELL students and employs intersectionality has clear implications for research and teacher education. As such, we believe that intersectionality challenges researchers and teachers to conduct more nuanced analyses of the science experiences of marginalized students. This work underscores the tenets of social justice education and has the important long-range objective of providing opportunities for students from marginalized subgroups for future careers in STEM fields. In addition, this research can also inform preservice and in-service teacher education. A recent publication of *The Science Teacher* (2011) used the theme "*Science for all*" and included several articles on teaching science to ELL students. Those articles provide teachers with pragmatic advice on working with ELL students, such as knowing language proficiency levels of students and aligning content and language objectives (Bautista and Casteneda 2010). However, beyond just incorporating specific methods, it is critical that teachers have a keen, multifaceted understanding of their LM/ELL students' experiences, identities, and backgrounds.

Some courses and texts attempt to facilitate understanding about ELL students by providing overviews of different cultural groups, noting patterns in behaviors, beliefs, and other cultural aspects. These broader descriptions of patterns about students can be useful to teachers, school leaders, and policymakers, but we are hesitant to encourage reinforcing certain attributes or practices as "typical" because of the dangers of stereotyping subgroups. Rather, as teacher educators, we recommend that practitioners consider the intracategorical complexity in students' multifaceted identities. Teachers can develop their own understandings about individual students who belong to larger groups such as "girls," "ELL students," or "Puerto Rican female students in my science class" by engaging in action research on their teaching and student learning. Teachers can conduct interviews or surveys to gather information that allows them to develop a more nuanced, individualized perspective of their students. A growing number of urban science education researchers are supporting teachers and their K-12 students to implement cogenerative dialogues, a structured discourse method between students and teachers, that have been successful in transforming teachers and student practices in science (e.g., see Martin 2006; Martin and Scantlebury 2009). By engaging in cogenerative dialogues with students outside of class, teachers can expand opportunities for LM/ELL students to gain access to not only a new language but also improved understandings about the purpose of school and science. Additionally, through these dialogues, we believe teachers can gather information that will enable them to better differentiate and support their students' English and science learning while simultaneously offering opportunities for these students to become integrated into the learning community in more meaningful ways.

Finally, there are important implications for this research with regard to the development of policy that impacts research funding, curriculum, and assessment and mandates informing educational reform at local, state, national, and even international levels. So that educators can understand the impact of macro level processes like global and local migration and labor patterns at the classroom level, we need funders to support research that examines these issues at the national, state, and local levels. Drawing from this research, curriculum for teacher education programs could be developed that supports teachers to build and challenge their own understandings about what it means to teach science to linguistically and culturally diverse students in this era of globalization. For example, courses could be developed that enable teachers to appreciate the larger impact of globalization on education. We think this should be a critical component to teacher education programs in the future because the micro level understandings we advocate that teachers, administrators, and other school-based practitioners should have about students are directly impacted by the macro level processes of global and local migration patterns and labor patterns for immigrant families. Research examining the intersections of race, ethnicity, class, and gender on English language learners is needed if researchers and teachers, in the USA and in countries around the world, are to understand who students are as learners. We offer policymakers, educational researchers, teacher educators, and teacher practitioners two complementary frameworks, cultural sociology and intersectionality, as powerful tools for conducting research, which allow for more nuanced and complex understandings about issues facing science teachers and learners in an increasingly connected world.

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Chapter 7
Elementary Students' Ways of Seeing Globalization in Science

Bhaskar Upadhyay

Marco: My family [we] talk [during dinner time] lots of food come from other places, I mean other country. We buy food to eat in lunch, dinner and snack and breakfast. On the box it's written and says pro…product of like Chile, Mexico, India…All this place grow things and come here like they come from Texas or Florida.

Jevan: …Yah. All this different countries and food like rice, flour, fruits, and clothes too. Food has date and label is here [pointing to the expiration date] on say can't eat the food after like July 2010 or 2012 like that… Fruits are like real fresh and come from long distance like strawberries and kiwi from Chile. How they get here so quickly from so far? Food comes to us so quickly. But we always buy strawberries in Cub Foods® when it's cheap or old. Do people grow there different time and how they get money for food [sold to us]?

In this conversation, Marco and Jevan, students in grade five in one of the poorest urban schools in Minneapolis, discussed the relationships between them and the food they normally eat at home and at school during breakfast, lunch, snacks, and dinner. These two students not only talked about the food they and their families eat but also about the larger connections across their food choices, practices, affordability, and those who produce these food items in distant places. Both Marco and Jevan brought to the forefront some very important aspects of globalization in the postmodern era. First, they presented the accessibility of unseasonal food in distant places, such as strawberries in winter in Minnesota. The accessibility of goods to people in remote areas has been made possible by rapid growth in global transportation systems. However, who gets the most benefit from access to goods

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and services is a question worth asking, and Jevan pointed to this disparity of distribution of resources because of globalization. Second, the students pointed out the possibility of the accessibility of food that cannot be grown in a particular place or locality, such as kiwis in Minnesota. Third, they mentioned the minimization or shrinkage of the sense of space, geographical distance, or geopolitical space. Fourth, they pointed out the shrinkage of the sense of time because of the speed at which goods and services across vast distances can be transported. Finally, they wondered how this kind of interconnectivity, deterritorialization, speed of transportation and communication, and the increased mobility among people and goods impact the people who produce these products at different stages and those, including them, who seek to utilize these products in their everyday lives.

Similarly, the above conversation pushes our students and us, as science educators, to ask important questions about the role of science education in the larger global context, in national science education documents, in science curriculum materials, and in everyday science classrooms. In other words, what should be the purposes and goals of science teaching and learning in poor urban schools in the age of globalization? What does teaching and learning science to poor urban children mean in the global age where our students' choices, practices, communities, cultures, and their own values and beliefs are connected to individuals in foreign lands (in a geopolitical sense)?

In this chapter, I try to answer these questions based on my work with urban students, many of whom are children of immigrants, in two Minneapolis elementary schools. First, I discuss what globalization is and how globalization relates to science education in the urban science context. Second, I present how students in urban elementary science classes see globalization in their teaching and learning. Third, I discuss the complexities of globalization and science in the local sociocultural context. Finally, I present how and why science education needs to be researched in the context of globalization.

This study specifically focuses on children who are still in the early years of their formal schooling. They will be most profoundly influenced by globalization in what they will learn, the jobs they will take, the foods they will eat, the languages they will encounter, the cultures they will know about and participate in, the movies they will watch, the material things they will purchase, the technologies they will use, the economy they will participate in, and the groups they will gain membership to so that they can function in a more globally connected world. There are very few research studies that directly investigate how children or youths in general view globalization, what they contribute to this phenomenon, how they wrestle with globalization in their lives, or how they are actively creating new identities for themselves and also for the next generation of youths that will follow them. There are studies that have focused on youth and globalization more directly related to popular culture and media (Appadurai 1996), rather than direct youth and globalization interactions. It is hoped that this study will add to the connections between youth and globalization literature, and help educators, parents, policymakers, and researchers to get a glimpse into how children find globalization to be a part of their being and schooling.

What Is Globalization?

In contemporary social theory, globalization plays a central role in understanding the processes of social change (Elliott 2009) taking place over large and small parts of the world. These social changes resulting from globalization are not identical in all local contexts, but they are socially and culturally transforming for these communities (Baker and LeTendre 2005). This suggests that globalization has different meanings and outcomes for different individuals and communities. For some researchers, globalization is pure economic gain; for others, globalization is deterritorialization; and for some others, globalization is temporal and spatial compression (Scholte 2000). Hence, there is a need to establish the meaning of globalization in research to make sense of the social, cultural, economic, and other changes that one might be interested in investigating or understanding.

Despite many variations in the meaning of globalization, there is some agreement on the basic origins of globalization among the scholars who study this phenomenon (Cox 1997). For the purposes of this chapter, I conceive of globalization as a process that has the propensity to deterritorialize and interconnect the social, cultural, economic, and other practices of people from traditional geographic boundaries (Ong 1999). Therefore, globalization is a set of processes, which rapidly integrates the world into a super economy space through trade, growth of markets, and a consumer culture connected via rapid communication systems (Gibson-Graham 1996). There are three key terms, deterritorialization, interconnectedness, and space-time compression, that are routinely used to describe globalization, and I discuss them below to help readers understand why and how these terms are so powerful in understanding globalization.

Deterritorialization

Deterritorialization is the process of reconfiguring geographically demarcated spaces, borders, and distances into one single space (Elden 2005). In this case, social activities take place irrespective of geographical locations of individual participants. Even though many social activities are local in nature, such as farmers' markets,[1] there are numerous possibilities for actions that are geographically unconstrained, such as electronic stock markets and teleconferencing. The social space for different activities is now defined less by the traditional idea of bordered

[1] A farmers' market is a locally designated space where farmers from a certain region or community bring their products, such as vegetables, grains, canned goods, and locally produced garments, potteries and trinkets, etc., to sell or barter during certain days of a week. Each community has its own farmers' market schedule. For example, in Minneapolis, many farmers' markets are open from the middle of June to late October (growing season for a typical Northern climate region).

territory (Sassen 2005). Thus, globalization can be defined as the process of expanding and transforming social activities with new and expanded territorial boundaries (Scholte 2000), or creating borderlessness.

Interconnectedness

Deterritorialization facilitates the growth of social, cultural, and economic interconnectedness among individuals across geographical, political, economic, and cultural boundaries (Scholte 1996). Globalization as a process of social interconnectedness argues that events in distant geographical locations may be local, but these local events may be impacted by other factors in other distant locations (Williams 2003). Thus, globalization is the process by which there is some kind of global diffusion of a local phenomenon, such as organic farming in a small town in Nepal or laws forbidding child labor practices in a South Asian country or attaining gender equality in the school curriculum. For example, when the legislature in Nepal passed child labor laws in the late 1990s, they passed the laws because there was a demand from many Western countries that all Nepali carpets exported to their countries be certified as child labor free. Thus, distant events and forces can influence local activities, practices, ventures, and businesses (Tomlinson 1999). These distant events and their connections to geographical regions have become more regular and predictable, thereby expanding and linking human activities and affairs across continents (Held et al. 1999).

Time and Space Compression (Speed)

Human experiences in the recent globalization process have been highly influenced by the speed at which temporal and spatial compression have taken place (Harvey 1989). The development and growth of high-speed technologies have allowed the processes of deterritorialization, interconnectedness, and socialization to proceed at a very accelerated pace. However, globalization has been taking place for centuries as a long-term process of social change and transformation (Harvey 1989). Time and space compression may accelerate the processes of deterritorialization and interconnectedness, but the impact of these processes is not uniform and universal for individuals who participate in social activities (Erickson 2001).

There are many different ways in which educators, researchers, scientists, politicians, and lay people understand the meaning of globalization and participate in social activities based on those personally understood meanings. As one contemplates the meanings of globalization based on these three dimensions, the basic underlying theme of globalization seems to direct us to believe that there is a wave towards homogeneity and universalization of all sociocultural activities and knowledge structures all over the world. This raises the idea of a "global village"

(McLuhan 1962), where geographical boundaries disappear and instantaneous communication takes hold as a norm, bringing the end to provincialism and nationalism. The notion of a global village is further internalized by many scholars through postmodernism and creation of "time-space compression" (Harvey 1989), linking societies in distant places through quick transportation and communication tools, such as air travel and the Internet.

Globalization, Locality, and Science Teaching and Learning

Local space and nonlocal spaces are connected to each other, but the nature of social activities, the reasons for connections (Sassen 2005), and the knowledge that is gained through these connections are all significantly understood and defined based on the local actors (Fadzillah 2005). The local actors play a very significant role in the process of globalization. This kind of local-global interaction injects more diversity, rather than sameness that many believe globalization promotes. As the interconnectedness between local and global increases, the local, social, cultural, political, economic, and linguistic characteristics are more prominently manifested in the global interactions (Du Gay 1997). There are greater demands put on global economies and policies to accommodate and provide for local demands, thus promoting many local characteristics in many interactions (Crane et al. 2002). For example, McDonald's serves only *halal* meat in its burgers in Muslim countries; similarly, many Central African nations now grow nontraditional crops, such as green beans, to export to many European Union nations (Singh 2002) because of air transportation and demand. Even though the globalization process promotes sameness among communities, there is constantly local adaptation to fit the needs and desires of the local people who are the potential beneficiaries of globalization (Taylor 2000).

When individuals develop connections in the new global space, they also establish themselves as one of the central loci in the space where social activities take place. For example, when students in a Minneapolis elementary science class wanted to learn about the impact of swine flu on their lives, they connected themselves to the Center for Disease Control (CDC) in Atlanta and the World Health Organization (WHO). Through these links, they created, shared, and talked about a daily bulletin to disseminate new information and to discuss how they could help in controlling the spread of swine flu in the school. One of their suggestions was to control the crowd during lunchtime so that fewer students would be in the cafeteria at one time. Students in grade five based their suggestion on information found on the CDC and WHO websites. Another suggestion was to give each student a small bottle of waterless soap that he or she could carry at all times and use after touching anything or anybody, rather than one big container at the school that all students used. The personal waterless soap was uniquely the students' idea. These solutions were based on what was locally available. Thus, the solutions point out the need for local and global connections in science teaching and learning, gaining diverse ideas through connections, and the interdependence of relationships through connections.

As I draw our focus into science curriculum with globalization as an important component of science teaching and learning in K-12 settings, I find that the urban elementary schools in Minneapolis, the schools that I have partnered with for the last 6 years, very rarely mention globalization and global connections in their science curriculum materials. Additionally, when teachers enact science curriculum materials in elementary classrooms, they discuss globalization as a scientific idea in reference to global climate change, earthquakes, and other natural disasters, such as the Indian Ocean Tsunami of 2004. Students in these classes hardly ever get to connect globalization as social, cultural, and economic processes influencing people and places near and far. Most science curriculum materials either relegate the issues of globalization to the margin or do not bring it into science instruction at all. There is very little evidence in my own work with elementary and middle school teachers in the USA that they connect science to globalization when they are teaching science content, such as balance and motion, processes of land formation, and matter and energy.

My review of Minnesota State K-12 science standards and benchmarks (Minnesota Department of Education 2010) shows that there is a distinct lack of importance placed on issues relating science education and globalization. Instead of just teaching water cycle concepts, teachers in elementary grades could teach a lesson on the water cycle and water usage that connects larger social and cultural practices related to water, the distribution of water, and the effects of engineering and technology on water distribution and usage. In this regard, teachers could utilize the social and cultural practices in India or Native American communities surrounding water usage, as well as investigate the distribution of water between Bedouins and Jews in Israel (Tal and Alkaher 2010). I am concerned that leaving the task of connecting globalization and science education in the hands of teachers and students of urban schools, where the pressures of making the annual yearly progress (AYP) in mathematics and language arts is a primary concern, will rob these students of a valuable learning experience that explicitly allows them to imagine the connectivity between science and globalization.

As another example, when elementary students are learning how water interacts with materials such as fabric, paper, and wood, teachers can easily engage students in how jeans have been accepted around the world as a universal product. Jeans are an exclusively American clothing product, and yet, jeans are now as popular in Nepal, Ethiopia, Guatemala, and Papua New Guinea as they are in the USA. Globalization has made jeans a global cultural phenomenon and a contemporary cultural product. Similarly, brands such as Lee, Levi’s, and Wrangler have become symbols of the acceptance of Americana (Western) globally. In Nepal, Lee, Levi’s, and Wrangler are synonymous with jeans and accepted in Nepali and many indigenous and local vernaculars. Yet, our new science education framework in Minnesota is disconnected from the new social, cultural, and economic realities of globalization. I believe that a curriculum should be “the collective story we tell our children about our past, our present, and our future” (Grumet 1981, p. 115), and that our national and local science curriculum materials need to represent the concepts of globalization for future growth of our students in science, technology, engineering, and mathematics.

In this chapter, I seek to answer the following three questions concerning science education and globalization in a poor urban elementary school context: (1) How do elementary students see globalization in a science classroom context? (2) How do elementary students engage in science when Western scientific knowledge and non-Western knowledge interact as global and local knowledge structures? (3) How do students view their connection to larger global issues and the science they learn in school?

Methods

I collected the data reported here over a 2-year period when students were engaged in science learning through food, environment, gardening, and connecting personal decision-making with science knowledge they learned in the class. The data used in this chapter are part of a larger project and span from January to May 2010. During this time, students learned how different "counterseason" foods, such as strawberries, tomatoes, kiwis, melons, beans, and cucumbers, could be brought into Minnesota during the middle of winter. The students also learned about the global systems of transportation, food preservation, and the farmers who grow these food items in distant places, such as New Zealand, Chile, and Panama. Furthermore, I observed students discussing what could be considered as scientific knowledge in opposition to local and personal knowledge. In the class, students also discussed how global commerce empowers some and disadvantages others, particularly the poor, women, and marginalized groups in countries that have very low United Nations Human Development Index (HID) rankings[2] (UNDP 2010). In the class, the students and their teachers did not mention HID, but did discuss countries such as El Salvador as poor and USA as rich.

I observed and videotaped 12 lessons and interviewed six students from one fifth-grade urban classroom; similarly, I observed and videotaped nine lessons and interviewed four students from another fifth-grade urban classroom. All the students were interviewed to understand how they see themselves as being a part of the globalization process, how science helps them to understand how their decisions influence larger global connections, how they see science learning to be an important component of local–global connections, and how science knowledge aids them to be better global citizens.

I also collected some of the students' class work and writings related to science activities, such as their science notebooks and worksheets. Field notes that I kept for each observed class were also used to augment the analysis. The field notes

[2] United Nations Human Development Index (HID) is a composite statistic, which is used as a relative measure of social and economic development of a country. HID is the combined score of life expectancy, educational attainment, and income of a country. The HID index is expressed as a value between 0 (minimum) and 1 (maximum).

provided my immediate reactions of the observations and also helped me record some of the conversations that the students had that were not captured by the videotapes.

I used an iterative and progressive approach to data analysis to ensure that data coding, indexing, and theme generation were cohesive (Charmaz 1983). The data were first open coded (Miles and Huberman 1994) to generate as many nodes about student views of and experiences with globalization as possible. For example, the open code nodes included items such as global, poverty, science, nonscience, environment, distant places, working conditions, and connection to people and goods. These open codes were then grouped into larger and more cohesive themes through an axial coding process (Miles and Huberman 1994). The themes included coexistence of classroom science and globalization, Western science and local science, and effects of globalization on personal life choices. Some of the codes and themes were generated directly from the data and some were generated from existing literature reviews. I further refined the themes by collapsing other smaller codes or themes into larger ones, which are presented in the following paragraph.

Themes

In this section, I present two themes that emerged from the data analysis. These themes represent how students see globalization and global perspectives integrated in science teaching and learning, and how Western scientific knowledge and non-Western local knowledge learning are envisioned through the networks of globalization.

Globalization and Global Perspectives in the Science Classroom: Where Is Globalization?

Dejan and Eileen's conversation, during the middle part of a 6-week-long science unit on the connections between nutrition and the human body, caught my attention as they discussed the importance of science in their successful future lives. They were talking about the kind of community and world that will be awaiting them when they become adults and how the science that they were learning now would be helpful to make important decisions about their health, food, the homes they will live in, and the source of power to cook and heat their homes in winter. However, when I asked these students during their group discussions in the class how often they connected science content and ideas with examples from other countries or life experiences of people outside the USA, they believed that greater global connections to science were few and far between in their class. Their science learning and engagement in the class were hardly about global connections.

The only time globalization was talked about or mentioned was in passing during lessons on the environment or when natural disasters happened in other parts of the world.

Dejan: Yah…We don't talk about the global things in science…. When we studied about rocks and volcanoes and how rocks are formed, [we] talk about only America. We talk like California earthquake not other countries and how they [both people and places] are related to what we are learning in science.

Eileen: …and we didn't know Joan's parents came to America from Haiti. And earthquake in January [in Haiti] we then talk about Haiti. So many people get affected by the earthquake. We raise money for the people [of Haiti] and we also bought things from Haiti like mangoes from grocery store…. We want to help people in Haiti and we ask our teacher to buy things like coffee, clothes, and fruits like mangoes from there and people need money to buy food in Haiti….We care [even if] in small ways.

Dejan and Eileen expressed at least two different dimensions of globalization. First, they noted that events in one part of the globe affect everyone. Because of time-space compression, these two students were able to build connectedness with the events in Haiti and to feel that they were a part of the global village. Furthermore, both students also expressed their frustration that their "science teacher, [the science curriculum], textbooks, references [available at school], science journal [entries]," and discussions in the class rarely highlighted global connections as a part of the science learning process. They felt that the science they learn in school does not clearly connect to "globalization" as a contemporary feature of the world.

Having expressed their eagerness to learn science in a much more global context, the students understood that their participation as consumers of Haitian products would eventually help the people who produced those products in Haiti. Through their actions in Minneapolis as conscious and deliberate consumers, the students engaged in the process of economic globalization. In economic globalization, the relationships between nations and people are forged through exchanges of goods and services that are considered to be financially and mutually beneficial to all the parties involved. In the case of these students, economic globalization is not only financial in nature, but also moral and activist in nature. This second aspect of globalization, in my opinion, is a more activist-oriented socioeconomic action. The students used economic globalization as an empowering tool to influence both national and local humanitarian actions. Eileen saw that their act of buying Haitian goods may not amount to radical change in the lives of Haitian people, but that small steps add up to a much larger influence.

Further, other students noted that those who make products in developing countries rarely receive as much money for their work as those in the USA. Once again, I remind readers that the students were talking about global issues during these lessons because of the Haitian earthquake – a rare onetime opportunity – not as a regular classroom event. Manuel from Guatemala interjected that he constantly hears his family members talk about how hard they worked in "big company farms" to make ends meet. He also now knows that people in Guatemala get so little back after "chang[ing] American dollar to quetzal." Similarly, Abdi whose family lived in Ethiopia as refugees before coming to the USA. noted that his family and many others in similar situations got very little for their work in factories in Ethiopia. All students were very surprised how little people who worked to produce the goods they bought in the USA received.

Interestingly, the teacher asked the students to convert the US dollar into their respective countries' currencies using the existing exchange rates. The teacher also mentioned that the currency conversion was a mathematics task and that they should be able to complete it without much trouble. I believe this kind of classroom activity is a weak example of the connections between globalization and science. Such an activity might help to improve students' mechanical (conversion) skills, but does not enhance their critical thinking skills. A much more robust and useful conversation in the class could have been to examine the purchasing power of the money in those countries, and the subsequent social and economic implications of money on the local people. This latter kind of discussion did not take place in the class as a regular part of science teaching and learning.

Furthermore, in subsequent science class discussions, students also talked about the lack of connections between what they were learning in science and the knowledge they needed to be active in their community and diverse global communities. Students reported that the science materials (physical materials used in carrying out activities) and curriculum only taught them to "learn science content and know the content and no connections to other things," rather than to connect to their lives in global ways. The students believed that they learned science as a distinctly separate act without much understanding of how these discrete pieces of science knowledge and processes will aid them in the new global cultural discourses.

Scientific Cosmopolitanism: Accepting or Abdicating the Non-Western Ways in a Globalized Classroom

Students in a second school discussed the cost of fresh vegetables and fruits. They were especially concerned with and also wondered how these fruits and vegetables became so expensive during early and late parts of the growing season in Minnesota. Many students expressed their dismay and concern that sometimes healthy fruits and vegetables were not sold at their nearest grocery stores and corner stores. The students in grade five suggested that they should grow some of these food items in class. The class decided that they would try to grow strawberries because the plants are small in size, easy to take care of, need little space to grow, and can be carried home during weekends. During the weekends, the school shuts off the heat; hence, students were concerned that the plants would die or not do well if exposed to constant temperature change.

Students transplanted strawberry plants from small containers into large pots. During this time, in one of the groups, two students discussed what the "scientific method [was for] planting" strawberries. This discussion occurred between one of the Hmong students, Mia, and an African American student, Tara. Mia's family planted strawberries without following the planting guidelines, i.e., the written steps that come with the strawberry plants to help correctly plant them in the ground. Mia's parents had been planting strawberries for so long that they never used a guide, but just followed their many years of experience. Some students in Tara and Mia's group were concerned that their strawberry plants would die or that they would not have any strawberries because Mia did not follow what they considered to be the scientific method. Here, for students, the scientific method included the steps that came with the plants. Mia assured her friends that she had been planting strawberries for some years like this – that she had "never followed" any "written guidelines." In the following excerpt, these two students discussed the advantages and disadvantages of following the steps [method] of planting as described by the sellers of the plants:

Tara: You didn't follow the direction. We have to follow direction in science….See this is like doing experiment without following method, you know, like we do in science class….You can't do different things in science because there is one answer. Like food from other countries follow our rules, no disease, no upset stomach.

Mia: I have planted lots of strawberries and other plants. This will grow. We don't have to look at all this how to plant guide….I just have to make sure the roots are deep in the dirt and not loose. It will grow. You can plant differently and it is correct way and get[s] same result. Like Juan told us that his parents and uncles plant strawberries without this guide….Health rules for safety is different from scientific method. We shouldn't tell people that their knowledge is bad and change it.

Tara: Don't we have to follow directions in science?…We can't just do things without safe directions. Our science books and in the Internet we got directions how to plant. Everybody is planting following the science book or Internet method.

Mia: We can put my way of planting on the Internet too. Do you think that is considered scientific? We have different ways of doing the same thing. Our knowledge has worked for a long time so it doesn't matter – scientific method or our method. I don't think my way of planting is wrong….It will grow and give strawberries. This not [a] onetime thing. I have done many times and our family has done many years. See Juan's families even [pollinate] some plants [flowers] to get fruits. They do by hand and follow what grandparents have taught them.

As evident from the above discussion, most of the students looked for the directions to planting strawberries in different resources so that they could follow the standard procedure. On the one hand, Tara believed that doing science experiments was about following written directions. For Tara, science is based on the written procedure that had been established and written in the science books and websites. Tara was very reluctant to agree to Mia's ways of completing a science experiment. For Tara, scientific methods were no different than health rules and guidelines that the USA imposes on imported food to control the spread of disease and ensure the health and safety of the people. Ignoring these rules in the globalized economic market would not benefit many poor countries. At another level, Tara was arguing that if people who are marginalized do not follow the rules of science they are the ones who would not get the benefits of globalization. These poor people who we want to help are the ones who will be disadvantaged. From the discussion in the class, Tara seemed to believe that scientific global language is important to learn and adhere to at all times.

On the other hand, Mia believed that her way of planting strawberries had worked for years and such a tried and true method could be used in science class as well. Mia stressed that her method of planting strawberries was a time-tested procedure that had not failed her family to grow and sell strawberries for years. She stressed that health rules for importing food are somewhat different in that they are for safety and public health reasons. The health rules are not about telling people that their knowledge is not acceptable. However, in further exploring this statement during her interview, Mia expressed that "her parents had to worry about malaria and stomach upset [because of polluted] water but here [U.S.] we [family members] worry [about] flu…. We don't worry we catch malaria…. We get water from the taps and it's treated…" Mia's comments related to health and safety indicate to me that she had a clear awareness that climates and diseases are interrelated. Similarly, she also showed an understanding that waterborne diseases are of less concern in the USA than when she was in Thailand, because her tap water comes treated and purified. What I find very intriguing about these students is their understanding of many issues, such as health, local knowledge, and climate differences, that intersect with the science content that they learn in school.

Mia was unwilling to give up her knowledge that has helped her family in growing strawberries. In Mia's responses, I saw her attempts to place her knowledge in her own cultural and local spatial context. For Mia, knowledge is useful or valuable if that knowledge is useful in the local social and cultural contexts. I further sensed Mia placing a greater value on locally generated knowledge because, in this case, her process of planting strawberries had always given her family economic benefits that they had sought. I also viewed Mia as having a distinct sense of differentiation between local knowledge and universal knowledge. The local knowledge is more suited for the locale in which the knowledge is being produced and practiced, whereas universal knowledge is more homogenized and undervalues the local knowledge (Carter and Dediwalage 2010). Mia did not believe that she had to give up her knowledge about planting strawberries to scientific knowledge, because "it works all the time." She was not devaluing scientific knowledge as bad or distinctly inferior to her knowledge about strawberry plants and growth, but she was questioning the authoritative nature of Western scientific knowledge (Rival 2000) as the only valuable knowledge for every context and community. The struggle between local knowledge and Western scientific knowledge is an important component of globalization and we see this tussle taking place in this fifth-grade science class.

Discussion and Implications

As stated earlier in the introduction to the findings, in this chapter, I only present views, experiences, ideas, and real and potential connections that elementary students in these classes made between science and global events, such as the aftermath of the earthquake in Haiti, and science and global processes, such as transportation of food across the territorial boundaries between nations. This chapter does not highlight classroom teachers' attempts to connect science and globalization in their science classes. This does not mean that the teachers were not interested in connecting science to larger global issues, global communities, and global events. Even with much interest, teachers tended not to make such connections, and curriculum materials and state benchmarks support this void.

I do not claim that the students who are represented in this chapter clearly understood all the complexities and meanings of globalization. I also do not claim that these students viewed globalization (the process of interconnection) and globalism (the state of being interconnected) as being distinctly different ideas. However, when elementary students in this study used the terms global, world, other places, distant people, distant places, and other countries, I believe that they were consciously talking about both globalization and globalism that represented them as youths, their culture, and the discourses of both science and globalization.

Making Here and Now Connections Between Science Content and Globalization Issues

To the elementary students in these schools, immediate events seemed more interesting and connected to learning science than how science has the potential to help them in the future. For Jevan and Marco, for example, food was connected to their immediate everyday lives and health. Their comments about imported food and health were connected to their day-to-day well-being, rather than some futuristic health goal, because having enough food to eat each day was more important to them. Many of the students who attend these schools come from transient, homeless, and financially very poor families. In many instances, when I mentioned to the students that science will be useful later in their lives and for making good decisions so that they "can compete globally," the students commented: "that's [a] very long time [from now]," "that's not related to me now," and "I don't think I will get to go to high school." Other students discussed ways the science they learned was useful in their immediate lives: "I liked to know where my food comes from," "learning earthquake helped me know [how] my friend [got] affected," and "know[ing] measurement in America and other place[s] help[ed] me talk to my friend." One student commented that she "won't be coming [to] school no more because [her] parents are going to California [to] pick strawberries…I no need science to pick strawberries." In all these conversations, the students saw science through the lens of immediate value, and their sense of immediate connection was related to global connections as well – such as the earthquake in Haiti or the Hmong and Spanish experiences that their friends shared in the class.

This indicates that science teachers and curriculum developers need to revise their curriculum so that students in the elementary grades see direct connections between the science that they learn and their immediate lives (Upadhyay 2009) – including global connections. In the global context of rapid connections among people, culture, place, and language, there is a need for a school science curriculum that explicitly and critically permits the inclusion of globalization in science instruction. I use the term explicitly to emphasize that elementary students need to know directly from their teacher that the inclusion of global issues in science is permitted and that the students should actively participate in conversations about globalization. This is because many elementary students in poor urban schools are hesitant to deviate from what the teacher explicitly allows for fear of reprimand or noninclusion in science activities. As one of the goals of science education in K-12 settings is to build critical thinking skills in students, the teachers can utilize globalization and globalism as a framework to build criticality in thinking. I believe in this respect globalization fits very well in connecting science to larger global issues related to pollution, poverty, diseases, trade, and communications in science teaching and learning.

Emphasizing the Relationships Between Science and Global Systems in Policy and Curricular Documents

Science policy documents, curriculum, and teacher education and professional development programs need to include how our children in K-12 schooling will understand global systems in their various incarnations over their lifetime. Science and technology will continue to influence our communication modes, culture, transportation, human migration patterns, and access to capital. Sometimes, these influences will have tremendous benefit to almost all of humanity, and other times, these influences will come with a tremendous price to many communities (Nakashima and Roué 2002). Many issues of globalization will become apparent to our students through popular media, such as the Internet, Facebook®, Kindle®, etc., but other more complex issues have to be concretely taught in science classes along with appropriate science content. For example, the complexities of the innovations in green energy and technology, how these may bring cosmological shifts in energy usage and consumption, and hopefully how they may bring great benefits to peoples of poorer nations should be examined with students (Nordgren 2002). On the other hand, how the hybridization of indigenous and local crops as well as the spread of sterilized seeds can be both potentially fatal to traditional crop practices and cultural habits, and bring very marginal economic benefits to these people – for example, the devastating economic effects of the spread of hybridized Minnesota Wild Rice to the Native Americans in Minnesota and the surrounding states in the USA – could also be examined (Vennum 1988).

I found students in this study struggled with complex issues surrounding doing and learning science. Both Marco and Jevan noted personal relationships to people who were territorially separated, but connected to them through food. They recognized that without the efforts of those people, they would not have been able to purchase healthy foods for breakfast, lunch, and dinner. Marco, Jevan, and other students attempted to connect the global system of food transportation and food production to science content. In this instance, the students were trying to connect their science content directly to the process of globalization, and this connection was made possible because the teacher directly asked the students to find out how "food such as berries, bananas, grapes, and cucumbers traveled from other countries" to their kitchen tables. In my opinion, without such direct attempts, the students in this class may not have thought about the global system and the issues of globalization deeply enough to find connections to their own actions. The teachers, Ms. G and Ms. M, took more time to teach science in ways that connected it to global social, cultural, and economic issues (Merryfield 2002) than other teachers whom I have observed and worked with in those schools.

Preserving Knowledge Based on Different Cultures and Promoting Hybrid Self (Identity)

Chet Bowers (2009) described the "cultural commons" as "the forms of knowledge, values, practices, and relationships that have been handed down over generations that have been the basis of individual and community self-sufficiency – and that have enabled members of the community to be less dependent upon a money economy" (p.7). Knowledge that children receive from being well informed about a particular culture's knowledge, traditions, and practices provides invaluable resources and a source of self. When Tara and Mia discussed the validity and usefulness of Mia's traditional knowledge on growing strawberries, the students were engaged in figuring out the value of Mia's cultural commons and the standard school science's cultural commons. The students seemed to recognize that both these cultural commons are valuable even though the cultural commons are different in many respects. Mia's Hmong cultural commons allowed her to make sense of the science she was learning in school and to gain skills to be comfortable in both her Hmong cultural group and the Western science culture taught at school. For Tara, learning and utilizing the skills of science were very important because that was what she was supposed to learn in school to be successful. Tara and Mia present to us the struggle between the local and global cultural commons.

The impact of personal connections makes the local a very significant player in the globalization process. Even though many believe that the purpose of globalization is to promote sameness (McCarthy et al. 2003), there is a significant influence of the local that has to be a part of the globalization process. Tara and Mia made the point that local knowledge has to be linked to the global, so that the knowledge serves the local in a much better way. Furthermore, if the goal of science education at the elementary level is to prepare youths for globalization, science education has to be crafted in ways that help youths to work, think, and interact across cultural boundaries. Sandra Harding (1998) and David Turnbull (1997) have also made similar assertions that all knowledge is spatially situated in specific local conditions and cultural values. Both also argued that all knowledge traditions link people, places, and skills to a specific spatial context. From the point of view of postcolonial and anti-imperialist traditions, knowledge has to sit in the local practices and traditions, and cannot be absorbed into an imperialist archive. However, here, I prefer Turnbull's (1997) argument that knowledge is created to perform something (functional) and, at the same time, represent something (representational) in the local context. Mia's argument fits very well with that of Turnbull's regarding local knowledge production. Mia, in her argument, asserted that the strawberry planting method that she utilized based on her knowledge at home produces strawberries (functional), and it represents the success of her knowledge (representational).

As schools become increasingly multilingual and multinational, teachers must learn to help youth to comfortably travel or cross between multiple cultural boundaries (Glasson 2010). As our school-going youth increasingly come from multilingual and multicultural families, our schools have to promote and privilege multicultural and multilingual identities in students to be successful in an increasingly globalized world. Encouraging teachers, educators, and policymakers to develop and enact policy documents and curriculum materials that emphasize global and local connections in science instructions will not only promote science learning, but also help augment a hybrid identity in students. Enforcing monolingual and monocultural policies in schools will harm our youths and make them lose in all areas of their lives in an era of globalization.

Methodological Issues in Globalization Research Involving Youths as Participants

The emphasis of this study is on children and their ways of connecting to global issues, finding their place in the world, and attempting to be a part of the global community through local actions. Additionally, the study investigates the connections that children attempt to make between science learning in the classroom and the process of globalization in various forms. In this study, I place children and their voices at the center because they are the most avid and sophisticated producers and consumers of the products of globalization. Research about the role of youth cultures in a local context allows communities to understand the meaning of globalization.

Yet, in the age of rapid globalization, youths are seen more as "cultural dupes [rather than as] active creators of their own lives" (Maira and Soep 2005, p. 131). Globalization has viewed youths as consumers, but not as active creators of knowledge and cultures (Giroux 2001). They are also not seen as individuals who correctly "appropriate raw materials of globalization [such as] commodities, mass media, and displacements and turn them into tools for building community"

(Lipsistz 2005). In this study, Dejan and Eileen actively participated in figuring out how to help Haitians as they learned about the sufferings of children in Haiti caused by an earthquake. They used mass media, such as the Internet, newspapers, and television to get information about various aspects of the earthquake and used that knowledge to learn science as well as to energize their class to participate in helping Haitian people in need. The class also used the Internet to find out the products that are imported to the local stores from Haiti. Further, the students used the mass media to find out products imported from other poor nations, such as Vietnam, Ethiopia, and El Salvador. They put those items on the list of things that they could potentially purchase or advertise during parent-teacher meetings and school fund drives. I claim that these actions are evidence of appropriately utilizing the products of globalization to build a more caring community. I also observed that many other teachers in the school followed these students' lead, thus building a new school culture that looked for more global connections in their school.

In research concerning youths as the central figures of globalization, Arjun Appadurai's (1996) idea of cultural globalization is a very powerful theoretical and methodological tool. In his description of cultural globalization, Appadurai coined the term *escape* to account for the cultural forces of globalization. In cultural globalization, escape also accounts for the contribution of culture to be asymmetrical in nature. Appadurai argued that global cultural flows are fluid and dynamic, rather than fixed and finite. Contrary to Appadurai's framework, many researchers studying the effects of globalization with youth participants tend to place youths in either a positive or negative light (Comaroff and Comaroff 2001). However, youths are much more complex, and viewing youths and their interactions as simply positive or negative is a gross oversimplification of the discourses of globalization affecting youths and vice versa.

As an adult researcher, I need to treat these students as subjects who are making sense of school science and the world around them, and also defining and finding ways to deal with globalization. I do believe that these students are very sophisticated, intelligent, passionate, caring, and thoughtful in what they believe science learning means in the globalized context. Therefore, the children in this study are not merely participants who lack sophisticated adult qualities, but individuals in their own ways possessing values and qualities that fit their lives (Maira 2004).

Globalization is a very complex process and requires researchers to draw from multiple methodological and theoretical frameworks. Interdisciplinarity of scholarship is required to understand and inform the intersections and connections between science education and globalization. Youth cultural research can inform science education in framing globalization as an integral part of science teaching and learning, as well as researching the effects of globalization on the meaning of science learning for youths. In this regard, ethnography, case studies, and reflexivity, to name a few, are all well-founded research methodologies that could guide future work in globalization. Similarly, methods of data collection and analysis have to be multilayered as well. For example, contemporary youths are avid consumers and users of mass media; thus, methods such as videotapes, Wikis, Blogs, Facebook, and Twitter are all very useful tools of data collection and analysis processes.

Researching and writing on globalization necessitates the employment of varied theoretical frameworks, such as identity, critical theories, feminist theories, cultural theories, social theories, and political theories. Science education researchers and educators need to be open to bringing multiple theories to make sense of science education and globalization. In future work in science education where youths are the major participants, researchers need to treat "youth" as a socially created category in which the market plays an important role in framing their identity (Cohen 1997). As adult researchers, we need to recognize that youths are able to construct their own meanings about globalization utilizing all the materials that are available to them through various media, organizations, social networks, and cultural transactions. Therefore, youth voices and youth identities have to be appropriately acknowledged in any science education research project related to globalization.

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Chapter 8
International Response for Part II: Globalisation and Science Education: A View from the Periphery*

Lyn Carter

The Complexity of Globalisation

With chapters from Alejandro Gallard Martínez, Bhaskar Upadhyay and Sonya Martin and her colleagues in this volume, we welcome three worthy contributions to the nascent field of globalisation and science education. The geopolitical, economic and sociocultural complexity that is the twenty-first century has demanded globalisation become part of the lexicon of science education scholarship and practice. Yet globalisation itself is a complex, contested and highly unstable notion whose conceptual terrain and content are far from determined. Rohan Kaylan (2010) reminds us that globalisation "signifies nothing other than itself… [and as an] impossibly wide term, includ[es] everything… [and] is as flexible as it is pervasive." For him, the global has become a placeholder that "designates a kind of newness, a potentiality, [and] one that is impossible to separate from its virtuality: [that is] its distribution of images, discourses, and signs" (p. 546). Virtual or real, as we all know, its effects are felt everywhere these days! Since education (read science education) is a constituent of both the virtual and the real, education and globalisation are necessarily mutually entwined categories where globalisation has become the macro level sets of forces shaping the conditions for and being expressed within science education, and science education circulates and indigenises globalisation. Mapping these effects real or virtual, let alone proactively addressing their outcomes, is certainly science education's major challenge for the twenty-first century.

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*In Australia, globalisation is spelt with an 's' rather than a 'z' as in globalization. This simple letter change encompasses the very complexity of globalisation itself in that it is indigenised in all its possible settings.

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Despite globalisation's nebulous state, it is useful to start as the authors have done here, with some view as to what globalisation may encompass. Upadhyay tackles this task admirably with his thoughtful and useful discussion of globalisation as *deterritorialisation, interconnectedness* and *space-time compressions*. However, I am following Gerard Delanty (2000), Fredric Jameson (1998) and many others who view globalisation instead as the recent transformations of innovations and ideas broadly grouped into the twin categories of geopolitical and economic changes as well as sociocultural upheavals. I do this as it helps structure my response here but also because it utilises another conceptualisation of globalisation of which there are many within the literature.

Within Delanty's (2000) and Jameson's (1998) first category, the processes of convergence foster an increasingly hegemonic homogenisation embodied in the growth of neoliberal market ideologies and of supranational regulation, the extension of the enterprise form to scientific and technological innovation and the expansion of Western-style capitalism and culture. These ideas and practices have been applied to education, and hence science education, through the adoption of market regulatory procedures like curriculum and teacher standards, funding arrangements, introduction of charter schools with their focus on individualisation, and test performance and hierarchical league tables that lead to closure for underperforming schools. This neoliberal reform of education and its impact on teaching and learning, while discussed at length in the policy and other educational literatures, are only just beginning to feature in science education scholarship (see e.g. Bencze 2008; Carr and Thésée 2008; Carter 2005, 2008; Tobin 2011). Neoliberalism reduces science education to 'goods and services' able to be transacted in the market place, while neoconservatism ensures that the perspectives and advantages of traditional power elites are retained despite moves to ensure greater equity and social justice through education. Certainly, Gallard Martínez's chapter adds to this literature, reminding us of the high price paid by the have-nots of geopolitical/economic globalisation.

Sociocultural characterisations, on the other hand, emphasise the divergence in local adaptations of larger global forces. Cultural diversity, identity, cosmopolitanism, indigeneity, fragmentation, hybridity, deterritorialisation, mobility and interstitiality become the leitmotifs of the global age. There is, pleasingly, more science education research tackling these complex issues. Indeed, a casual glance through the titles of the prominent science education journals will identify articles from science education scholars that engage with the issues of diversity and so could easily be collected under the umbrella of sociocultural globalisation. Here, I speak of work from researchers like Pauline Chin (2006), Sun Won Hwang and Wolff-Michael Roth (2008), Olugbemiro Jegede and Glen Aikenhead (1999), just to name a few. Moreover, the increasing scholarship in globalisation and science education has been elaborated in three special editions of the *Cultural Studies of Science Education* (*CSSE*). The first issue published in 2008 (Vol. 3, Number 1) focussed on "why and how the notion of identity can be helpful in tracing the trajectories of people teaching and learning science" (Lee and Roth 2008, p. 14). The second produced last year (Vol. 5, Number 2) worked on the theme of globalisation as "authors explored ways in which individual teachers, students, and their communities were experiencing the affects of globalization on science education within differing local contexts" (Martin 2010, p. 264). The final issue published in 2011 (Vol. 6, Number 1) looks at urban science education as a manifestation of globalisation. In addition to a 2011 issue of the *Journal of Research in Science Teaching* (Vol. 48, Number 6) devoted to globalisation and science education, many other articles and book chapters are beginning to appear. Martin, Wassell and Scantlebury's chapter with its focus on migration, diversity and language interstitiality would fit well within this strand of sociocultural globalisation.

Globalisation, then, can be thought of as a complex dialectic of both geopolitical-economic and sociocultural transformations that are still to be fully configured even as they work themselves into the materiality of the everyday (Jameson 1998).

Conceptualising Globalisation: A *Wicked Problem*?

Kalyan (2010) argues that globalisation's indeterminacy opens the door to many different interpretations, and uses of the term, underpinned by contesting and competing ideological interpretations, numerous paradigms and theoretical models. In addition to Upadhyay's description and the categories presented by Delanty (2000) and Jameson (1998), a more recent way to conceive globalisation is to view it as a *wicked problem* (for a fuller discussion, see Carter 2011). The notion of the wicked problem was first proposed in 1973 by the urban planners Horst Rittel and Melvin Webber from the University of California, Berkeley, to describe the inability of the paradigmatic mode of technical rationality to tackle real-life conditions that are complicated, uncertain and unstable. Rittel and Webber (1973) provided 10 criteria for characterising a wicked problem that might be summarised as dynamic and interlocking issues that lack definitional clarity because multiple stakeholders in shifting social contexts have different interpretations and seek different outcomes. Surely, globalisation is such an example *par excellence* characterised as it is by its multicausal, multidimensional and transdisciplinary nature; its instability; its social complexity; its forced behavioural change; and its endemic climate of uncertainty. Looking a little deeper into some wicked problems already identified in the literature like climate change, land degradation, indigenous rights, global financial crisis, GM foods, health care and 'war on terror', we can see that globalisation underpins and is responsible for many of them. Indeed, globalisation may itself be the *ur*-problem, that is, the wickedest of a wicked bunch.

Being aware of our own conceptualisations of globalisation whether as a wicked problem or otherwise[1] is important. The global constitutes its own content in the various fields in which it gets deployed, selectively affirming particular images and

[1] Other conceptualisations of globalisation within the literature range from modernity through alternative modernities to postmodernity, postindustrialism, postmaterialism, cosmopolitanism, universalism, governance, fundamentalism and so on.

representations, while denying, repressing or otherwise excluding others. When science educators use the word 'globalisation' in pedagogical research or policy contexts, it carries with it all types of assumptions and repressions be they ideological or indeed economic, political, social or cultural. Joseph Zajda (2006) contends that if taken uncritically at face value, scholarship on globalisation and education risks the development of a *globocratic* (in the sense of being technocratic) sensibility. The politics of globalisation, he goes on to argue, particularly the hydra of ideologies inscribed in the discourses of globalisation, need to be analysed critically to avoid superficial and one-dimensional interpretations that will ultimately limit (science) education scholarship.

This deeper consideration is also necessary, I believe, to avoid globalisation becoming a type of 'bolt-on' topic within science education, which already has a vast research and praxis agenda. After all, the complexities of globalisation demand that a 'business as usual' approach will not do. This is similar to the thought often attributed to Albert Einstein that we cannot solve problems by utilising the same kinds of thinking that created the problems in the first place. The task of elaborating globalisation and science education requires a reimagining of its conceptual spaces to which these three chapters fully contribute. Unfortunately, as Jay Lemke (2001) believes, many science education scholars are not well equipped for such tasks as their backgrounds in cognitive psychology limit their focus to a narrow range of rationally framed concerns. There could well be conceptual difficulty, as well as perhaps some unwillingness, to move beyond science education's conventional categories of analysis and explore the impact of the changing theoretical and global landscape. Science education's deeply rooted dependence upon restricted social and cultural forms needs to change in the new reality of globalisation.

Globalisation in Australian Education

In responding to the three chapters in this part, I was asked to reflect upon similarities they raised to globalisation issues from my own part of the world. Australia, from where I write, is both literally and figuratively a long way from the centre from which globalising forces emanate. It is in the unique position of being a modern and affluent Western democracy with all the economic/political, sociocultural and technoscientific capital available under globalisation. It is geographically Asian, multicultural in demographics and with strong cultural referents that look back to the United Kingdom. The Indigenous Australians (Australian Aboriginals) are the world's oldest continuous human culture, and we live within the most ancient eroded and driest landscape on Earth. Our more recent settler-state history casts us as a postcolonial society with all the multiple identities and fusions that that entails. We are an English-speaking outpost, globalisation's language of choice, but as voracious travellers, we also know the world better than many. With only about 22 million consumers (deliberately chosen terminology), despite our affluence, we are too small a market to figure very significantly on the global radar. Nonetheless, our massive natural resources in iron, coal, uranium and the like provide many countries, particularly our largest trading partner China, with the wherewithal to fuel the world's market economy. The raw materials trade along with our tightly regulated financial sector ensured we were the only developed country to avoid recession in the recent financial crisis. This cultural and geographical positioning gives us a sense of looking back from the periphery to the centre, with perhaps the allusion that we can select from the array of what is on offer. Together, these features afford Australians a significant amount of conceptual distance and space, allowing our scholars a distinctive take on how globalisation works its way into the materiality of the everyday.

That said, the global geopolitical and economic orthodoxies of neoliberalism and neoconservatism discussed in Gallard Martínez's chapter feature prominently within our education system, though differently manifest from other countries. In a complicated arrangement between the state and federal governments, educational funding at roughly the same per capita figures as the USA and the United Kingdom is distributed according to socioeconomic status (SES scores), although that is now being reviewed. Neoliberal moves to decentralise the public schools' organisational arrangements exist alongside centralising, accountability and regulatory mechanisms that include developing standards for everything, the introduction of a homogenised national curriculum and recently implemented national testing programmes in numeracy and literacy (NAPLAN). The NAPLAN results and other metrics are published on a website known as *My School* that acts as a de facto league ladder of school performance. These moves have caused controversy in the Australian educational community, as we do not have a strong tradition of standardised testing. Nonetheless, we perform well in (neoliberally inspired) international testing and are to be found within the top 10 for science and reading and top 15 in mathematics in the 2009 OECD Programme for International Student Assessments (PISA). These results are significantly higher than the United Kingdom and the USA and comparable to Canada and New Zealand, which have similar settle-state histories to our own.

Gallard Martínez's other focus on inequality also finds resonance within the Australian context but with our own local nuances. Sources of inequity include remoteness (Australia is around the same land size as the USA but with its 22 million people largely hugging the south-eastern seaboard, nearly everywhere is remote!), indigeneity (particularly when combined with remoteness), low SES and diversity from the multicultural mix of the school population. As a point of departure, the notion of 'race', as Bill Atweh (2011) suggests,

> is not often used [at least in current literature] to describe distinctions between groups of people and consequently does not figure as prominently in our education discourse. For sure, this is neither to say that social tensions do not arise from perceived racial differences within the Australian society nor to ignore the suffering of some groups of people as a result of their perceived race. I take the stance that racism is alive and well within the Australian society. (p. 38)

Certainly, the 2005–2007 Australian Bureau of Statistics figures endorse this perspective particularly when it comes to Indigenous Australians. The figures suggest that while Aborigines constitute only 2.6% of Australia's total population, an indigenous person is 11 times more likely to be in prison and twice as likely to be a victim of violent crime. Only 39% of Indigenous Australians remain in school until year 12, compared to 75% of non-indigenous people. A mere 4% of Indigenous Australians hold a bachelor's degree or higher. In response, the Australian government has formulated the National Aboriginal and Torres Strait Islander Education Policy (AEP) to mixed success. Chronic unemployment, alcoholism and substance abuse are all systemic in some communities, and overall, life expectancy of the average Aboriginal male is around 12 years less than the rest of the Australian community. Our own inequalities are not something of which we can be proud!

As a largely e|im|migrant (to borrow Martin and colleagues' notation) society from about the late 1700s, Australia has had a much chequered history. Fears of the early British and Irish settlers being 'overrun' by Asian and Pacific islanders as cheap labour led to the highly discriminatory 1901 White Australia Policy which officially lasted until 1973. The policy aimed to keep Australia culturally, ethnically and linguistically uniform. It was successful at its task until the end of World War II when Australia began to encourage displaced western and middle European e|im|migrants in addition to those from the United Kingdom in the belief we had to 'populate or perish'. These people flows lasted well into the 1970s until Australia's part in another war brought with it a new diaspora from South East Asia. With the demise of the White Australia Policy, the Vietnamese led the way to flows of people from all over the world such that Australia has now become very multicultural. Unlike the USA though, Australia does not have significant numbers of Latinos/as.

Our e|im|migration brought with it the same issues Martin, Wassell and Scantlebury identify for English language learners (ELL) as children come into Australian schools with little or no English. English for many of these students would also be their third or fourth language. Despite the increasing linguistic and cultural diversity of our schools, teacher pre-service degrees offer little preparation in ELL. These courses of study are usually electives or offered as postgraduate specialisations for teachers returning to further study. Hence, many teachers, particularly discipline teachers like those of science, are ill prepared to cope with ELL students in their classrooms. Martin and her colleagues' focus on South East Asia also has resonance for Australia. South East Asia is our closet neighbour (baring New Zealand) and is a place where many Australians go to work, to holiday and to pass through as a stopover to Europe. We have an increasing affinity with the region, and most Australian schools offer Asian languages –particularly Mandarin or Cantonese Chinese, Indonesian and Japanese as foreign language studies. Our politicians certainly see Australia's economic and social future as being regional. With China already our largest trading partner, and with strong ties with India through our colonial pasts and the bonding effect of India and Australia's most revered game – here I speak of cricket – not to mention Australian universities as major destinations for students from the subcontinent, we are already inextricably linked to these two powerhouses of globalisation.

In light of increasing global mobility, Martin and her colleagues' calls for more research in the area are fundamental. Their proposal of intersectionality as method seems to offer excellent promise as a means to consider the complex identities of students impacted by migration and other aspects of globalisation. These authors also rightly identify the macro, meso and micro levels of globalisation, but we need to go further and explore the dynamic and iterative relationships between the global and local so that policy, pedagogy and curriculum make explicit the specific links between globalisation and science. It is in this area that Upadhyay's chapter makes its excellent contribution and rounds out the trio's focus of globalisation and science education. Upadhyay's research is unique as there are hardly any studies that purposely represent globalisation in science education classrooms and investigate students' understandings of the phenomena. Upadhyay rightly reminds us that, in any case, youths are constructing their own meanings about globalisation from available resources like the media and social networking. It is incumbent on us as teachers, in general, and science teachers, in particular, to do as both Upadhyay and Gallard Martínez implore and make explicit globalisation's ideologies, theories and politics within the classroom so students can become increasingly knowledgeable about the origins of its inequalities and its effects. As scholars, we also need to be highly analytical and canny in our research to avoid globalisation 'bolting-on'.

After all, what we want from science education, don't we, is to help citizens and civil society contribute to the building of a fairer, sustainable and more democratic coexistence of human beings in a global world that will only intensify further.

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Part III
Introduction: Context and Culture

Alberto J. Rodriguez (Lead Editor) and Okhee Lee (Co-editor)

The authors in this part encourage us to explore notions of culture, context, place-based learning, and equity in the science classroom. Even though these concepts are inextricably connected, we seldom see them addressed in depth. If we are to seriously address issues of equity in the science classroom, we must become better researchers of how cultures interact and are (re)shaped within given contexts for neither of these constructs are ever static. Therefore, the goal is not to seek a Western science approach of "controlling/defining" the complexity of how individuals' cultures may manifest themselves in given contexts but to "capture" a glimpse of this complexity in a moment in time. This glimpse could then be used to continue informing the creation of multiple spaces for place-based learning. That is, spaces where individuals could consume and produce knowledge as we were meant to as independent thinkers—critically, authentically, and always engaged in collaborative discourse. I believe that Sonia Nieto describes best the organic nature of culture. Culture is the "ever changing values, traditions, social and political relationships, and worldview created, shared, and transformed by a group of people bound together by a combination of factors that can include a common history, geographic location, language, social class and religion" (Nieto 1999, p. 48).

To illustrate how an individual's culture provides another lens for meaning making, Leon Walls, Gayle Buck, and Valarie Akerson describe in their chapter the similarities and differences between traditionally marginalized students'

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conceptions of the nature of science (NOS) and those of students from mainstream backgrounds. By using a critical theory lens to interpret marginalized students' multiple socioculturally based understandings of the NOS, Walls, Buck, and Akerson make a strong case for the need for more research in this area.

Similarly, in their chapter, Eileen Carlton Parsons and Gillian Bayne point to the importance of better understanding the context in which culturally diverse students learn. They draw from multiple theoretical perspectives to interrogate two conceptualizations of context and then recast this construct by "zooming in" and "zooming out" of the multiple spheres of influence in which context evolves. As mentioned above, context is not a static construct, and it takes shape through an individual's sense of agency (or lack thereof) within it. Parsons and Bayne argue that a multilayered understanding of context will not only help create more effective policies and learning opportunities for culturally diverse students but it will also assist in generating a deeper understanding of the historical, institutional, and social factors that fuel the current educational inequities we observe today.

From students' conceptualizations of the nature of science to exploring the multiple layers of context in the first two chapters, Gayle Buck and Cassie Quigley point the researcher's lens inward in their chapter. In other words, they use a reflexive approach to investigate their own theoretical and methodological assumptions as they conducted research with African American girls in a public girls' school. They provide an important model for how science education scholars could engage in meaningful and collaborative self-study that could lead to enhanced professional growth and more rigorous and socially relevant research.

In the last chapter for this part, Miyoun Lim, Edna Tan, and Angela Calabrese Barton demonstrate how students can more meaningfully engage with science content knowledge when given opportunities to (co-)author their own learning experiences. These hybrid spaces—where the traditional and expected Western science content knowledge becomes just another tool for meaning making and not the driving force of the teacher-learner relationship—enable students to envision the critical role they could (should) play as consumers and producers of knowledge.

Finally, the international commentator, Tali Tal, provides an insightful review of these chapters. She contrasts some of the authors' key points with similar issues occurring in the Israeli educational context. Her commentary makes us realize the importance of continuing the kind of cross-border conversations being promoted in this volume, as our notions of *context and culture* are indeed influenced by similar political, social, and cultural factors.

The authors have raised excellent questions for further study in their respective chapters. I would like to recast some of them and add a few more here. If we agree that culture and context are organic and always in flux and if we agree that culture and context influence student learning, what are the implications of these insights on the extensive research that has already been conducted on the nature of science? In what ways does the work presented by Walls, Buck, and Akerson in their chapter help instigate more research on culturally diverse students' understanding of the nature of science?

What are the methodological implications for researchers interested in working in culturally diverse settings if the context in which their study takes place is so multilayered and complex? In what ways does Parsons and Bayne's chapter provide suggestions for how researchers can become more skillful at zooming in and zooming out of the multiple context spheres in which individuals construct knowledge?

Similar to the above question, what are the methodological implications for researchers interested in working in culturally diverse settings when they also choose to become the subject of study? In other words, instead of only studying the other, Buck and Quigley ask us to consider, through a reflexive approach, what our findings might look like if we were to include in the final analysis how our involvement in the research enterprise also transforms us.

Finally, if we agree that culture and context are organic and always in flux and if we agree that culture and context influence student learning, then Lim, Tan, and Calabrese Barton's work indicates how the multiplicity of knowledge construction is not "lightening to be caught in a bottle" through research. Instead, the theoretical framework and methodologies guiding the research enterprise must also be organic and responsive to the evolving contexts. In this way, the traditional boundaries between the (presumed) detached researcher/observer and the researched/observed are blurred. What are the implications then for the purpose of our equity research in culturally diverse settings? To capture a stream of "facts" as constructed through a (supposedly) fixed, detached, and Western-style equation (theoretical framework + methodology = robust findings), or to work with the other in their specific contexts to assist them in enacting transformative change? What theoretical frameworks and methodologies could then best inform this approach?

In order to explore these and other questions raised by the authors of *Context and Culture*, we need to more carefully document the successes, as well as the obstacles, encountered in our research enterprise. To that end, we need to expand our notions of context, culture, equity, and place-based learning—these chapters provide a good start.

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Chapter 9
Race, Culture, Gender, and Nature of Science in Elementary Settings

Leon Walls, Gayle A. Buck, and Valarie L. Akerson

We begin this chapter with the simple assertion that science education in the USA has a problem, but as in most cases, this simple assertion is a bit more complicated than it seems. Even calling it *a* problem is misleading; it is really more appropriately described as three, like the legs of a stool. The first is highlighted clearly in the reality that race, culture, and gender continue to influence not only those who can access quality school science instruction, but also those who ultimately will become the producers of scientific knowledge. At almost every turn, from the learning of elementary science to choosing careers, the enterprise of science education has failed to adequately prepare and subsequently attract members of diverse populations to join the ranks of scientists and engineers. This is partially attributed to the fact that economically disadvantaged girls and students of color continue to be hindered by different aspects of oppression within the US formal K-12 science education program.

The second part of this triad comes in the form of a looming reality that birth rate forecasts indicate further exacerbation of the condition just described. By the mid-century, the nation's racial and ethnic mix, including diversity in the country's classrooms, will look quite different than it does today. Non-Hispanic Whites, who made up 67% of the population in 2005 will decrease to 47%, Hispanics will increase

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from 14% in 2005 to 29%, Blacks at 13% in 2005 will remain roughly the same, and Asians at 5% in 2005 will increase to 9% (Passel and Cohn 2008). In several states, such as Texas, California, New Mexico, and Hawaii, there already exists a majority-minority population. Females in general have never been a numerical minority in the USA because they comprise better than 50% of the population. Yet, it is also true that females have suffered in K-12 science education (Baker 2002), resulting in a dearth of representation in science and engineering careers (American Association of University Women 2004), particularly for women of color and low-SES backgrounds. Therefore, the real dilemma is how to equitably treat, effectively teach, and successfully engage those whom we have excluded and prevented from receiving equal access earlier.

The third problem we will explore, arguably the least understood of the three, is the nature of science (NOS). The term *science* itself evokes different images in different people when challenged to define it for themselves. Accompanying these images are formed beliefs that when combined shape an individual's understanding of where scientific knowledge comes from; how scientific knowledge is used; who uses scientific knowledge, including scientists and their work; and most importantly, where individuals place themselves in the community of users and producers of scientific knowledge. It should be well understood that NOS conceptions are specific to the experiences of each individual, thereby explaining why each of our NOS conceptions would be expected to differ based on the uniqueness of our individual experiences. Norman Lederman (1992) defines NOS as typically referring to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development. From NOS research into elementary teachers' conceptions (Akerson et al. 2009) and elementary students' conceptions (Walls 2012), we have come away with a greater understanding of the NOS conceptions for both. One conclusion is clear – many in the K-6 system hold naïve and not fully mature conceptions about the NOS, but these conceptions can be improved as a result of appropriate instruction. However, fully understanding those conceptions about NOS and the educational experiences needed to enhance such conceptions is a discussion that needs to be more completely explored with regard to race, culture, and gender.

The purpose of this chapter is to explore the open-ended question "what do elementary students understand about NOS?" in a manner that deliberately foregrounds equity issues. We acknowledge that there is no single definition of NOS upon which all scholars will agree; in addition, there are different presumptions about the world that would impact any of those definitions. Indeed, the very discussion of NOS itself is only beginning to be explored with regard to diverse perspectives. However, we limit our discussion to the aspects of NOS that are emphasized in national and international K-6 science education standards documents and have been widely discussed in the literature (NRC 1996). These aspects are further explored in the later sections of this chapter. The discussion that follows addresses the theoretical and empirical aspects of elementary students' contemporary NOS understandings, elucidating the role of university personnel actively seeking to meet the science education needs of *all* children.

Theoretical Discussion

To initiate our development of a response to the research question guiding this discussion, we first examine what contemporary theoretical discussions are contributing to our understanding of the question itself. In the section that follows, we explore the underlying purpose of asking such a question through a critical theory lens. We follow this by exploring how the increasingly sophisticated ways in which students' identities are being theorized influence our very understanding of elementary students.

Critical Theory

An important theoretical thread woven into our work as researchers and aligning our vision toward equity is critical theory. Critical theory refers to one of the series of approaches to the study of culture, literature, and thought that developed during the 1960s. The basis of this theory lies primarily in the act of questioning and challenging commonly accepted cultural and societal norms. While traditional researchers seek out neutrality, critical theory researchers frequently announce their partisanship in the struggle for a better world (Kincheloe 2001). Critical theory research can best be understood in the context of the empowerment of individuals. Critical theory researchers often use their work as a first step toward forms of political action that can redress the injustices found in the field site or constructed in the very act of research itself. In other words, the critical theory researcher is never satisfied with merely increasing knowledge (Horkheimer 1972). Therefore, the importance of all research is best seen from a transformative-oriented perspective. It is not enough to simply gain insight into what elementary students understand about NOS for the sake of that knowledge; it must be used to ultimately inform how and what we teach them.

Solutions addressing how to transform the ways we teach science to all children must involve *all* children. This is particularly true in light of our collective failure thus far to provide equitable science instruction along racial, cultural, and gender lines in our classrooms (Aikenhead 1996; Kahle and Meece 1994; Norman 1998). Even though reform efforts have turned a bright light on this stark reality for some time, not everyone shares the same sense of urgency to change it. In NOS research, the end game, of course, is to accurately assess individuals' conceptions of science. In our case, these individuals are children in the K-6 elementary grades. With the goal of science literacy as an outcome, identifying the science conceptions of young children is an essential step in crafting effective instruction for them. It is not by accident that our research questions foreground race, culture, and gender. Supporting this effort is a basic tenet of all research, which states that it is the research question that guides the investigation and determines how data are collected, analyzed, and what outcomes will ultimately be uncovered (Patton 1990). In short, that which is not questioned cannot be answered. In a review of more than four decades of published US NOS research, Walls and Bryan (2009) uncovered several noteworthy findings. In that review, the research question posed was simply, “Who were the US participants (racially) that took part in these foundational and seminal studies?” One of their findings was that of the 54 studies they reviewed, only four contained within them research questions specific to race or ethnicity. The question of race as a potential factor impacting and shaping children’s science conceptions appears to some to have been satisfactorily resolved. However, research that contains very few race-driven questions and very few numbers of racially defined participants does not suggest that such resolve is warranted. The researchers concluded that the decision to report the participants’ race appears to have been done arbitrarily, with no clear pattern or rationale for doing so. An additional finding was that the race of the majority of the participants was, in fact, not reported. However, when it was, the overwhelming majority of those taking part in research to uncover NOS views were White. African Americans, on the other hand, at <.1%, were the least represented racially identified group. Even questions specific to conceptions along gender lines were, in essence, absent from the reviewed studies. Yet, interestingly, when an actual tally of participants by gender was completed, it was found that over half of the participants were female.

The work that we present in this chapter is reflective of our complete agreement with this bedrock notion of questioning and challenging the commonly accepted norm of seeking science education for all. We do this by addressing the differences that are often not included in the term *all*.

Interactional Framework

As critical theorists, we believe that although research on NOS conceptions and teaching NOS is extensive, we will continue to be limited in our understandings as long as we persist in ignoring race, culture, or gender. We proceed to address these constructs of diversity; however, we are doing so cognizant of the fact that students are not simply of *a* race, *a* culture, or *a* gender, but are human beings affected by the interaction of all these systems. Therefore, our response necessitates that we approach our desire to foreground race, culture, and gender understanding of NOS in a new way. Our definition of elementary students has been enhanced by our attempts to respond to calls to consider race, culture, and gender in *systems of power* (Anderson and Collins 2007) as explained below.

We attempt to create a *system of power* underpinning for this discussion in three ways. First, our discussion does not define populations of students as the victims. Although many children in our school systems are subject to various forms of oppression, it is not oppression that defines them in our discussion. Instead, throughout this discussion, we acknowledge that we are all victims in a system of oppression, and therefore, we all must work to assure a more equitable system. Remaining ignorant of the understandings of any group of children affects negatively the understanding of the educational community as a whole and may lead to inadequate educational planning and teacher development (to name a few).

Second, our discussion of students is not directed by how any particular student or group of students compare to a norm. The literature based on NOS education is robust, and if we allow what we already know about one population to frame how we interpret the experiences of others, we risk losing many unique frameworks of understandings. Instead, we seek to not only add to the base, but redirect the discussion away from a norm group of elementary students, directing it in a manner that allows us in the science education community to understand multiple frameworks.

Third, we do not use an additive perspective in describing elementary students. As noted earlier, these children are affected by race, culture, and gender. Removing them from the system and placing them in a dichotomy, and often hierarchy, of oppression may open a discussion that leads to an even greater level of ignorance (Anderson and Collins 2007). For example, taking the NOS understandings of a group of African Americans (not focusing specifically on the girls within that group) and adding the understandings of a group of girls (not focusing specifically on the African Americans within the group) does not lead to the unique understandings of African American girls. Alberto Rodriguez (1997) argued for the importance of collecting data by gender WITHIN the ethnic groups, in which he found some differences in performance by African American girls that were missed by homogenizing all girls into one gender category. In addition, Cheryl Leggon (2006) highlighted the fallacy of collecting data that focuses on "minorities and women." She pointed out that the traditional way in which data such as those pertaining to the science workforce have been collected by race/ethnicity OR gender, but not by race/ethnicity AND gender, is problematic. One result of data collected this way is that "minority women" tend to disappear among aggregates of all women, or all members of a particular ethnic group (MacLachlan 2000). To discuss "women" or, for that matter, "women and minorities" as is commonly done in research discussions, "both reflects and reinforces the invisibility of minority women in science" (Leggon 2006, p. 325). African American girls from a poor urban district are a unique group, as are Latina girls from a rural district and first-generation Black males from suburban districts.

Our goal and efforts are guided by our desire to adopt a more inclusive view of elementary children – one that pays attention to the group experiences of many that are influencing and being influenced by race, culture, and gender. We do this in the following pages by deliberately addressing the fact that elementary students' understandings are situated within a social structure, and by acknowledging that the intersection of race, culture, and gender are manifested differently depending on their configuration with the other (Anderson and Collins 2007).

Empirical Discussions in the Contemporary Literature Base

We have explored the open-ended question "what do elementary students understand about NOS?" within the existing research base. Each of these studies has contributed to our understanding in some manner. We now look across these studies and bring in various aspects of the readings to deliberately foreground equity issues in NOS research overall.

Nature of Science as a Long Tradition

The connection between a student's understanding of NOS and his/her ability to learn school science has been explored (Meichtry 1992). The conclusions from this and other works have established a link that posits that successfully learning science in formal school settings is a more likely measurable outcome for a student with a healthy and mature sense of NOS than one with more naïve views. With the relationship between NOS understanding and learning science in mind, science education researchers (Abd-El-Khalick et al. 1998) and science organizations (NRC 1996) have placed great importance on teaching students to develop appropriate conceptions of NOS. These efforts have produced a general set of aspects characterizing scientific knowledge that should be taught in the science classroom. Though specific items that make up the set of aspects may vary slightly from one research study to another, the following list is representative of generally accepted tenets: (a) scientific knowledge is tentative, (b) scientific knowledge is empirically based, (c) scientific knowledge is subjective, (d) scientific knowledge is partly the product of human inference, imagination, and creativity, (e) scientific knowledge is socially and culturally embedded, (f) and scientific knowledge necessarily involves a combination of observation and inferences (Osborne et al. 2003).

The literature review established, in general, that students' NOS conceptions are inadequate and, therefore, a source of concern for science education reform advocates. It also illustrates the important role that constructivist pedagogical theory plays in helping transform student NOS understandings into desirable levels of science literacy. Included in a student's overall science literacy is the ability to more effectively and proficiently learn science in a formal K-12 setting. However, research on students' NOS conceptions has also identified gaps in the literature. There is a need for more research on (a) children from diverse systems of power and (b) elementary children. One reason for the lack of studies on the science conceptions of very young children is the difficulty in constructing instruments capable of accurately assessing those views. Continuing that line of deduction also leads us to include item (a) from above as an influence on item (b) as well. If diverse groups of students are not significantly represented among those who have been assessed with current NOS instruments, it must be inferred that the instruments are not inclusive of the cultural differences inherent to these groups.

Nature of Science Gaining National Importance

Research has consistently called for the establishment of adequate NOS conceptions as the foundation needed for increased science literacy for *all* students. However, this sought-after objective has not been achieved in part because underrepresented populations have not experienced the same levels of inclusion and, as a result, the same levels of academic achievement in K-12 classrooms as their White male classmates. However, when it comes to NOS research, there have been signs of progress on this front. For example, Walls and Bryan (2009) reported that over half of the total numbers of participants in their review of NOS studies were female. Additionally, the gender of the participants was reported in 78% of all the studies reviewed. Unfortunately, the study also revealed that race continues to be a more difficult issue to confront, which in turn affects the understandings associated with gender in overall science education reform efforts. It has also been noted that not only was the race of the participants reported in studies less often (24% of the time, when compared with 78% for gender), but racial representation itself was missing. Out of a total of 847 participants identified by race, 819 (97%) were White, 21 (2%) were Latino/a, 6 (<1%) were Asian, and 1 (<.1%) was African American. The goal of science literacy will remain factually unattainable if no change in the research agenda is made to address culture, gender, and nature of science.

Striving for a more inclusive school science classroom, researchers and science organizations have acknowledged a historical reality – females and students of color have been routinely underserved in US science education (Bryan and Atwater 2002). This same research has shown that the marginalization of ethnically and linguistically diverse groups has contributed to their lack of interest in science, lack of academic success in mastering scientific concepts, and ultimately, to a dearth of representation by these group members in traditional science-based professions. For example, Muller et al. (2001) examined data from the first three waves of the National Education Longitudinal Study (NELS) in an effort to gain insight into how race-by-gender subgroups (e.g., African American men or Latina women) differed in mathematics, science, and engineering education. The authors looked specifically at factors identified in previous research and the relationship of those factors to eighth-grade science achievement and growth rate in precollege science. The findings indicated that African American eighth graders' mean science achievement was lower than that of all other racial groups. Additionally, African Americans' annual mean growth rate was extremely low – so low that, by twelfth grade, they still had not reached the mean science achievement that Asian Americans or Whites had attained by eighth grade. What is highlighted is that without possessing a fully developed and mature view of the scientific enterprise, including scientific knowledge usage and production (NOS), attaining science literacy becomes problematic. The goal of NOS research ultimately is to be a catalyst for increasing scientific literacy for all K-12 students by first ensuring that NOS conceptions of *all* students are considered in the research phase. Success in achieving this goal rests upon a thorough understanding of not only the various factors that affect and shape individual and group conceptions of the NOS, but also an understanding of the cultures and norms of the individuals and groups.

Race and gender have been identified and documented as factors that contribute to disparate experiences and academic outcomes in science classrooms (Center for Research on Education, Diversity, and Excellence [CREDE] 2002). It is, therefore, reasonable to hypothesize that NOS conceptions constructed along racial and gender lines would be equally disparate, when compared to those held by populations represented in current US NOS research. Michael Reiss (as cited in Bentley et al. 2007) agrees when he argues that every science is an *ethnoscience,* such that "a scientist's *perceptions* of the natural world, as well as her interpretations, come through her senses, herself, as a person, and her culture. There is no single, universal, acultural science" (Reiss 1993, p. 24). With the typical classroom portrait becoming increasingly diverse, studies of students' conceptions of NOS should better reflect the diversity of our population.

An equally important consideration related to the research on the NOS conceptions of a more diverse population are the NOS conceptions of very young learners of science. Few NOS studies have focused on examining NOS conceptions of elementary students in grades below fourth grade. Without investigating the formative and foundational NOS conceptions held by the very young learners of science, teaching NOS in hopes of shaping those conceptions in subsequent years is less likely to succeed. This pedagogical theory is in accordance with extensive research into constructivist learning and pedagogical theory. A key component of learning emphasized in constructivism is the significance of each individual learner's previous knowledge and experiences in subsequent learning (Bischoff and Anderson 2001). If it is important to address NOS to improve scientific literacy, then it is of equal importance to know as early as possible the prior NOS views held by the learner. As David Ausubel and Floyd Robinson (1971) stated,

> The most important factor influencing the meaningful learning of any idea is the state of the individual's cognitive structure at the time of learning….[I]f new material is to be learned meaningfully there must exist ideas in cognitive structure to which this material can be related. (p. 143)

Part of positively shaping NOS conceptions of all students requires knowing the NOS conceptions of all students. The implication of not examining the NOS conceptions of children and people of color is that these groups may be deprived of fully realizing the power of science as a way of knowing and maintain a status as *outsiders* in scientific knowledge construction associated with scientifically based professions. In a larger context, the US K-12 science education as a whole will not realize its full institutional potential if underutilization, alienation, and disenfranchisement of populations of color are not abated.

Empirical Discussion on Current Efforts

Collectively, we have explored the open-ended question "what do elementary students understand about NOS?" within different sociocultural settings in the USA. Taken individually, each of these studies has contributed to our understanding in a manner specific to these populations. We now look across these studies/populations and bring in various aspects of the findings in a manner that supports our efforts to foreground equity issues. In light of our interactional framework, we neither merge these findings nor compare and contrast. Instead, we discuss and explore each in a similar manner, thereby allowing each to contribute to the overall picture much like the members of a family; each individual is valuable in his/her own right, but is also a member of a larger picture of the family.

Context Explored

Over the course of 3 years, we examined elementary students' NOS conceptions. The three studies that we use for this discussion include two large urban school districts with large percentages of African American male and female students (Walls 2012), a heterogeneous classroom population in a suburban at-risk school (Akerson et al. 2010), and a girls' academy in a large urban district (Buck et al. 2010). These individual studies explored students from multiple intersections of diversity. We acknowledge that discussing multiple intersections of race, culture, and gender adds complexity to the discussion of the NOS conceptions of all children; however, it is a complication that is necessary if we are to authenticate our understanding of what elementary students understand about NOS.

Low-SES, African American, Males and Females

The first study included two urban school districts. Each of these schools had (1) a large percentage of African Americans in the school population (>80%) and (2) large percentages of students eligible for school-wide free and reduced lunch (>75%). The participants were 23 (12 females and 11 males) third-grade students, all African American. Although the focus was not specifically on gender differences in NOS views, any emergent trends or patterns along gender lines were noted. Using a multiple instrument approach, students' conceptions about science, scientists, and their own relationship with and place within science were investigated in this study.

Low-SES, Heterogeneous, Males and Females

The second study explored a third-grade classroom in a suburban at-risk school. The school had not met Adequate Yearly Progress for 3 years, and included a diverse group of male and female students. There were 24 students in the class, with 80% on free or reduced lunches. There were five African American (three males and two females) and two Latino/a American (one male and one female) students, and one male Native American student. The remaining students were Euro American (nine females and seven males). To track students' NOS conceptions, we administered interview versions of the VNOS-D2 (Lederman and Khishfe 2002) to all students prior to instruction. The interview data were transcribed and analyzed by a team of researchers for themes of NOS understandings by NOS aspect.

Low-SES, African American, Females

The third study included a fourth-, fifth-, and sixth-grade classroom in a girls' academy in a large urban district in a low-SES community. The majority of the approximately 350 girls at this school lived locally in one of the two public housing developments within four blocks of the school. The student population of the girls' academy was 99% Black and 1% Multiracial. Additionally, 88% of the students qualified for free lunch. The elementary students in this study included 75 African American girls, 23 from the fourth grade, 24 from fifth grade, and 28 from the sixth grade. To track the girls' NOS conceptions, we administered a questionnaire, conducted one individual and one three-to-five person focus group follow-up interviews per girl. The interview data were transcribed and analyzed by a team of researchers for themes of NOS understandings by NOS aspect as well as more open-ended ideas about science.

Findings Related to Race, Culture, Gender, and NOS

Low-SES, African American, Males and Females

The primary question guiding this study sought simply to investigate the participants' NOS views. Included in an individual's overall view of the NOS is his or her conceptual image of scientists and the work they do as well. The composite makeup of the study's participants themselves, being both very young [8-year-old third graders] and also persons of color, added to its unique perspective. To accomplish the given task – seeking NOS views of participants who heretofore have been routinely excluded from research (African Americans), and in an age group historically difficult to accurately assess (8-year-olds) – an equally unique approach was deemed necessary. A novel multiple instrument investigatory method was used in an attempt to capture the most comprehensive understanding of this group's science views as possible. The three instruments used were the following: Views of Nature of Science Elementary [VNOS-E] questionnaire (Lederman and Lederman 2004), Modified Draw-a-Scientist Test [M-DAST] (adapted version of the traditional draw-a-scientist test from Chambers 1983), and the Identify-a-Scientist [IAS] protocol (a simple photo-eliciting technique developed for the present study by the researcher).

Not surprisingly, the qualitative content analysis used in this study revealed a range of conceptions held by these students, some traditional and some novel. These students held a view of science as a function primarily used to learn about the natural world around us. The natural world for them included not only the biotic (animals, plants, and humans), and the abiotic (weather, fossils) ones here on earth, but also the astronomical (planets, stars, universe) ones. How they understood this scientific learning to occur was mainly through the processes of experimentation, invention, and discovery. Carey et al. (1989) also found this to be true of the participants in their study: "The students' ideas about the nature of science ranged from a notion that *doing science* means discovering facts and making inventions to an understanding that *doing science* means constructing explanations for natural phenomena" (p. 520). Though invention and discovery can be thought of as similar in what they accomplish, invention appeared to be distinct from discovery. The students made consistent reference to things "never made" or "never heard of" when responding to invention.

Concurrent with their conceptions of science were compatible images of scientists. If, for these participants, science is the systematic way that we learn about the natural world through experimentation, discovery, and invention, then scientists are clearly the people who wield these tools. Their responses indicated that they viewed scientists very positively in that they see them as intelligent, studious workers, and happy doing their jobs. They also identified scientists as people who fill multiple roles. Along with discoverer, inventor, experimenter, and interpreter of the natural world, they included the role of teacher as one that scientists take on. Further these students clearly had very strong conceptions about the distinct physical appearance of scientists. This, for the most part, was not unlike the stereotypical image of a Caucasian (White) male, w/glasses, facial hair, wearing a lab coat, manipulating symbols of research (laboratory equipment) uncovered in previous research (Chambers 1983). However, the use of two of the instruments, the M-DAST and the IAS, did highlight an interesting and noteworthy counterpoint. Unlike the traditional Draw-A-Scientist Test, the M-DAST, when analyzed using the DAST-C checklist (Finson et al. 1995), produced relatively few stereotypical images of scientists or symbols of science. By comparison, the scientists selected in the IAS activity (Tables 9.1 and 9.2) and the reasons provided by the students for their selections were textbook examples of the stereotypical images Chambers (1983) and others uncovered when using the drawing activity. Additionally, though the students reported encountering scientists in many contexts, the laboratory remained a strong contender for where they perform their work.

The final research question investigated what relationship these students had with science and to what degree they viewed themselves as users and producers of scientific knowledge. This is not a question that has been generally highlighted in previous studies seeking to determine the NOS conceptions of the participants. However, it was a critically important one to consider for this particular racial group. Given the persistent outcome of underachievement experienced by African Americans at all grade levels (Parsons 2008) it was essential to determine whether any self-exclusion or disengagement (Ogbu 2003) was evident even in children of this age. It was clear from their responses that this was in no way the case for these students. For example, learning science in their school setting appeared to impress them quite favorably (96% spoke positively about science during the one-on-one interviews). It was apparent that they held a distinct view of their science learning as compared to their other disciplinary learning in school. Engaging in science allowed them to be actively involved in socializing while they learned, whereas other learning did not afford them to do so. They saw science as generally being fun and unanimously spoke positively about it in their responses. Finally, they demonstrated no limitations or hesitancy about their abilities to take part in or to use science, whether in a school context or outside of school. Although this was clearly brought out in their general responses to the VNOS-E questionnaire, it was most evident in their M-DAST drawings. Here, there is ample proof to conclude that not only did they see themselves conceptually as scientists [the majority of the drawings were of children], they also implied their own race [shading in of drawings] and explicitly indicated so through verbal responses. The fact that the researcher asking

Table 9.1 IAS scientist descriptors

	Males (%)	Females (%)	Individuals (%)
Students selected photographs of:	73	27	–
Professional attire	71	95	89
Glasses	78	36	67
Gray/graying	61	3	46
Facial hair	57	N/A	41
Female students selected photographs of:	69	31	–
Professional attire	89	97	92
Glasses	80	49	70
Gray/graying	60	5	43
Facial hair	54	N/A	38
Male students selected photographs of:	76	24	–
Professional attire	83	92	85
Glasses	76	23	64
Gray/graying	62	0	49
Facial hair	59	N/A	45

Table 9.2 IAS race and gender traits of selected individuals

	Males (%)	Females (%)	Individuals (%)
Students selected photographs of:	73	27	–
White	44	13	35
Asian Indian	20	10	17
African American	19	32	23
Asian	12	25	16
Latino/a	5	21	10
Female students selected photographs of:	69	31	–
White	45	11	34
Asian-Indian	18	8	15
Asian	16	30	20
African American	13	32	19
Latino/a	8	19	12
Male students selected photographs of:	76	24	–
White	43	15	36
African American	25	31	26
Asian Indian	22	12	19
Asian	8	19	11
Latino/a	3	23	7

them questions was an African American may have played a role in their answers, yet, the drawings themselves were produced while the researcher purposefully was absent from the classroom.

With this first study, we support our endeavor to add to the current research base on NOS understandings of students by exploring conceptions of NOS by male and female, African American elementary students from low-SES communities.

Low-SES, Heterogeneous, Males and Females

As evidenced from the responses to the VNOS interviews, all students in this classroom held a mixture of adequate and inadequate understandings of the various NOS aspects. Out of the 18 students who had given human subjects approval, seven believed that scientific knowledge is absolute, indicating an inadequate conception of the tentative aspect of NOS. For example, when asked to elaborate on their responses, one of the students (Betty, White female) said, “They always don’t change.” Moreover, among those students who believed that scientific knowledge is subject to change, five (four African Americans) could not elaborate on the idea of how or why it could change, just that “anything can happen” (Eliza, African American female). Only three students (two White males and one Native American male) explicated that scientific knowledge changes as either new evidence is discovered or scientists try new inventions. However, their responses did not show informed views. For example, Nate (White male) answered, “[Scientists] probably [change their ideas] because they learned more stuff.” The other two students simply referred to scientists changing their ideas because of inventions.

Regarding the empirical aspect of NOS, five students (one Latino American male, one African American female, two White males, and one White female) understood that science was a way to learn about the world, as illustrated by Denny’s comment, “Science is about studying other stuff in the world to learn about” (Latino male). Twelve (three African Americans, one Native American, and eight Whites) responded by providing examples of science content, such as Carl (African American male) who responded, “Science is like when you study liquid, solid and gas.” Two other students responded, in unique ways; for example, Anny (White female) responded that “science is a type of math,” and Andy (low-IQ White male) stated that “it is something that helps people.” However, all students realized that scientists use empirical data collected from the natural world to form a conclusion. For example, all believed that scientists used dinosaurs’ bones, footprints, and fossils as evidence to conclude that dinosaurs existed in the past.

Most students responded to the interview questions in ways indicating they had some understanding of the role of inferences in scientific work. The only student who stated that scientists had seen dinosaurs and that was how they knew they existed was Shea, a White female. The other students recognized that scientists used evidence, such as footprints and fossils, to develop an understanding of dinosaurs. For example, Terri (African American female) stated, “They see bones left on the earth, and fossils, and figure out it had to be left by something, so they think it is a dinosaur." Similarly, Anthony (White male) stated, "[Scientists] have bones and they put them together to make a different creature." When asked for an explanation for what makes scientists unsure about their conclusion about what dinosaurs look like, the same student said, "[Scientists] only have the bones. They don't have the skin or the eyes." Cory (Native American male) also referred to dinosaur skin when asked the same question, stating, "The skin doesn't stay behind, so there is no way to know the color of a dinosaur, for example." These responses indicate that most students recognized that scientists need data to make claims and inferences.

Eight students (seven White and one African American female) indicated they did not believe that scientists used creativity or imagination in developing scientific knowledge. These students believed that if scientists did use their creativity or imagination they would not get the right answer, as when Harriet (White female) said, "They can't use imagination or they would get the answer wrong." Ten students (six White, two African American, one Latino, and one Native American) believed that scientists use their creativity and imagination in their scientific work. These students stated in interviews that scientists have to think and that is how they used their imagination, as when Morty (White male) stated, "They have to use imagination and hard work to figure stuff out." Chris (White male) also shared, "They are creating things and thinking about them, so they are imagining things." Further, Cory (Native American male) said, "Basically thinking is imagination, so they are imagining in their heads what their data says."

Most students held inadequate conceptions of the subjective aspect of NOS. Five out of 18 students (two White females and three White males) either provided irrelevant answers or did not provide responses to the question related to this aspect of the NOS. Three students (two White males and one White female) thought that different evidence looked at and used by different scientists caused them to disagree about dinosaurs' extinction. Seven students (one African American male, one Native American male, two African American females, and three White females) were able to relate the disagreement to different ideas or opinions held by different scientists, such as when Cory (Native American male) stated in his interview that "[a scientist] has heard different stuff and they just think that some stuff is more reasonable and scientists are about different ideas." Carl (African American male) shared a similar view, stating, "Scientists are different people so they will never all agree on the same thing." Terri (African American female) stated, "Because they are all scientists, but they have their own opinions. They are all smart and have their own ideas, but they don't know who exactly is right." Two students (one White male and one Latino male) shared responses that indicated that people, in general, simply disagree. They Denny (Latino male) stated, "They want other people to agree with them so they are right." Mack (White male) shared, "They all think they are the right, so they argue to be the most right."

With this second study, we again add to the current research base on NOS understandings of students by exploring conceptions of NOS by male and female elementary students from low-SES, heterogeneous cultural groups.

Low-SES, African American, Females

The primary question guiding this study was: What understandings do urban, low-SES, African American girls have about NOS? In light of our desire to explore these girls' NOS understandings while simultaneously expanding our understanding of how their unique experiences were influencing those understandings, we needed to use different data collection instruments. Our exploration utilized the Views of Nature of Science Elementary [VNOS-E] questionnaire (Lederman and Lederman 2004), follow-up individual interviews, and three five-girl focus group interviews. The data from the three were integrated in order to use the focus group interviews to further assist us in explaining the questionnaire and follow-up interview findings.

Through our study, we discovered that the majority of girls had adequate informed conceptions of science as observation/inference and as tentative, and they had naïve or partially adequate conceptions of science as subjective, as a creative endeavor, and as socially and culturally embedded. Through the interviews with the girls, we enhanced this understanding and discovered that there were common ways in which they talked about science. These were categorized into three overall themes. These themes were a broadened conception of science, a connected understanding of science, and a constructive view of science.

First, these girls expressed a broad conception of science. When asked what they would like to study in science, or what they had studied previously, the girls' answers included not only all science disciplines (biology, physics, etc.), but also topics such as art. The most common broad description of science among the girls was the seamless connection between God and science. To these girls, God is included in their understanding of science. Nishi stated, "I wanna know how God made everything." In another group, Tomi noted, "I would study the Sun and how it is in the sky and bright and shiny." To which Sheri responded, "That is easy, just read the Bible." Tomi agreed that the Bible explained things about the Sun, but also noted that she could still study questions about the Sun. With regard to the aspects of NOS in the K-6 standards, such a connection may mean an understanding that there is one that does know the answers, God, and that scientists are merely seeking to discover those understandings. This may explain the girls' adequate understanding of the aspects of standards-based NOS that lead people to discover processes through observation and inference. Our analysis further revealed a belief by these girls that scientists can be wrong. The girls expressed a belief that science can change because scientists do not know all the answers and can be wrong. This may be a result of the girls' faith. This is important to note because these girls do not currently view science understanding in opposition with their beliefs, and we do not seek for this to change as a result of our future instruction.

We posit that by supporting the girls to continue to talk about their faith with science, they will retain this understanding. Because faith is such a strong part of this mid-western African American community, this seamless integration between faith and science is crucial in order for these girls to continue participating in science. There is much science education research that discusses how incongruent belief systems disengage students from science and implicate the importance of resolving this incompatibility (e.g., Staver 2010). We must continue to explore how the teachers supported this congruence in the classroom in order to extrapolate it to other classrooms.

Importantly, these girls described a connected understanding of science by viewing science as inherently useful. They described science as being useful both personally and more broadly to their community. The girls discussed problems in their community and illustrated science as a way to solve those problems through specific examples. For these girls, there is a reason for conducting an experiment – one is done when one gets a product that will improve the condition of one's situation. The problems noted in their discussions can be traced to their local community. The condemned homes, potholes, and trash they mentioned were very evident in the local context. For example, the girls began hypothesizing why the potholes existed. Lexi hypothesized that "…potholes happen because of the rain. People say the rain and people ride over it too much. That is how my mom got a slit in her tire." Nishi thought that the "salt that they put on the ground eats it up." As these girls continued to discuss this problem in their community, they began to talk about how science could be useful in solving this problem and stated, "Maybe we could learn about how the potholes happen?" The abundance of problems to address in the local context may explain the inadequate conceptions of the social aspects of science (it either fixes the problem or it does not). We argue that this relevance to their daily lives is one way the girls feel connected to science, which is important for them to continue participating in science (Tan and Calabrese Barton 2008).

Many of the girls discussed science as inventing things or fixing things. This was strongly related to their view of technology as a part of science and a way for scientists to be creative. Alexis described her ideas about how science is not tentative, but constructive (focused on a product) when stating, "[Science cannot change] 'cause they already have a lot of good stuff in science that if we didn't have science, we wouldn't have lights and stuff. And if it changes, we won't have lights probably." Here, Alexis believes that although science is creative, as it is product-focused, it cannot change. Several girls repeated this idea in different ways. Hope simply said she wanted to learn "how to make things in science." In this way, their conceptions of science are revealed as something that is constructed.

Our analysis revealed different understandings of science. For example, even though the girls held a strong sense that science was a human endeavor in which they believed that they could participate, they also tended to focus on the science of doing or as an end product. Being able to see these confronting ideas is critical to understand how these girls view science. While working in NOS research, we often see certain conceptions as separated into the seven aspects as recommended by national and state standards—particularly, when we code the data as such. However, these girls have a more complex view of science. This is why it was critical to look at their conceptions using a secondary analysis. Without this analysis, we would not have understood the particular nuances by which the girls viewed science. These girls do not view science in opposition to their beliefs.

They view science as a collaborative and human endeavor, while they see science as producing a product. They have a broadened conception of science, but also see it as useful to their lives. These complexities are important to document not only to include their conceptions in NOS research, but also to understand how we can capitalize on this multifaceted way of thinking so that these girls continue to participate in science.

With this third study, we again support our endeavor to add to the current research base on NOS understandings of students by exploring urban, low-SES, African American girls' conceptions of NOS.

Concluding Thoughts

The connection between successfully learning science and a mature sense of NOS has been established. In addition, an adequate understanding of NOS is necessary for science literacy. And of course, science education stresses the need for science literacy for *all* students. In light of these emphases, many science education organizations have placed great importance on enhancing our understanding of the teaching and learning of NOS, and a robust literature base has emerged. However, as our query into the contemporary literature base revealed, those understandings are extremely limited with regard to the intersections of race, culture, gender, and NOS. The implication of not examining the NOS conceptions of children from diverse populations is that many will be deprived of fully developing an understanding of NOS, not fully meeting state and national standards, and remaining outside the scientifically based professions. Thus, it is necessary that we now take a critical look at our approach to NOS research in a manner that foregrounds equity. We sought to contribute to this endeavor by proceeding to explore one of the questions from the NOS research base – "What do elementary students understand about NOS?" – in a manner that addresses the intersections of race, culture, gender, and NOS. However, as illustrated in this chapter, our question quickly became more complex as we were compelled to explore the underlying purpose of the question itself and then our very understanding of students. Our responses led us to research many children from diverse intersecting categories of oppression and experience. However, this has only provided a very brief glimpse into a sea of diversity – one that must be explored much more deeply before we can even begin to believe we have an inclusive understanding of elementary children's understandings about NOS. Even now, we can see that our small number of inquiries has led to many more questions (somewhat explored in the following paragraph).

Overall, we believe that what we have succeeded in demonstrating to the reader is that our question is in reality a stand in for a larger and more contextually complex query, and that is, "How can science education be made a more equitable and effective tool for educating *all* children?" As critically oriented researchers, we ask this question first and foremost from a fairness point of view. For us, equity is part and parcel not only of how we envision our concept of a transformed science education agenda, but also of how we necessarily approach our research in creating that agenda. Yet, equity, as compelling as it may be alone, is not the sole rationale for this present writing. It is also out of necessity that we have shared our aforementioned thoughts on why educating all young learners of science is so important. Though we are comfortable and skilled at working with children, such as those in our selected studies, we profess possessing nothing more extraordinary than our determined will to do so. We are, however, fully aware that for others, research that involves the intersection of race, culture, and gender may prove more of a deterrent. Even so, we stand as proof that through creativity, imagination, and collaboration, not only *can* those deterrents be overcome, they, in fact, must be. We have indeed made considerable progress in the area of inclusion when it comes to race, culture, and gender in NOS research, yet, more needs to be done. Much like the myth of Sisyphus and his stone demonstrates, progress that never fulfills its ultimate goal, however noble, in the end is simply reduced to wasted energy and effort.

What Do the Theoretical and Methodological Lenses Used in This Scholarship Enable? What Do They Constrain?

We believe the theoretical and methodological lenses used in our scholarship enable a broader understanding of young children's nature of science. The theoretical lenses of critical theory and systems of power enable the dialogs fostered through science education research to include students from multiple, interacting systems of oppression. The methodological lenses of our own empirical studies, as well as those studies that we reviewed, were ones that are well established in the field of science education, specifically in NOS educational research. The use of similar methodological lenses will allow the conversation, already made more complex by the new theoretical lenses, to focus on similar aspects of NOS explored through similar means. However, we also believe that the theoretical understandings of NOS guiding our efforts, as well as the traditional methods noted above, also serve to constrain a more open view of nature of science. The concept of NOS itself is influenced by sociocultural understanding and, thus, needs to be explored.

The efforts to foreground diversity lead to unique findings, which in turn lead to more questions. This enables diverse paths for future inquiries. For example, across the various sociocultural groups, we found that young students held formed ideas about science and scientists, pointing to the need to help build on those ideas, rather than to ignore them. The African American girls from the low-SES community talked extensively about faith, God, and the collaborative nature and usefulness of science. None of the students in the suburban heterogeneous group spoke of any of these ideas, including the African American females in the group. Could this be because they were talking school vs. what they really thought? Or maybe they know you do not talk about God in school, whereas in the other setting, it was okay to talk about God. Or maybe the children from the suburban heterogeneous group see school science as more individual vs. collaborative, at least at the beginning of the school year when they had not done any collaborative science. The fact that the children from the public school spoke in terms of school-based science in which they had participated draws attention to the need for appropriate school-based science to help them build good understandings of science and NOS.

What Are the Ways Ideas in This Chapter Can Be Used to Inform Research, Practice, and Policy? More Specifically, What Is the "So What" for Graduate Students and New Scholars Looking for Ways to Conduct Research on Equity and Diversity? What Are the Implications of This Research for Classroom Teachers and Policymakers?

As noted several times throughout this chapter, understanding NOS is important for all children. Fully conceptualizing NOS understanding among elementary children is particularly important. To date, too much of what we know is based on youth from the interacting system of White, male, and middle class. The diversity of the population has grown tremendously in the past several decades and is predicted to become even more diverse. In order to even begin to believe we understand what elementary children know and can attain about NOS, we need to study the complex matrix of social structures and look upon this as a discussion – not a positivist approach to finding the answer. In this chapter, we only began this discussion by looking at three systems and focusing solely on NOS. There is a long way to go. We need to look further into interacting systems that address religious affiliation, age, physical ability, and nationality (to name a few). Also, in our queries, we focused exclusively on NOS; yet, there are many other areas that need to be explored from a more inclusive approach (e.g., scientific inquiry, social and cultural aspects, environmental education, other science content knowledge). Only then will we understand science teaching and learning in elementary schools. In effect, this approach opens the field more fully. Even aspects of science education that have been thought to be fully explored are opened up as we question our understandings of students and the purposes of science education research.

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Chapter 10
Conceptualizations of Context in Science Education Research: Implications for Equity

Eileen Carlton Parsons and Gillian U. Bayne

We explore, through considerations of our own research, conceptualizations of context. Context is commonly equated to the setting in which events take place. Researchers often capture this place in their descriptions of participants, physical surroundings, and artifacts (e.g., curriculum) relevant to the phenomenon under investigation. Our work treats context as part of the researched phenomena.

The first treatment of context is primarily situated in cultural psychology where factors internal and external to the individual are considered. I, the first author, use context in a manner that is analogous to the literary use of it; I treat context as consisting of, at a minimum, setting and time in which a story unfolds. I recast the setting as layers of influence (Bronfenbrenner 1979) and the time as chronological and eventful (i.e., occasions that are significant and momentous) (Cole 1996). In this chapter, I illustrate the conceptualization of context by way of research on middle school science teachers working with predominantly African American students. I consider contexts, layers of influence, and time, both proximal and distal to the teachers. This multifaceted view of context facilitates the examination of the teachers' views about students in relation to their life experiences situated within the sociopolitical milieux of societies in which they occurred.

Fields, places, and sites that are separated both temporally and spatially constitute the second conceptualization of context and are situated in cultural sociology. Fields have resources (e.g., human) that promote structure; agency within a field

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involves being able to access and appropriate these resources. Social life within a field (e.g., life in an urban science classroom) is mediated by a dialectical relationship between agency and structure. In this chapter, I, the second author, discuss cogenerative dialogues (Roth et al. 2002), fields within which participants engage in critical reflection by making meaning of shared experiences through polysemic (multiple understandings) and polyphonic opportunities. Participants featured in two vignettes involving cogens devise agreed-upon measures to address science teaching and learning concerns through a developed sense of solidarity among teachers and students. This solidarity can ultimately catalyze change at the individual and collective levels (Bayne 2009).

In this chapter, then we present two conceptualizations of context and discuss their affordances and constraints in addressing inequities in science education. We discuss how these conceptualizations can inform research, practice, and policy.

Context as Spheres of Influence Across Space and Time

Generally, context is in the background of much of science education research. For research in which context is in the foreground, most often it is implicitly defined (Furberg and Arnseth 2009). In cases in which it is explicitly defined, its definition, e.g., activity structures and setting (Luehmann 2009), is local to the investigated phenomenon (e.g., classroom surroundings pertinent to high school students' sense making of genetics). Although other phenomena (e.g., culturally relevant pedagogy) are of interest in my research, I, the first author, treat context as integral and consider it among the phenomena to be studied. In order to capture the complexities of context, a phenomenon in which I centralize space and time, I synthesized the work of two cultural psychologists, Urie Bronfenbrenner (1979) and Michael Cole (1996). Human development, specifically the development of individuals, was the primary focus of these psychologists, but I extend and reappropriate their constructions of context to areas tangential to human development.

Bronfenbrenner (1979) depicted contexts as concentric circles with the local as core, much like a tree's rings of life. These contexts are spaces that influence and are influenced by individuals. I view these spaces as including, but not delimited to, physical surroundings and the actors and actions within those settings; these spaces also encompass the influences, impacts, and effects of actors and actions. As denoted by Bronfenbrenner, these spaces are both proximal and distal to an entity (e.g., individual, group) of interest.

Spheres of influence in which individuals are directly involved are called microsystems (micro). For example, home may be the closest micro to a student. Because individuals participate in multiple contexts that vary, the interactions among different micros are captured as another sphere of influence called the mesosystem (meso). Examples of the meso for a student may include a church where the student regularly participates in youth activities, school classrooms in which the student engages in formal school learning, and a community youth program in which the student is involved. The micro and meso are acted upon by more global influences, spaces in which individuals are not directly involved. These spheres are called the exosystem (exo), influences more distant from the individual than local contexts but less distant than the society at large (e.g., the nonprofit organization that sponsors the community youth program), and macrosystem (macro), patterns and ideologies that exist at the level of a society (e.g., the country in which the student resides). These spaces excluding meso—micro, exo, and macro—dialectically exist within and with time (e.g., memories or learned renditions of the past influence occurrences in the present and future).

Cole (1996) dealt specifically with time in his conceptualization of context and separated time into four domains—phylogenesis, cultural-historical, ontogeny, and microgenesis. Phylogenesis refers to the history of the human species; it highlights the universality of being human and the commonality among human beings. Unlike phylogenesis, cultural-historical captures the collective differences in humans. Cultural-historical recognizes the categorization of humans into groups; it refers to the history of the cultural group into which an individual is born and situates the individual as a member of a larger group in a society. Ontogeny and microgenesis, bounded by the cultural-historical, focus on the individual. They accommodate individual uniqueness. Ontogeny pertains to an individual's history and microgenesis refers to the moment-to-moment interactions that comprise an individual's experience.

When I, the first author, combine the constructions of Bronfenbrenner (1979) and Cole (1996), the roles of context and the significance of these roles are amplified. Individuality, processes within local contexts, the impact of structures that exist inside and outside local contexts, and large-scale patterns that signify group realities are captured in the synthesis of Bronfenbrenner and Cole's constructs (see Fig. 10.1). The ideologies and subsequent events of a society (macro) set the stage in which actors in that society live and are translated into the actors' lives through contexts that are somewhat removed from (exo) and near (micro) them. Although these translations may differ in form and scale from their ideologies and events of origin, they nonetheless impact the actors' experiences as members of groups that organize the society (cultural-historical) and as individuals. Moment-to-moment experiences (microgenesis) accumulate over time as life histories (ontogeny). The impact on experience is not delimited to external contexts (macro, exo, and micros) but also includes the actors' interpretations of experience such that the interpretations influence present and future events (microgenesis-ontogeny feedback loop). This feedback from past experience can occur through the retelling of experiences to others (e.g., parents recounting events or teaching lessons learned throughout life to their children) or the reliving of them in memory (e.g., a female professor remembers a childhood teacher's declaration that she would one day be a published author when she receives her first book off the press). In summary, the synthesis in Fig. 10.1 shows multiple layers of contexts and their corresponding structural influences, the uniqueness of individuals without negating the realities associated with group memberships, and the impact of group realities upon the functioning of individuals in a society. In a highly stratified society (e.g., hierarchies based on race) like the United States, the consideration of this multifaceted view of context showcased in the synthesis

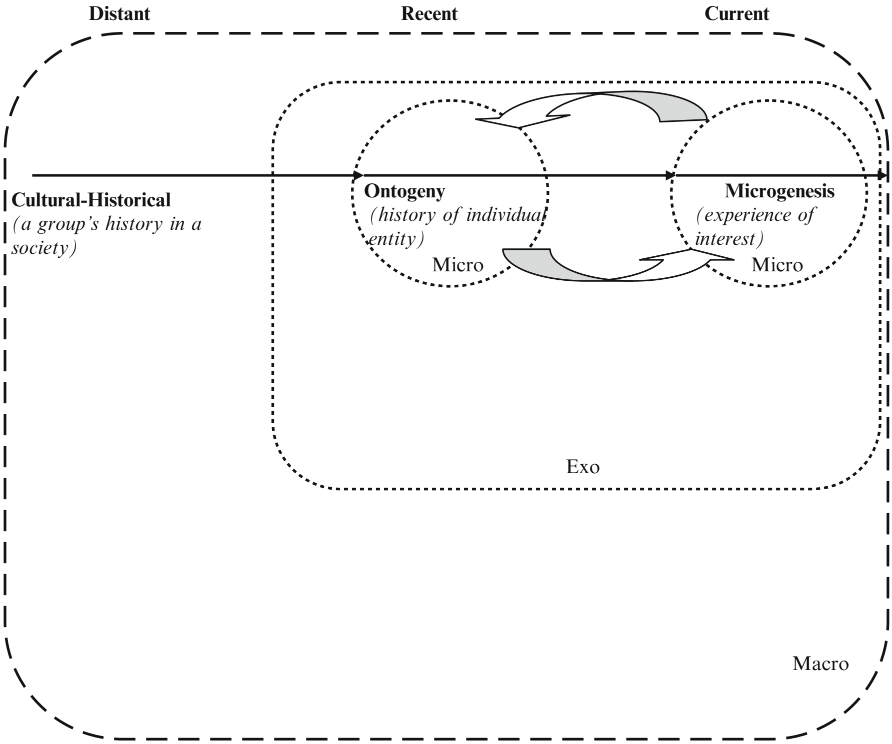

Fig. 10.1 Synthesis of context from Bronfenbrenner (1979) and Cole (1996)

is not only warranted but necessary, particularly in the investigation of phenomena in education, an arena in which disparities have existed since its inception. I demonstrate the use of this multifaceted view of context in an empirical illustration that examines the perspectives of two middle school science teachers.

Empirical Illustration: Teachers' Views of Students

These data are part of a larger project that examined the views and practices of middle school science teachers in relation to values characterized in the literature as indicative of African American communities and mainstream USA. The empirical illustrations involve two teachers. Ms. Vince, a pseudonym, taught at Castle Middle School, an urban school in which African Americans made up 40% of the student population. Ms. Vince, a Black female born and educated in the southern USA, held a Masters in Health Administration as her highest academic degree. At the time of the study, she taught eighth-grade science, her 21st year in the teaching profession.

Ms. Neamans, also a pseudonym, taught at Eastport Middle School, an urban school in which African Americans constituted 63% of the student population. Ms. Neamans, a White female seventh-grade science teacher, described her highest academic degree as a Bachelor of Science in botany, zoology, chemistry, and math from institutions in South Africa where she was born and educated. She taught high school biology, grades 8 through 12, for 12 years in South Africa. She came to the USA through an international exchange program for teachers. At the time of the study, she had completed 1 year of teaching in US public schools, specifically at Eastport Middle.

Ms. Vince and Ms. Neamans participated in four and six semistructured interviews, respectively. Their interview responses constitute the data upon which the empirical illustrations presented in this chapter are based, but classroom observation data and student survey data were collected for the purposes of triangulation in the larger project. These interviews, conducted over a 1-year period, lasted from a minimum of 45 min to a maximum of 90 min and elicited the teachers' views about the realities and ideals of science teaching specific to their experiences and science teaching in general. In this chapter, I, the first author, report data associated with only one theme that resulted from inductive and deductive analyses of the qualitative data and supported by triangulation with other data sources: the teachers' perceptions about students. The teachers' perceptions about the students they taught, in this case primarily African American students, are used to demonstrate the previous conceptualization of context.

In Their Own Words

Ms. Vince. Ms. Vince espoused a very positive view of students. She believed they possessed capabilities in multiple areas.

> I think for the first few years of my teaching, I saw students who came in and they could be feeling a lot of different things but they had a variety of intelligences in other areas. And no one was seeming to be able to pick up on reaching this child in different ways. And so the child in essence was deeming themselves as failures when they were not actually failures because it could have been they could have been gifted in art, in music, in athletics, whatever the talent was. But it wasn't being used to reach them in some of the areas that they might have been weaker in terms of the abstract thinking, the intellectual part. (Interview #4)
>
> So, I think the multiple intelligences is the, kind of the driving force for a concept; you have to have it all. And because I realized a long time ago from listening to some of the research that was coming out, that minorities would be lost if we didn't use them all. I think being a minority myself, it made me want to incorporate it. (Interview #1)
>
> The experiences that I've [had] with multiple intelligences tries to bring out art, music, other ways in which students may have high IQ's vs. the paper and pencil and the testing format. So with a lot of minorities…they may be truly gifted in writing or music or are either being able to learn something in a different way and express just as great learning as it is on standardized tests. (Interview #2)

At every available opportunity, she eagerly applauded their performance. In watching a video clip of a class session, she beamed and stated,

> Self-control and they're doing wonderful. I mean I haven't even really thought about it until I looked at this clip how everybody is in their seat and on task. This needs to be shown to a whole lot of people because they don't believe that if you do something where kids are hands on that it's going to all be an on-task group. Somebody's going to be playing …these kids are all in their seats and are all engaged in their activity…. (Interview #6)

And she was always ready to share what the students could do,

> It's so funny because I just left looking at a single high school science fair and I was thinking in my mind that those kids needed some more real life experiences because I saw the traditional "go to the books and try to come up with a science project" versus the science projects that I know my kids have done this year. They have actually took on real situations and real issues and they didn't feel intimidated by doing the science and they didn't feel they needed to go to 131 science experiments to come up with one. They actually went out and began to ask questions and they observed things and they asked more questions…. (Interview #2)

Even though Ms. Vince acknowledged the diverse roles and responsibilities students had in the educative process, she expressed grave concerns about the views and actions of teachers.

> A lot of teachers don't want to deal with the audience that they have. And they try to find ways in which to escape their audience—whether it is to get a new certification that puts you in an only AP classes or if it's certification that will make you a specialist amongst the specialists in the school.…But that is why I really believe minorities statewide are still scoring poorly and not closing the gap as fast in the math achievement. Because you've still got teachers that don't want to work with a child that doesn't come in there brilliant… I definitely remember in segregated schools that the focus was on getting kids prepared to be in the mainstream and you had more of the teachers with the attitude on helping everybody. And now that we've integrated, there's not that community push to see the best and brightest come out. (Interview #4)
>
> You've got to get that interest developed. And I do believe I fight the battle with people because once I see kids in here that are naturally interested in science research, then they come back to the real world and people are telling them, "Oh you can't endure the training." They'll say, "Did you realize how long it's going to take…to get that career?" And that's not what you should be saying. You should be saying, "Would you like to get some more jobs to keep?"…Because kids will endure whatever it takes if it's something they really want to achieve. That's basic human nature…. I even had that with my child. I had to detox my child because somebody was telling her, "Well, you can't. Do you realize it's going to take you sixteen years to get to work with babies?" I kept saying, I said, "That's not the important thing. The important thing is that you want to work with babies. It will be ok, whether it takes ten, twelve whatever. You'll be ok. In that process, you will be earning money to do what you want to do." But I really find that a lot of people have set the systems up to turn kids off before they're really turned on. (Interview #3)

She attributed the existence of these views and actions to larger societal influences.

> For a long time in the United States of America, we saw middle class values come out on the television screen starting from the late fifties. Middle class values were that everybody had professional parents and the father went to work and the wife stayed home. And in that middle class you also had the perfect home where there was never any problems or anything dysfunctional. And that kind of stayed in the educational arena for a long time and you had a lot of people that despite what was being shown on TV that were still being successful.

> It is a system of prejudices that figure, “Well hey, you don’t have, your mom’s just a maid or your dad just a janitor and so you know you can’t account to too much because they probably don’t know how to read too well and they don’t know how to write too well.” But I am convinced that there are some multi-skilled people that are in low places and you need to remember to remove those prejudices because you never really know who’s going to go against the odds. When you set advance math up only for the middle class students that you’ve met, I think it’s a level of discrimination that sets in simply because you have denied access to this kid who may be from the project who’s got a high IQ for math. And so in essence we’re still battling that…. Because you know I just looked at our algebra statistics for my team and who was taking a test. And we only had 22% that was even a minority and out of that 22% maybe 11% of it was African American. And I know that in [this] county who has grown children from third grade that there is a higher percentage of African Americans as well as minorities that can actually be capable of advanced math in eighth grade.

Although the influences existed at the level of society, she declared that individuals had a responsibility to develop awareness and sensitivity. Because she believed that individuals can become great or impoverished because of the teachers they have (interview #1), she deemed it especially important for teachers to be aware and sensitive.

> I think you can’t be sensitive to individual differences unless you have an awareness of the fact that you’ve got to spend time observing your students and getting from in front of the room and the classroom desk and actually talking to the child …. In order for a teacher to truly be able to stay in the classroom, you’ve got to realize that it is more of a people profession.… It is not a product-oriented business. Yes, the product is education. Yes, the product is learning. But in order to get the product to its completion you’ve got to have interaction with individual people. And you’ve got to have sensitivities to the differences and diversities of the students that are presented. I don’t think you can maximize learning until you get past some of your own personal ways in which that you view what a person is supposed to have and how a person is supposed to act. Yes, there are some constants. Every student should bring a level of respect. Every student should respect the rights of others and that sort of thing. But after we get past those first, basic virtues then you have learning style differences and even cultural differences. And that is something that I think is important for people to be aware of. (Interview #4)

Ms. Vince directly connected her views to her experiences as a member of the Black collective in the USA. She described her experiences in segregated settings prior to the implementation of *Brown vs. Board of Education* and in desegregated settings as crucial to the development of her views.

> I think the greatest contributor to that was to go to non-historically Black college for university training and to see the way in which they sought to flunk students out. I never quite understood why you would get students that had their SAT scores and advanced science courses and the goal was only to keep a few…. I knew how it was when I went through seventh and eighth grade because they only would put, you know, a few of you in a class so I dealt with issues of isolation but we managed to support one another. And I’ve dealt with individuals saying that I’m not sure how you did it, but you did it and, you know, those kinds of things. So I’ve dealt with that in my early years. And I think it kind of helped me when I went to the university because, having to have it in greater terms, it was not unexpected so I had been kind of given some tools in how to deal with it. (Interview #4)

She also linked her views to her experiences as an individual, independent of her membership in a racial group.

> And the first experiences I had was the student that when you looked at him on paper he had failed science for two nine-weeks and I didn't know it until after I got ready to do grades. But when I came and that child actually became my helper, he became an A student and when I went back to give him a grade for that nine weeks I was in shock that he actually had been failing. So it reaffirmed to me that every child needs a second chance and you don't always know who's going to be successful. And I think had I not been the new person on the block who knew nothing about this kid because I came at a time when we were still doing junior high schools. And it was really reaffirming to me to realize that I have to be the one that believes and stays positive. And so along with my own personal ethical beliefs and trying to remember each day is a new day. And you've got to shake off the bad from yesterday and start afresh.

Ms. Neamans. Ms. Neamans held a deficit view of students. She emphasized what they lacked.

> If I'm just thinking about following logic steps, I see a great lack of logical patterns and learning patterns and doing patterns with my students. So maybe that's where our students really veer off from mainstream culture because simple tasks that are just, it's just logical to start at point one and stop at and end at point five because that's the shortest way of doing it and you know…it doesn't always happen. I find myself having to go through steps that I assume or I would like to assume is something that they would think of anyway. We did a practical this morning and they had to look at a slide in the microscope. They had to draw a diagram and they had to answer questions. Most of the students were unable to start. They found themselves floundering at where to start. But they, I needed to tell them, "Ok, you have three things in front of you. You have do it in the following sequence if you want to finish within the time given." You know, …and it was a pretty easy activity but many of them struggled. They were, the slides were numbered from one through eight. When you look at the worksheet you could start on any slide, you know, it didn't occur to many of them to start with slide one because in their booklet of information has the same label, same number…they could have just looked at any old slide. There's no logic. It's something that is lacking in at least 80% of my students. Following a logical sequence of events or approaching a problem in a logical way doesn't happen. It's one of the things that I have to constantly work at because I get impatient when something seems straightforward to me and the students are not thinking of step one because they can't start because they can't think of step one. (Interview #3)
>
> So, but not only that, a lot of my students, their motor skills, their fine motor skills are very limited so I have to take that into consideration when they are working with focusing or having to move the slide around. I have to give them a lot of time. A lot of opportunity to get it right so something that, you know, to somebody with better motor skills would take maybe half an hour, I would need to give them an hour, maybe even more because, you know.…So I would have to take that into…not only what they know but what they can do… what they're capable of. Previously I had just given them an activity where they had to fold paper in a certain way to create a diamond in the middle and, even that, they could not do it. (Interview #4)

In the instances in which she described what students possessed, she viewed their assets (e.g., interests) as impediments to learning; she positioned them as deficiencies that needed to be fixed.

> … students have a very developed interest in music and sports, that sort of thing and, like you said, with the beating on the desk, it's that, you know, even though (a slight sigh). I think that's a combination of what they have and also just a lack of self control there. Because some of it, I do have in each class one or two students that are still doing it six months into the year but others have stopped now. You know, they've learned not to do it. But if you give them half a chance… they would be beating and getting up and they would be lively…. (Interview #5)

Ms. Neamans believed that educators played a major role in students' life opportunities. Considering her belief in educators' impacts, it appears that she was unaware of her deficit view of students and the potential impact of this view on students' lives in the present and future.

> We, the teacher staff, the educators are actually closing doors for these students already now because, you know, they don't. We don't know which doors are going to be opened for them when they're older but they're going to come to a door when they're older and they're going to realize I can't go through this door because of something that happened when I was in middle school or high school. Because of something I didn't do or because of something I didn't realize and the opportunity that wasn't given to me at the time. And that concerns me a lot, the fact that we are closing doors for students because we are rewarding them for the wrong things.

Her comments implied that this belief was restricted to certain domains, in this case, the evaluation of student performance. From the sentiments shared by Ms. Neamans in our contemplation of different ways to teach science, it appeared that this belief did not apply to teaching and learning science content.

> Students would have to be coached into it. They would have to learn a degree of self-discipline and self-control. Because as much as I like the idea of incorporating all of this and as much as I like the idea of having a lesson where students can move around and they can present what they've discovered, I would be very hesitant to do it with the majority of my classes simply because I would be afraid of what would happen when I can't see everything all at once. I would be afraid that some of the interactions would erupt into personal situations with disagreements. Because immediately when you allow this kind of movement, you no longer control what is said between the students…. What is going on is not immediately evident. So to me, this is a great theory but the reality is something else for me. To me the reality is that I would like to do some group work but it would be very limited and it would be short and it would, as soon as things get a little rowdy and out of control, I would have to stop it and move onto something else. (Interview #5)

Not surprisingly, this deficit view of students, which extended to what could and could not be done with students, was also reflected in Ms. Neamans' expectations:

> …their education is not something that is that important to them and so it's very important to realize that and work within that framework even though I understand the importance of education, they don't. So you really have to entertain so they can say they learned. (Interview #1)

The low expectations for students became marked when Ms. Neamans discussed the desire of middle school students to be accepted by their peers and to fit in with a group-and how this explained some of what she experienced in the classroom.

> And a few ones that do get their individual recognition, they almost do not [fit in], they are not the stereotype of their culture. They are the ones that stand out anyway. They are the ones that have other expectations. In some cases, because let's face it, we're not talking about individuals here. We are at, in a school situation where the majority of the students do not fit into the category of people who get individual attention and individual rewards. The majority of the students are just part of the masses…. At this school there are smaller groups of students that, whose individual performances are outstanding. I have not been at another school but I have spoken with some of my colleagues at other schools, different types of schools than this and they say there seems to be a larger population of students that perform well and get recognition and more kind of personal satisfaction. Where I think here, the kids really don't get any personal satisfaction out of doing well and they have to be

> recognized to get the satisfaction. Whereas I believe, I can tell in other schools, even though they may not make the grade or whatever because of certain performances that they do, they have a feeling of personal satisfaction. (Interview #3)

Ms. Neamans did not connect her views to any particular life or societal events. However, parallels existed among the life circumstances described by Ms. Neamans and her views of students with whom she worked. For example, as denoted in the previous quote, Ms. Neamans located her students within the "masses." This idea of the "masses" corresponded with her understandings of South Africa.

> …when you talk about South Africa, you have to consider post Apartheid, you've got to consider interim, you've got to consider present. And at present, I was saying and even in the changeover, individualism is protected but the group's needs are considered very much and in fact overly much…. The constitution of South Africa counters very much the United States' democratic constitution and because of that there have been changes in the last few years where individuals have had more, there has been more emphasis on individualism but historically it was all about the group and the native culture of South Africa is very much about the group. It's the tribes that were together and discuss a situation of a person as a tribe and come to a tribal decision about it. And, you know, the outcome would have to be for the benefit of the entire tribe. So that's the historical and even though it's, you know, historical it's still even in urban societies, still happens. They still have their groups that look after the interests of where they have the elders and executive branches of the group. White culture in South Africa, White Africans and English speaking culture is a little more individualistic although family is a guiding factor. (Interview #3)

She also emphasized certain capabilities (e.g., logic) in her views of students.

> South Africans … people are interested in the outcome. They are interested in what happens at the end…. I guess people [South Africans] are more result oriented. I think that's very much part of South African culture, you know, working things logically. (Interview #3)

Lastly, she gave primacy to certain propensities (e.g., self-control, self-discipline, recognizing and working with and within one's limitations).

> The kids in South Africa are required to do a lot more independent work. A lot more independent work so we do not guide them as much. They can do it by themselves…. I think that the standard, if you compare ages, the standard ability of the kids, same age in South Africa is higher because they are expected to do a lot of independent work from an early age and there's not as much as spoon feeding as I'm finding I have to do here. I find that I literally have to spoon-feed every step of the way almost…. (Interview #1)

Direct parallels were not limited to spheres distal to Ms. Neamans, but were also evident in Ms. Neamans' personal experiences.

> I do like to approach problems in a logical way if it is that kind of problem. But I also realize that some things you have to approach from other angles and I know myself that I'm not a very good thinker but I believe that one has to expose yourself to that kind of way of doing things as well. And I'm not a good artist but I go to art classes now and again because I feel that is a good thing to do because it gets me out of the mold of thinking of things as step one, follow step two, step three. The individualism I believe that when you referred to that earlier, being an individual is very important and if you stand out because of your individualism, that is something to be proud of rather than frowned upon. But I do believe that you have to function within a group as well. And individualism should be appreciated but not at the cost of a group. (Interview #3)

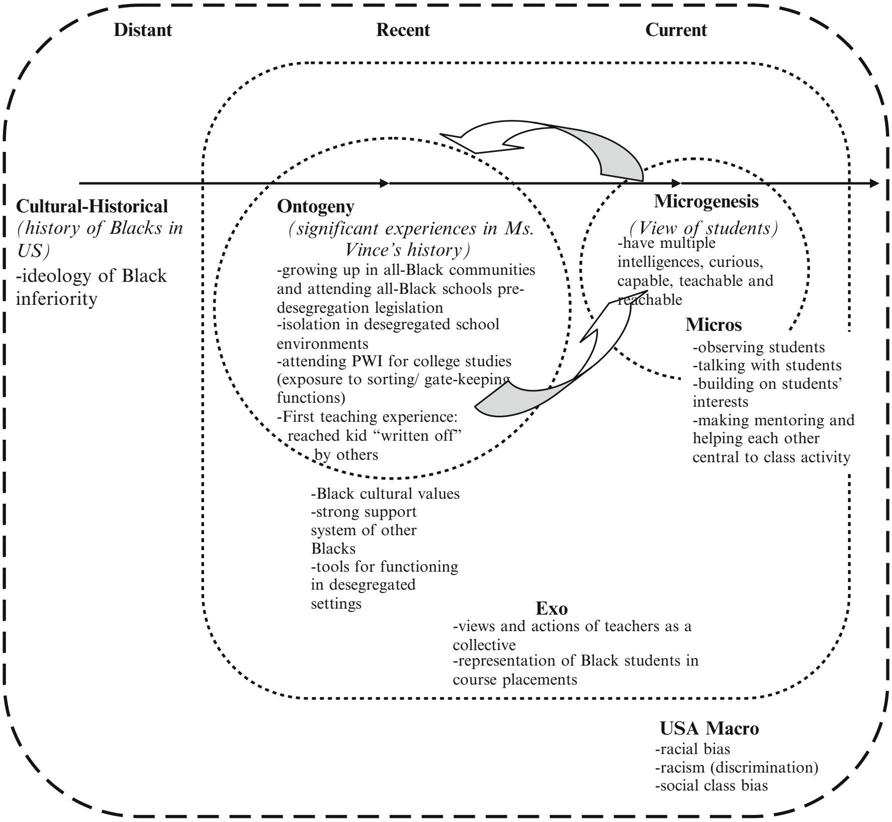

Fig. 10.2 Spheres of influences described by Ms. Vince

> …for myself I'm a person that can take a lot of time in doing things so I'm not very task oriented. I believe that even though it may take me a long time to get something done, I want to be assessed on the product. But I believe if you cater too much to somebody's personal needs you're not doing that person a favor. Because the person needs to start accepting their own limits, who they are and work within that framework. (Interview #3)

Ms. Vince vis-à-vis Ms. Neamans. In many ways, Ms. Vince and Ms. Neamans are stark contrasts. As depicted in Fig. 10.2, Ms. Vince shared a positive view of students (microgenesis). She believed that students had multiple intelligences and that their capabilities could not be delimited to narrow domains. She believed that all students were capable in situations that held high expectations for them, cultivated their interests, and offered necessary assistance. These views of students appeared to be a negation and continuation of what she experienced in predominantly White educational and predominately Black settings, respectively (ontogeny, exo), situated within a history specific to the USA (cultural-historical, macro).

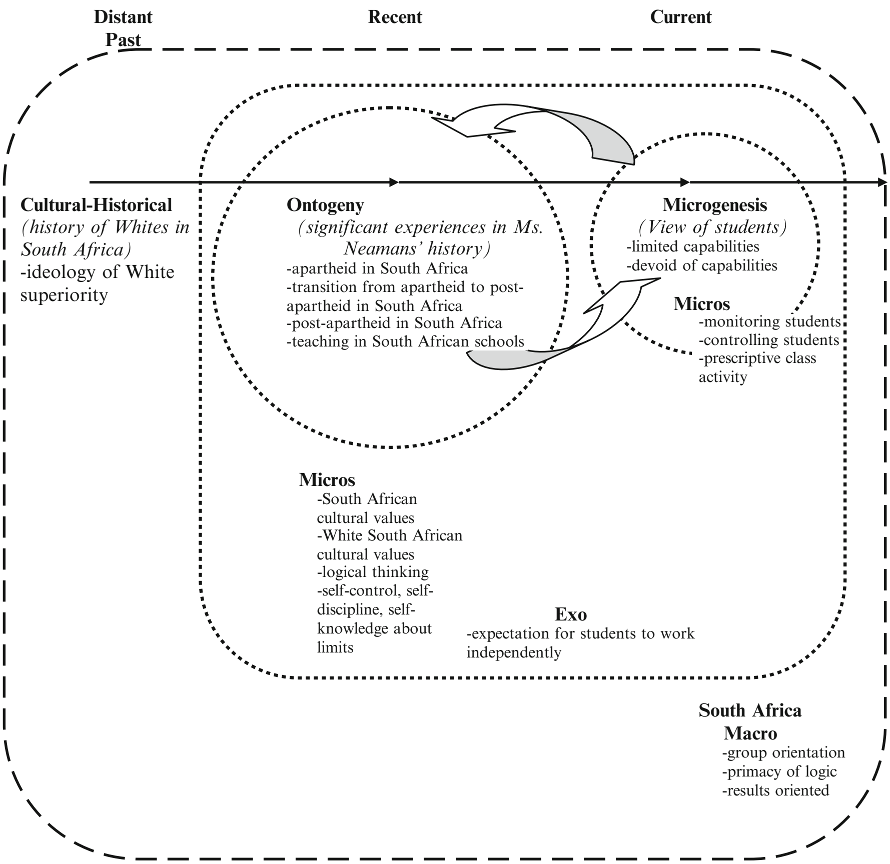

Fig. 10.3 Spheres of influences described and implicated by Ms. Neamans

Ms. Vince appeared to draw from her experiences to create a learning environment that enacted, supported, and perpetuated this positive view of students (micros for microgenesis and ontogeny). As depicted in Fig. 10.3, Ms. Neamans, on the other hand, articulated a deficit view. Using a specific way to think, a specific way to act, and a specific way to be as criteria that she situated within a South African worldview (ontogeny) and positioning these criteria as the only worthy ones (cultural-historical, macro, exo), Ms. Neamans believed that students had limited capabilities, saw what students lacked, and distorted what they possessed (microgenesis). She educated them accordingly (micros of microgenesis and ontogeny).

In sum, as denoted in Figs. 10.2 and 10.3, an examination of Ms. Vince's and Ms. Neamans' views in relation to contexts, spheres of influences across space and time, situated their views more broadly and highlighted correspondences across space and time. These connections across space and time introduce a plethora of possibilities on the origins and maintenance of these views. These possibilities, in turn, offer insights for rethinking equity in science education.

Context as Fields: A Focus on Cogenerative Dialogues

The notion of fields captures the second conceptualization of context where cogenerative dialogues, as a tool used by the teacher researcher in working with diverse students, are central. I, the second author, examined the creation, enactment, and the ability to sustain the interstitial culture created by and inherent to the nature of cogenerative dialogues (cogens). I worked with ninth-grade science students in an effort to learn how to best create fluent science learning environments. In using the experiences, knowledge, and practices of urban students, I examined the interplay between *context and culture*. Additionally, the ability to learn how to sustain meaningful action-driven dialogues involving a developed sense of solidarity and trust among participants, at both the science teaching and learning levels, became evident. In this section, I discuss cogens and share two vignettes that detail how cogens were used with a diverse student body to accomplish a variety of goals.

During my tenure as a teacher researcher in a small, public, and high-performing high school in New York City, I developed a special interest in learning about the needs of students of color, how they develop forms of culture, enact them in science classes, and then utilize their individual and collective agency and understanding of theory to make transitions from participating marginally to accessing structures, which enable them to contribute to their own learning and the learning of others in more substantive ways. I used cogens over a period of 3 years, each year with a different class of ninth graders. The students were diverse in a variety of ways, and the fields within which they were engaged in producing, reproducing, and transforming culture also varied greatly. Two vignettes feature Theo, a second-generation Dominican male, and Riah, a smart and very outgoing African American female. Theo professed a dislike of science and Riah believed that science did not allow her to utilize her social and writing capital.

It is through the sociocultural theoretical grounding of this research that the vignettes can offer insights into many aspects of what unfolded within the different science teaching and learning fields. Through utilizing cogens, which serve as seedbeds and catalysts for generating new culture, teacher and student researchers not only greatly impact the life of a science classroom but also experience ontological shifts as they, for example, work with others and become more reflective about the acts of teaching and learning. They also experience ontological shifts as they take advantage of the capital that participants bring with them to the science learning environment from a variety of social fields within which they interact. During the years I worked with students using cogens, anticipatory, timely, and appropriate actions, including those that involved student agency, ensued with noted changes in the roles of both teachers and students. Development and extension of science understandings also resulted, building new interactive interpersonal styles that provided a foundation for ongoing cultural growth and expansion.

Establishing a Consistent and Robust Practice

During each year of the 3 years that I used cogens in my science classroom, I typically introduced them at the beginning of an academic year. My students and I would decide the general goals of cogens. Students who wanted to participate in them with me did so at a mutually agreed-upon time during the school day—usually during our common lunch period. We met once a week, or as needed, to discuss the details of how teaching and learning science could be improved, and insights that were gained because of being able to share ideas and experiences. Science lessons and laboratory sessions were documented using videotape and audiotape and were followed by a discussion in cogens about the occurrences that unfolded.

Participants in cogens are represented hermeneutically, differing in a variety of ways to ensure a diversity of perspectives, ways of being, learning styles, and a balance of gender and ethnic backgrounds. On average, the number of cogen participants involved ranged from 4 to 6. On occasion, I found it suitable to have one-on-one cogens, as well as cogens involving up to 16 students. To capture social life in the science classroom, student researchers (those who participated in cogens) and I used iMovie HD computer software and the professional version of QuickTime Player (Macintosh OS X), which allowed us to modify the recording speeds, thus providing the possibility to interpret images frame by frame. Transcripts were generated; the two vignettes highlighted in this section were derived from these data sets.

Cogenerative Dialogues

Cogenerative dialogues are conversations with stakeholders that are geared toward creating agreed-upon measures by which improvements can be made in an environment. Cogen work is grounded in a sociocultural framework, which affords an examination of social life, including contradictions, through the philosophy of difference and the emotional content of interactions via face-to-face interactions. The work also provides a venue by which various forms of capital (Bourdieu 1986) may be examined. Social life, as experienced in cogens, is explored through the dialectical relationship of agency and structure (Sewell 1992). Agency and structure exist in recursive relationship denoted by the Sheffer stroke, "|". Agency|structure implies that there is a back and forth nature whereby the pair "mutually presuppose or constitute one another…although they are radically different entities" (Roth 2005, p. xxi). Agency is viewed as the power to act by accessing and appropriating resources in order to meet varying goals and motives. Structure is comprised of resources that are human and/or material commodities that aid in meeting individual and collective motives and goals. Cogens utilize the agency|structure dialectic to transform what currently exists.

Cogens are social fields within which new culture is produced. When we hear the word *culture*, many definitions or associations may come to mind. I view culture as that which is done by participants, and exists as a schema|practice relationship (Sewell 1999). Culture that constitutes and is enacted in one field can also be enacted in similar or distinctive ways in other fields. This means that culture exists as actions that are shaped by a collection of symbols, stories, rituals, beliefs, and worldviews. It is often identified at the individual|collective levels, and the ways by which we relate to each other via transactions. When enacted, culture is said to be "once occurrent." As such, any act of reproduction of culture simultaneously is an act of transforming culture. Thus, teaching and learning science are forms of culture. Within cogens, participants engage in critical reflection by making meaning of shared experiences, by generating agreed-upon measures to address concerns through a developed sense of solidarity, and by catalyzing change at the individual and collective levels. The production of this new culture warrants further examination; consequently, cogens have become tools for both pedagogy and research.

Cogens unfold as conversations and can be imagined as "in-between spaces" or *third spaces* (Bhabha 1994), where newly transformed, hybridized culture is created. This culture is one that acknowledges the value of difference and the acceptance of insurgent personalities and dispositions. Consequently, cogens encourage successful interactions across sociocultural differences, including those related to race, ethnicity, class, language and learning differences, gender, and age. Cogens also encourage mutual understandings through polyphonia and discourse. Opportunities for interactions, outcomes of cogens, are resources for helping science educators, students, and other stakeholders to develop better understandings of the complexities of science education and the dynamic nature of the formation, reformation, and transformation of culture.

Vignette 1: Creating Resources

The first vignette involves the student, Theo, who at the beginning of the school year told me on several occasions that he neither felt comfortable learning about and "doing" science, nor liked science. Initially, Theo marginally participated in discussions and activities. As the semester progressed, and as we met consistently for cogens, Theo began to ask questions about content, get clarification on protocols, and share details about his academic experiences and familial life. Toward the end of Theo's ninth-grade biochemistry experience, he had become more engaged in class and laboratory work, and more excited about it.

In one of our biochemistry lab activities toward the end of the school year, both CO_2 and O_2 gases were being collected. Throughout the lab, Theo had clearly demonstrated his evolving ontology of thinking *about the other* while working/collaborating *with the other*—strengthening solidarity with both his peers and teachers. In this vignette, Theo and his lab partner Zack did not understand the lab directions and how to implement the prescribed protocol. After approaching several of their classmates and getting conflicting information, Theo approached me. He identified the wording in the protocol that was problematic to him (and others), and suggested rewriting a section of it for the benefit of all students in the class. Together, Theo and I quickly reworded the script and presented it to the class. Theo was especially excited that he and Zack were successful because adjustments to the protocol had been made. He expressed a desire to provide a demonstration of the modified protocol, which detailed a more appropriate way to carry out the lab in order to obtain the desired results to not only his class but also another one of my biochemistry classes.

In this vignette, Theo's role became one that took on the characteristics of a coteacher. Through his own praxis of being reflective in the moment, an opportunity for all to learn was created. As illustrated in Theo's case, capital produced in one field, the cogens, can be used to attain goals of both the individual and collective in other fields. Theo was able to restructure the laboratory field because of the culture that was mediated through his participation in cogenerative dialogues. As demonstrated in the vignette, students are able to harness the culture they bring with them from various fields into the science classroom, changing how social life unfolds there.

Vignette 2: Reproducing and Transforming Culture

Riah was known by all of her ninth-grade teachers as a young lady who was extremely social, oftentimes bringing her personal life into the classroom by discussing those things that were heavy on her mind and heart with her tablemates and, sometimes, the entire class. While I found her to be an extremely intelligent, articulate, and vivacious student, I found that she often did not make her talents known. In other words, she was not demonstrating her true potential in science discussions, lab activities, and in the written work that she submitted. Riah commonly completed assignments that met the expectations and standards of her other teachers (she often commented on this), but had difficulty in appropriately managing the demands (especially those related to writing) of her biochemistry class. As her teacher, I saw tremendous potential in Riah and made several attempts to encourage her to join cogens, as other students who were involved in them often spoke openly about how they were helping students individually and collectively. I found myself becoming increasingly frustrated with Riah, as it seemed that often her personal life was interfering with the quality of her work and the interest and enthusiasm with which she approached it.

One day, to my surprise, another student participating regularly in cogens announced that Riah wanted to be involved. Riah was very frustrated with having to make corrections on much of the written work that she submitted to me. She told me later that she initially felt that I was being very unfair in my grading of her work—requiring her to edit and/or revise it. Riah, after all, was a strong writer, and was very disappointed in having to tend to her work again after turning it in. She believed that science was not an English class and should not have the same (and sometimes more stringent) requirements as one.

Within our cogens, we discussed her frustration with the other students, each giving an interpretation of what they heard and possible solutions. Riah became an active member until the end of her ninth-grade experience, becoming a much stronger science student and paying closer attention to the quality of her work. When the same student who encouraged her to participate in cogens was having trouble revising his own assignments, she offered the following:

> I used to not want to get criticism because I used to not want to change anything. I didn't want to go back and revise or edit anything because, but like to me, it felt like, do it all over again, and that is what was really discouraging about it. But, after I realized that it only helps to make my work better. It might seem like something strenuous but, in the end, it's pretty much worth it, you know….

As the year progressed and my understanding of who Riah was deepened, I realized the value that Riah's social nature was adding to our science class and how it was changing the culture of our classroom into one that was more productive than it had been. The content of the conversations that emerged with her peers increasingly involved her points of view, clarification, and explanation around that which was the focus of our lessons. This had not been the case previously. Had I not had the opportunity to work with Riah in cogens, my perception of her would likely have been one which was more limited. I may not have been able to see the potential that her talkative nature was having on helping to engage her classmates in the details of the content. As such, there were many instances of my own ontological shifts, as I witnessed Riah's social capital being used increasingly in instances that involved collaboration around science. My experience with her afforded the witnessing of the reproduction and transformation of culture that was produced. The culture that was being generated promoted the utilization of Riah's capital (i.e., talkative and social nature) to enhance the collective teaching and learning that was occurring in our science learning environment.

Conclusions

Context as a theoretical construct and as a lived experience is the medium through which inequities are promulgated and enacted. When context is relegated to the background in science teaching, science education research, and science education policy, structures that facilitate and perpetuate inequities remain intact; implemented efforts to address inequities result in short-term cosmetic changes, at best. In this chapter, we proposed two conceptualizations of context that foreground it.

These two conceptualizations of context, one rooted in psychology and the other in sociology, situate context as a construct differently and emphasize varied aspects of the construct. Independent of one another, do they do enough to foreground context? Do the disciplinary assumptions (e.g., primacy of individual versus primacy of social interactions) of each make them incommensurable? Could they be employed simultaneously and would such an employment be fruitful in addressing inequities? As indicated in the previous questions, much conceptual work remains but the two conceptualizations posited here are beginnings that move context from the background to the foreground—an essential task in recognizing the significance and the role context plays in inequities and addressing them.

Common Questions

1. What do the theoretical and methodological lenses used in this scholarship enable? What do they constrain? The first conceptualization of context provides the flexibility, in a discernible fashion, to zoom in and zoom out when examining phenomena. It enables scholarship that considers individuals (zooming in) without ignoring the realities of group membership (zooming out). It also accommodates what is most immediate (zooming in) without disregarding the impacts of the recent and distant past (zooming out). This zooming in and zooming out is especially important in equity issues. Equity issues often require the critique of power (e.g., the ability to impact various forms of capital that influence another's access to a better life). Also, these issues often necessitate the deconstruction of group advantage; such activity often propels many researchers and scholars into a disconcerting space that challenges the status quo-sustaining view that situates inequity as an *individual* and *local* rather than a *systemic* and *historically engineered* matter. The first conceptualization of context proffers a tool to help researchers and scholars navigate the previously described space.

   The second conceptualization of context enables scholarship to look beyond what appears at the surface of teaching and learning—to dig deeper into the complexities of what makes for good, equitable teaching and learning of science, and to take action in helping these opportunities to unfold. Sharing the theoretical underpinnings of cogens with students and other cogen participants, having students vested in taking ownership of their learning by playing an active role in facilitating necessary changes to do so, and involving students in the methodological practices of cogens, strengthen their individual and collective agency and create opportunities to *learn from and with* the other. Using theoretical applications inherent to cogens helps to create solidarity, which is an integral component to learning how to create successful interactions and generate positive outcomes in the teaching and learning of science in diverse classrooms. Challenges that I, the second author, have encountered while enacting cogen practices primarily involve issues related to temporality constraints and being able to enact cogens with every one of the five science classes that I taught.
2. In what ways can the ideas discussed in this chapter be used to inform research, practice, and policy? The first conceptualization of context contrasts a very common approach in research, practice, and policy to address phenomena as though they are locally bound in their entirety and exist independently of larger milieus, in both time and space, thereby forcing a specificity that distorts the phenomena

they seek to address and offers solutions with short-lived and limited results. For example, the majority of research, practice, and policy concerned with the underachievement of African Americans are similar in one way: They approach the persistent challenge as though it is a locally, isolated event. Research, practice, and policy approach the underachievement of African Americans in a vacuum; these attempts often begin and end with the underachievement of African Americans positioned within the immediate here and now, as though the state of affairs emerged in the present day. In well-intentioned efforts to address the underachievement of African Americans, research, practice, and policy do not consider pertinent historical and contextual information surrounding African Americans. The first conceptualization of context presents the possibility for generating informed research, practice, and policy that are simultaneously specific and comprehensive. The synthesis of constructs posited by Bronfenbrenner (1979) and Cole (1996) enables researchers, practitioners, and policymakers to more thoroughly examine the contemporary, existent conditions, by considering the phenomena both locally and globally with respect to time and space.

The second conceptualization of context situates agency and structure, individual and collective, and schema and practice as dialectics. In the typical positioning of context, the previously listed dichotomies and individuals are *acted upon*. In cogens, agency|structure, individual|collective, and schema|practice exist in recursive relationships, which situate individuals as *acting*. Individuals possess various forms of capital, are able to access capital beyond what they possess, and use them to enhance their experiences. Cogens present fields, contexts per se, as dynamic and viable tools to address inequities. As discussed in this chapter, cogens can be used as methodological tools in research; they can be also used as tools in enhancing science teaching and learning. Both uses of cogens can offer instrumental insights in developing science education policy that effectively addresses equity.

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Chapter 11
Allowing Our Research on Urban, Low-SES, African American Girls and Science Education to Actively and Continually Rewrite Itself

Gayle A. Buck and Cassie F. Quigley

Introduction

Although research over the past several decades has increased our understanding of girls and science education, only recently have we begun to see inquiries in gender that consider race and culture (Scantlebury and Baker 2007). This emerging research base demonstrates that some claims regarding girls and science education are not true for all girls and that problems cannot be addressed by responding with strategies that have only been shown to improve the situation for girls from middle class White populations. For example, research has revealed that Black girls in a metropolitan school in England (Rollock 2007) and girls from low-SES backgrounds in the USA (Chavous et al. 2008) are uniquely affected by school experiences. Nicola Rollock's (2007) work associated with the silencing of Black girls and Tabbye Chavous and colleagues' (2008) work associated with the high value girls from low-SES backgrounds place on education are only two examples of how girls' experiences are being theorized in increasingly sophisticated ways. These challenges to our underlying assumptions about gender, culture, and race are demanding that we take a critical look at our theoretical and methodological approaches to equity research.

Over the past 4 years, we have explored how to meet the needs of African American girls in science education in a public girls' school in a large urban district in the

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Midwest of the USA. The majority of the approximately 350 girls at this elementary school live locally in one of two public housing developments within four blocks of the school. The boys from the local community attend a boys' school approximately 2 miles from this school. The students are assigned to these single-sexed schools based on area of residence. The student population of the girls' school is 99% Black and 1% multiracial. The majority of the girls are from families that have lived in the USA for several generations. Additionally, 88% of the students qualify for free lunch. We were invited to the discussions involving this school due to our prior work and interest in gender issues in science education. We are proud to say that our efforts have contributed to the learning opportunities and outcomes of many young girls and their teachers. However, the naïve notions that have surfaced as we worked with these girls and the educators at their school continue to humble us. Standing back, we now can see that these girls and their teachers have taught us much as well, but it is only a result of allowing ourselves to embrace the differences within the construct of these girls.

The purpose of this chapter is to provide our account of a self-study focused on revealing how our theoretical and methodological understandings of gender research in science education have changed as a result of our involvement with the urban, low-SES, African American girls and their teachers at this school. Below, we provide a heuristic review of our work, storying its development and impacts on ourselves and our understandings of working within the complex, dynamic, and demanding area of gender research. The heuristic process included engagement, immersion, incubation, illumination, explication, and critical synthesis (Moustakas 1990). This heuristic process was not a process-product journey, seeking to correlate processes or products to results, but rather focused on developing a genuine understanding (Schulman 1989) of the experience of researching within a relationship with teachers, girls, and administrators. The creative synthesis is a personal way of communicating this process and our understandings. We chose to communicate through a narrative of the areas in which we believe our understandings and practices have grown. We locate the discussion in a theoretical framework that draws on feminist understandings of research. This situates the subsequent changes to praxis, which are explored through the categories of participant roles, research questions, and research methodology. Throughout, the narrative is guided by the empirical work that we employed in our studies, as well as the findings that ultimately helped us to take a step back and explain how we have rewritten our practice as a result of our efforts.

Alberto Rodriguez (2000) notes that heuristic work has potential for the field of science education due to the readers' capacity to empathize with the researchers' struggle to make sense of the complex and demanding contexts that are found in everyday teaching and learning. In our case, we tried to make sense of the complex and demanding context that we found as we sought to conduct research on the teaching and learning of girls in an urban, low-SES school. However, he also cautions you, the reader, that "there is a danger, however, in allowing [yourself] to be swept by the teller's captivating narratives without asking what are the teller's motives or intentionalities" (p. 14). Thus, we begin by providing our motives for sharing this narrative.

Science education research on gender and science is robust and many findings provide valuable understandings and useful directions, but we believe there is a level of understanding that will never be achieved until we put our categorical boundaries in crisis (Butler 2004). We have been encouraged and motivated by the willingness of those working in feminist research to take a critical look at their own biases and assumptions in the same way that they have looked at the biases and assumptions of others. Such a process is risky as the inherent impetus requires us to call our very selves into question and allows for a public reconfiguring of our research. However, although we have allowed our research on urban, low-SES, African American girls and science education to actively rewrite itself, it is but one population in gender research. Thus, we believe it is critical for our personal sense-making to be completed alongside collective sense-making. In addition, we seek to further demonstrate to the science education community the value inherent in challenging existing categorical boundaries of student populations and methodological approaches in gender research.

Confronting and Challenging Our Theoretical Framework

In furthering our understanding of the underlying assumptions of our efforts in regard to meeting the needs of underrepresented student populations, Sharon Willis (1996) developed a categorization system that classified these efforts based on some guiding assumptions: deficit (the problem is the necessary skills, knowledge, or motivation that some children lack), biased pedagogy (the problem is certain pedagogical approaches that advantage or disadvantage certain populations), inclusive (the problem is the sole reliance on curricula that reflect the interests and experiences of one population of students), and critical (the problem is curricula that work to maintain the interests of the dominant culture within society). Our efforts were guided by the inclusive perspective. As such, they were developed and initiated to address what we perceived as a biased approach to schooling: an approach to school curricula, content, and sequence that is narrowly focused on the values, priorities, and lifestyles of the White male population. We sought to explore and expand the potential curriculum that included all possible curricula and pedagogies by identifying and including ones that addressed the needs of the girls at this school. Thus, efforts were made to challenge and modify the hegemony of the selected curriculum explicitly in the service of social justice (Willis 1996). Our research efforts were structured to further science education's understanding of the developmental needs of *all* children, not just those from the more powerful members of the dominant culture. Our goal was not to replace one culture for another one in the dominant position in science education research, but rather to equally represent a broader range of social groupings in the research base.

We were not involved in the school for long before we had to ask ourselves: Do our understandings of "girls" fit these girls we were coming to know? We were invited to become part of the work at this school because of our work with girls and science education and we remained confident that we had something to contribute; however, as we got to know many of the African American girls from the housing developments in this urban district, we were often confronted with our own naïve notions of gender. Deborah Kerdeman (2003) proposes that a key dimension of teaching and learning that is largely unexplored is self-questioning, doubt, and "disappointment of expectation" (p. 295). Hans-Georg Gadamer (as cited in Kerdeman 2003) describes this as "being pulled up short" (p. 295), which Kerdeman defines in the following way:

> While the difference between the world and us can be experienced when unforeseen happiness comes our way, more significant disclosures of difference occur whenever our assumptions, expectations, and desires fail to materialize, are thwarted, or reversed. (p. 295)

We soon found ourselves "pulled up short" in regard to the understandings of gender and science we were bringing to the conversations occurring at this school. We were not confident which understandings developed in relation with middle-class White girls applied to these current efforts. For a short while, we wondered if we had left gender research and were in research on race/ethnicity. Or perhaps we were in research on SES or urban education. We even explored the connection to indigenous knowledge. Although all of the work we reviewed provided valuable insights into various aspects of our work, none seemed to fully apply. We were not surprised that our dichotomy was failing us, but we were feeling a little lost – a feeling that was exacerbated by the fact that the work of the school needed to continue.

Soon, the readings on critical feminism that we were mildly aware of began to take on new meaning for us and our work. It became essential that we take a critical look at our own perspectives on gender much in the way that we have taken a critical look at the biases in other perspectives (Crawford and Unger 2000). As critical feminists, we acknowledged these girls' construction of self was not only influenced by gender, but also by their race and socioeconomics (Hooks 1990). Contemporary feminists continue to question political and social inequalities in society, but are increasingly turning their critiques back on feminist theory itself (Lather 2007). Critical feminists seek to challenge what feminism has come to portray as the universal female identity; they note that although early feminisms sought to eliminate the political and social inequalities that affect women, it was often the White, middle-class females who were at the center of the plight (Butler 2004).

Critical feminist theory furthered our understandings of why we needed to deconstruct our existing schemas of gender; however, we could not afford to dwell too long in the rubble – we needed to construct a more comprehensive understanding of gender to guide our efforts. In our quest to adjust our framework for responding to the self-questioning and doubt we were encountering, we were directed to the work of Patricia Collins (1990). Collins encouraged us to rethink the framework we used in considering diversity. She writes:

> Additive models of oppression are firmly rooted in the either/or dichotomous thinking of Eurocentric, masculinist thought. One must be either Black or [W]hite in such thought systems – persons of ambiguous racial and ethnic identity constantly battle with questions such as "what are you, anyway?"…Replacing additive models of oppression with interlocking

> ones creates possibilities for new paradigms. The significance of seeing race, class, and gender as interlocking systems of oppression is that such an approach fosters a paradigmatic shift of thinking inclusively about other oppressions, such as age, sexual orientations, religion, and ethnicity. (p. 225)

She notes that traditional difference frameworks encourage comparative thinking. This is a necessary first step, but it is not enough. For one thing, it tends to promote ranking the oppression of one group compared to another, as if the important thing were to determine who is most victimized. In addition, a difference framework tends to foster an additive approach when we encounter students that do not fit any one particular category. In this manner, one would believe that they could understand African American girls from low-SES situations by adding what we have categorized as African American to both what we know about girls and what we know about students from low-SES communities.

Collins encourages people to view race, class, and gender as *systems of power*. That vision is guided by a matrix of domination framework (Anderson and Collins 2007). The major difference between the systems of power framework and the difference framework is thinking relationally. The systems of power framework (1) is situated within a social structure. The social structure influences an individual's consciousness, interactions with others, and access to institutional power and influences (Collins 2000). In our situation, the girls are from a predominately African American community in the Midwest, living in low-income housing, and attending public school with all the associated mandates (2) The framework acknowledges that the intersection of race, class, and gender are manifested differently depending on their configuration with the other. For example, a White female may experience privilege as a result of her race, but oppression as a result of her gender. The girls we are working with are African American, low-SES. Their stories are different from the boys at the neighboring school or the African American girls in the nearby suburbs (3) The framework is historically grounded. Forms of oppression and privilege can change over time and across given societies. The types of opportunities and oppression these girls are experiencing are not the same as a decade ago or a decade from now. However, all these areas have been affected by and will affect the types of oppression and privilege they experience (Anderson and Collins 2007).

We continue to work from an inclusive perspective. However, our time and self-reflection have resulted in furthering our understanding of whom we are trying to include. We are not studying girls, or African Americans, or urban students, or students from low-SES urban communities. We are studying urban, low-SES, African American girls and science education in their school and community.

Exploring Our Understanding of Participatory Research

Our work was always guided by the experiences within the school and sought to ensure that all stakeholders had a *voice* in the process. When referring to voice, we are referring to more than just the words of the girls and their teachers. We are referring to their point of views or understandings of reality (Belenky et al. 1997). Listening had a tremendous impact on our emerging understandings of gender research, including an understanding of the dynamic process of including and responding to the voices of persons from other intersections of race, class, and gender.

From the questions we asked to the interpretation of the findings, we focused on the voice of *this* particular school. Researchers have documented the important ways in which voice shapes learning and teaching (Moje et al. 2001) and the act of research (almost any anthropologist can attest to this). By looking at voice in a particular social structure, we were able to step away from our dichotomous thinking and see how the learning is controlled by the local context. The investigations into context were difficult. Context is not static and is dependent on many factors, including history, culture, personal experience, and self-efficacy (Lipka and Mohatt 1998). By including the voices of this school and moving the focus away from our own notions of context, we were able to examine the relationship between the girls, science, and the social structure. It was through studying the voice of the school that our participatory research was rooted.

When our relationship with this school began, our role was to observe the voice of this unique place. It is in an urban area. All of its students are girls and the majority of them are African American. In addition, most of the girls live in public housing. It is a science-focused school. In many respects, there is great power and promise that this unique place contributes to the study of science education. We needed to explore and document the voice of this place so that we, as well as other science educators, could understand why this community should be storied among the science education literature. Because so much culture is rooted in understanding place, it was important for us to become a part of the community before attempting to declare we understood this place (Chinn 2007).

After an inquiry into the voice of this place, we explored the voices of the people. As mentioned above, we operate from the critical perspective that helps individuals to "name and locate their realties within the social, cultural, economic, and historical formations of society" (Sikes 1997, p. 66). We believe that the curriculum of a school should evolve with teacher-proposed frameworks. Thus, the teachers worked with us to design the professional development that they believed necessary to become a science school. The first summer it was simple: They requested that together we pull out and unwrap the science supplies, books, and boxes from the corners of the classrooms and storage areas and see what they had in the building. It was during these initial conversations of this first working summer that the voices of the teachers were first heard. All the teachers were women. The majority of the teachers were African American and either lived in the neighborhood or a nearby suburb. All the teachers had between 10 and 25 years of experience teaching in elementary school. The teachers often discussed their dedication to the girls' education and demanded that the girls succeed in education in order to change their lives. The teachers talked about their struggles, worries, and strengths. This reciprocity of trust was critical to document their voice.

That first summer, after the boxes were unpacked, we began going through basic labs with them. They had not spent much time or effort teaching science in the past and were not confident they could teach "hands-on" or "inquiry-based" labs. During this phase of our participatory relationship, their desires for this school were explored. It began with the physical nature of the school. The teachers wanted a science lab. Initially, we were a bit disheartened by the request. As science educators, we often focus on getting students and teachers to understand that science is conducted outside the confines of the science lab. However, one of the teachers offered her reasoning for using the science lab, "These girls deserve to work in a science lab. That is why we created it. So they would have the same experiences as other students …." It is not that she associated science as only in the science lab – it is that she wanted the girls to have the same opportunities as other students. The teachers helped us to understand that other students in suburban areas have experiences in science labs and they wanted their students to succeed in science and knew that in order to do so they needed to be able to compete with them in "school science" (Quigley 2010). This sentiment was echoed by the principal who further noted that they wanted the girls to know that they valued science – and that they valued the girls.

Still, we cringed when they requested white lab coats and goggles for the labs for these things were, in our mind, artifacts of a stereotypical image of science/scientists. However, we heard the value these artifacts held for these participants. It was by listening that we began to see the importance of *equality of educational opportunity* (Mickelson and Smith 2007). Meaning, it was important for the teachers in this particular context that these girls would one day have the opportunity to become scientists or professionals in fields that required a high level of science education. We came to better understand how important it was to them that the girls had the necessary self-confidence, desire, and achievement related to future opportunities in science. They would listen to our discussions of changing the institutional aspects of science education and the importance of scientific literacy for everyday living in this low-SES community and we would have wonderful discussions associated with these areas and develop some related projects. However, the voices in this place were strong and determined when it came to assuring that their girls would have equality of educational opportunities that would allow them equality of opportunity in the future (Mickelson and Smith 2007). Ultimately, our desires were the same: to help these girls learn science and become scientifically literate.

Student voice was a theme throughout all our projects. This was done through classroom interactions, many interviews, and semistructured surveys. We focused our questions on things that interested them. We spent a great deal of time exploring the relevancy of science they found in their daily and future lives. For example, some girls stressed that science was important for careers in general while others gave examples of science-related careers such as medicine and forensics. Ericka discussed how science is important if you want to become "an investigator of bodies" or a surgeon. Corine mentioned that science is important for detective work to "help tell you how long it's been there and when it's been used" and "to uncover fingerprints." Moreover, Necie explained that she will need science as a veterinarian: "I'm going to need to learn science to treat pets and give shots." Here, the girls also thought science was important, but thought of it in terms of their future aspirations (Buck et al. 2009).

The conversations that began with their futures in science blossomed into deeper conversations about problems plaguing their community. The girls described problems in their lives such as condemned homes, poor roads, sickle cell anemia, trash thrown in their yards, and dangerous chemicals in their homes. They then discussed ideas about how to improve their community using scientific processes. They began wondering if there was a machine they could invent to "suck up the trash on the ground" and then the discussion moved into "have our roads fixed" and more specifically how to fix the potholes in the roads. As these girls continued to discuss this problem in the community, they began to talk about how science could be useful in solving this problem and stated, "Maybe we could learn about how the potholes happen?"

Similarly, the girls mentioned science as being useful for solving more immediate problems in the community, particularly in connection to weather. Weather was a very common topic as their city had recently experienced a devastating flood. This demonstrated the girls' ability to connect with science after this traumatic event. Several of the girls described science as being a way to understand how this event happened as well as how to prevent and/or predict such events in the future. For example, a girl thought that she could figure out how the flood began by watching the weather patterns on television. She was frustrated that there were not more warnings before the flood and worried about the animals and plants affected by the flood. It was through these conversations with the girls that we could bring this information back to the teachers to help them redesign their curriculum – one that was informed by research-based practices and these particular girls' interests (Buck et al. 2010).

We would have liked to remain in the observation phase of our inquiry into the voice of this place and the participants; but, the day-to-day life of an urban district is fast and furious, and the teachers and principal at the school were strongly focused on advancing the educational opportunities for these girls. Thus, together we examined the current pedagogical ideas and opportunities being pursued and explored in science education and selected those that best met the educational needs of the girls (based on the teachers' tacit understandings of the girls and the findings of the surveys, interviews, and classroom observations). Soon, we began to teach with them – modeling and adjusting problem-based science units, place-based science units, and nature of science explicit-reflective strategies. Often during these team teaching sessions, the researchers learned as much as the teachers. We designed, implemented, and reflected on the lessons with them and together we altered the plans according to the needs of the girls in this context. Together, we introduced new technologies such as the use of digital cameras as data collection tools and graphing calculators and probe ware for the upper grades. We learned from them and with them – we documented ways in which they were able to integrate science discourse into everyday discourse (Quigley and Buck 2010).

Development of a community is central to critical/feminist perspective (Sikes 1997). In the last few years, we have become a part of the community and watch as the school changes. We celebrate their successes and are saddened by their struggles.

As we step away from our role as the science education experts in this relationship, we witness the teachers taking a democratic approach to the school by incorporating the girls' ideas into the curriculum and the girls taking leadership roles in science throughout the school and district by participating in local science fairs and quiz shows.

Critiquing the Research Questions

These initial discussions with the teachers led to new questions about best practices. The teachers and we first thought it necessary to ask research questions that would provide information about a large number of girls. We initially asked a set of quantitative questions to understand the science perceptions of 89 fourth- through sixth-grade girls. These questions, which we reported on elsewhere (Buck et al. 2009), included: a) Did the students in the sample score differently on the scales of the attitudes toward science survey? b) What attitudes-toward-science profiles emerged from the scores on this survey? Because we also desired to attend to the uniqueness of the individual girls, we added qualitative questions as well: a) What were the urban, low-SES, African American girls' attitudes toward science and science learning? b) What aspects of their experiences and understandings contributed to differences in attitudes? Using both quantitative and qualitative questions allowed us to develop a deeper knowledge of a small number of girls, while simultaneously expanding our understanding by looking at a larger number of girls at our school site.

By focusing on the girls and developing rich profiles of their participation and perceptions, we were able to study how the science education reform impacted their perceptions, ability, and understanding of science. We also noted that this approach shifted the focus away from the teacher, supporting deeper teacher engagement of how the girls engaged in science in their classrooms. For example, teachers began to notice how the girls often used the collective pronoun "we" to describe when they were conducting science experiments, insomuch as they could connect this idea of collaboration to the larger community of science. One of the girls clearly demonstrated this collective view when she stated, "When working in a group, if you get stuck, you can ask someone else." The teachers also noticed that girls had a realistic view of the collaborative nature of science – as a process that is not done in isolation but as one that must include other people's opinions and ideas. Similarly, another girl stated that it is important to include other people in the data analysis portion of experimentation, because "then you get different opinions and ideas." In this way, the girls demonstrated both that they saw value in working with a group and also that they viewed science as a collective endeavor. Another girl pointed to problems with working collaboratively in science, because sometimes "everybody wants to do it their own way." This problem with the collaborative nature of science was echoed by another, "Sometimes they get in arguments." What is interesting to note is that these girls talked about the collaborative nature of science, but explained that collaboration sometimes comes with challenges. Thus, the girls saw both benefits and drawbacks of collaborative relationships, which is an accurate description of one aspect of the nature of science.

These girl-centered investigations with the teachers led us to more intently focus our work on the understandings that urban, low-SES, African American girls have about NOS, and on the kinds of pedagogical strategies that teachers might employ to support girls. As the teachers became more comfortable with this approach, they began asking for other strategies to improve student engagement in their science classrooms. Furthermore, once we developed a trusting relationship with the teachers and girls at the school, we found ourselves focusing on individual teacher's classrooms and studying what was happening for the students in these rooms. For example, we noticed that one particular teacher had an exceptional ability to translate scientific discourse for her kindergarten girls. We discussed our observations with her and together we wondered, "How does she do this?" More formally, this question became, "How does this teacher construct a congruent third space in an urban, all girls' kindergarten classroom?" (Quigley 2010).

What is important to note is that we did not enter the school with a set of predetermined research questions. Instead, we listened first. This approach was critical to developing a trusting relationship with the teachers, girls, and parents at the school. Overall, our research questions began with a focus on studying and documenting the teaching and learning of a large number of girls. Now, the questions focus on observing and reporting excellence in individual classrooms. Although no one question reflects a collective voice of the participatory group, we have come to realize that, taken together, the overall line of inquiry does.

Broadening Our Understanding of Appropriate Methodologies in Feminist Research

One thing that has not changed during our time with these girls and their teachers is our intent (although our understanding of the meaning underlying this intent has certainly evolved). That intent continues to be to use the research process to help these teachers and girls to understand and change their situation for the better; thus, our work continues to come from a feminist perspective and, as such, utilize feminist methods of research. In her exploration of feminist research(ers), Shulamit Reinharz (1992) showed that feminist researchers use a multiplicity of research methods. She concluded that "instead of orthodoxy, feminist research practices must be recognized as a plurality" (p. 4). Sometimes, feminist researchers adopt the methods of their discipline without any major modifications. In this way, they are able to use a discipline for its power, turning its power to feminist ends. At other times, feminist researchers make modifications to existing methods in their disciplines to meet the demands they are facing. And sometimes, feminist researchers find themselves seeking or developing original methods to respond to major challenges in their work. Amazingly, we have come to realize that we covered the range of these options throughout our time with these girls and their teachers. This characteristic is, in our opinion, one of the aspects of our own practice that has been significantly enhanced as a result of our experiences in this school and will be more fully explored below.

Overall, our work has benefitted greatly from the work previously established by science education researchers. Our work was informed by the quantitative studies that sought to identify the attitudes toward science and science education of a large demographic group (e.g., Weinburgh and Steele 2000) and the more recent work of qualitative researchers who strived to enhance our understanding of individual cases within those groups (e.g., Tan and Calabrese Barton 2008). With time, we added mixed methods (Creswell 2009), portraiture (Lawrence-Lightfoot and Davis 2002), Phototalks (Serriere 2010), and Photovoice (Wang 2005) to our arsenal of methods. Looking back over this group of research projects during this heuristic journey, we are surprised by how quickly we came to accept and use different methodologies, but also note that our use of one type of data collection became a very significant part of each and every other methodology used – the interview. We explore this throughout in the next section.

We utilized past data collection strategies in our work at this school. As our efforts expanded to include the nature of science, we were able to use validated and tested instruments that have been well established in our professional field (see Buck et al. 2010). Although many of the instruments we utilized were not designed for feminist purposes, we were able to use them to address such. These instruments not only provided a reliable and valid means to address the science education questions that emerged in our relationship with this school, but they also allowed our work to be informed, as well as to inform, the existing literature base in science education. Although measures such as these have provided us with valuable understandings of students' experiences in traditional classrooms, often they have not been used in a manner that has provided us with understandings in regard to students from diverse intersections of the population.

We also found ourselves using methods that have previously been accepted in our field of science education, but are not as well established. One of the methods was portraiture (Lawrence-Lightfoot and Davis 2002) (see Quigley and Buck 2010). Narrative inquiry is a methodology that acknowledges that communities share knowledge through sharing stories, and portraiture is a type of narrative inquiry that includes the participants. In this way, portraiture helped us to tell an authentic story of a community of which we were not members. As qualitative inquiry methodology, portraiture guides the construction of a story and relates that story to the wider contexts of the story in society and culture. Portraiture is described by Sara Lawrence-Lightfoot and Jessica Hoffmann Davis as an inquiry that blends art and science. During this blending of art and science, the portraitist uses qualitative tools of observation, data collection, and interview in a systematic and purposeful way to describe phenomena while using the beauty and aesthetic properties of art. As such, portraiture is a methodological approach in all aspects of the study, which includes a way to conduct, write, and record research (Yazzie 2002). Additionally, we purposefully wanted to employ a methodology that pays explicit attention to generating reciprocity between the participants and researchers – one in which there is an ongoing dialogue between the researcher and participants and benefits to both parties. In the "portraits" (Lawrence-Lightfoot and Davis 2002), the subjects benefit from seeing this "painting" of their classroom and interaction with their students, or students may benefit from reading about how they achieved success in science learning. Similar to the benefits of reflexive practice, the portraits create space for the participants to reflect and possibly improve practice. Portraiture and narrative inquiry are underutilized methodologies in the field of science education.

As we came into this school and started working with the teachers and students, these instruments were already included in our arsenal. However, as we found ourselves embracing the complexity inherent in working with diverse intersections of people, we found it necessary to find methods that were not so prevalent in our field of science education. For example, we found ourselves in the area of mixed methods research. First, we used a Sequential Explanatory Mixed Methods Study (Creswell and Plano Clark 2007) (see Buck et al. 2009). To address the research questions previously noted on the girls' attitudes toward science in a manner that would provide an understanding into all of the girls at the school while allowing for their unique perspectives, we needed two data collection phases: one that allowed us to use the methods established in research on attitudes in science and one that allowed for the unique understandings of these girls. We were able to integrate the two types of data during the interpretation phase. By using this approach, we were able to use qualitative results (interviews) to assist in explaining and interpreting quantitative findings (survey results). Second, we used a Concurrent Transformative Strategy (Creswell 2009). In this approach, the quantitative and qualitative data were collected concurrently with equal priority given to each method. The strategy is transformative in the sense that a voice is given to multiple perspectives in a reflexive manner. We used a survey to measure attitudes on a pre- and post-instruction basis and we interviewed the girls several times to explore changes in levels of emotional engagement throughout the year. The qualitative and quantitative data were integrated during the analysis phase to give these girls a voice in the change process. As feminist researchers, we place a high value on the voices of the individual; yet, we also seek to assure that the needs of all the girls are being met.

As our adoption of a system of power framework allowed the situation to become authentically complex, we found that our arsenal of available methodologies also had to become more complex. In this school, we found ourselves pushing the boundaries of feminist research methodologies in order to understand what was/should be happening within this unique context. However, looking back, we realize how our research efforts were greatly enhanced by incorporating interviews in each and every study. Interviewing the participants offered us access to the girls' and teachers' ideas, thoughts, and memories in their own words rather than in ours. In addition, the focus group interview format allowed for representation of the voices of a larger number of participants in the findings (Madriz 2000). We posit that by keeping the methodology in the words of the participants, some of the power remains with them.

As a result of our time with these girls and their teachers, we joined a growing number of feminist researchers in the accumulating stage (as described by Reinharz 1992). In our work, all methodologies have some claim to ideological validity. We believe that it was only through the acceptance and use of diverse typologies that we began to successfully navigate the complexity inherent in contemporary understandings of students' identities and the social forces, processes, and practices that shape these girls' educational experiences.

Conclusion

Developing a complex understanding of the interactions of race, gender, and culture for these girls and science education is not easy, and we do not claim to model perfection in this regard. Yet, now is the time to authenticate how the experiences with these girls, these teachers, and this context transformed our research and thinking. We have come to realize that although our prior experiences in addressing the needs of girls in science education afforded us an invitation to become part of the changes occurring at this public girls' school in a low-SES district, the resulting relationship positioned *us* to change – to confront the self-understandings that resulted from those prior experiences. Initially, we felt lost without the categorical boundaries of our research in gender; however, the efforts of other feminist researchers, the hope and expectations these teachers had for the girls, and the curiosity and excitement of the girls gave us the nerve to dive in and try to contribute to an improved school social structure. Our experiences resulted in a new understanding of gender research in science education. We found that working in gender research involves working within a complex system of oppression and privilege. What enabled us to get through the complexity of adjusting to such a mindset on diversity were the relationships we developed with *these* girls in *this* place – a relationship that was fostered by actively and reflexively responding to the voices of and in the school, developing research questions that supported that responsiveness, and establishing and utilizing an arsenal of methodologies.

We are not saying that our previous understandings and experience in equity research did not benefit us. Our understandings from previous research on gender, ethnicity, race, and students from low socioeconomic situations have all contributed to our experiences. What has changed was an approach that necessitated that we look toward one of these categories for the answer. We have come to realize that we benefitted from being able to look across these categories for possible understandings and approaches. The understandings from our field and our experiences were an invaluable part of the discussion; but, we allowed them to be adjusted and altered by the understandings and experience brought to the discussion by the girls, their teachers, and this place. In turn, we have been able to contribute to that knowledge base with research that addresses girls that cross those categorical boundaries. Although our research has actively rewritten itself, we know that there will be many more rewrites ahead. There are some issues that we know we will take with us as we face further revisions. These include how to foster strong relationships with a greater number of schools and teachers, including some resistant to change. In addition, we need to further explore the process of developing research questions that address inquiries of the school and research community, how to further involve the girls in the research relationship, and finally, the art of leaving the relationship in a manner that allows it to actively and continually rewrite itself.

Common Questions

1. What do the theoretical and methodological lenses used in this scholarship enable? What do they constrain?

Ultimately, this process has been a heuristic one. As we became more a part of the school, our theoretical and methodological choices became more about *this* school and therefore changed. However, we believe this ability to change according to the needs of the school helped us to meet our goal of understanding the developmental needs of *all* children, not just those from the more powerful members of the dominant culture. Our goal was never to replace one culture for another one in the dominant position in science education research, but rather to equally represent a broader range of social groupings in the research base. And, as our theoretical lenses changed, we realized that even by expanding our view of urban, African American girls, we still are being restrictive. One constant question remains in the back of our heads, “How do we understand each of these girls and how will that help us teach them science?” Moreover, as we were purposeful in the methodological choices we made to include participants, we enabled the teachers and the students to become a part of science, and not be bystanders to the research about them. But operating from an inclusive perspective has its limitations. We continue to struggle with ensuring that these girls are taught science that is culturally relevant using methods that break down the systems of power (Anderson and Collins 2007) while also ensuring that the girls know the Western Modern Science that will be expected of them as they continue their education.

2. In what ways can ideas in this chapter be used to inform research, practice, and policy? More specifically, what is the “so what” for graduate students and new scholars looking for ways to conduct research on equity and diversity? What are the implications of this research for classroom teachers and for policymakers?

We had several goals in writing this chapter. One goal was, to understand our own process in working with a marginalized community that we were not a part of – and through this reflective practice come to understand how our theoretical underpinnings and methodological choices enhance and/or further constrain science education for this population. Second, we implicate that it is critical that scholars' ideologies and methodological tools continue to change based on what they learn throughout their studies. Throughout our own heuristic process, we learned how our methods and theories changed as a result of what we learned in this setting. Third, by outlining the specific methods we used, we hope that scholars will see the many options available, especially for deeply disadvantaged students. Not only do we encourage scholars to challenge their own methodological choices but to look into methods that empower their participants. No longer is it adequate to conduct research on marginalized communities but rather our call demands research be carried out with such populations.

Throughout our teaching and research, many have noted how incapacitated they increasingly feel as schooling practices and policies intended to enhance girls' achievement are configured and reconfigured. We hope to assure new scholars that although confronting the authentic complexity in gender research in science education is unsettling and disrupting, it is also very rewarding and ultimately necessary if we are ever to realize science education for all.

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Chapter 12
Science Learning as Participation with and in a Place

Miyoun Lim, Edna Tan, and Angela Calabrese Barton

Introduction

Framing learning as changing participation is a powerful step forward in documenting the goals of science education. Learning as changing participation has its history within sociocultural studies of learning (Lave and Wenger 1991), but at the same time it calls into question the complicated ways in which the outcomes and goals of learning are shaped by the relations of power and privilege that often constitute a community of practice as well as by other historical, political, social, cultural, and physical factors (Gutiérrez 2008). Learning science is more complex than simply learning "about" science or even learning how to participate in a science-related community, for this does not fully capture the power dynamics imbued in doing science with and among urban youth in poverty. Rather, we view learning science as an *embodied* activity – one that takes place within context (Calabrese Barton and Brickhouse 2006). In other words, learning science involves not only learning the

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content of a discipline and how to participate within the negotiated boundaries of a discipline, but also learning how to challenge the norms of the discipline while simultaneously learning how to take a stance through discourse and action within the discipline.

A focus on changing participation calls attention to the role of place. How individuals value an activity depends, in part, on the purposes and goals of that activity, its relationship to a place (including local knowledge and resources), and the relative positions of power of the agents within that place. Informed by cultural-historical perspectives, we value *place* as a conceptual framework that helps us to understand the importance of the relationship between the individual and society, and also the local and the global (Nasir and Hand 2006). In other words, part of understanding how learning is "culturally mediated, historically developing" is to recognize how structures and trajectories interact in place-based ways (Gutiérrez and Rogoff 2003, p. 21).

Yet, science education seems to have ignored its intimate and unique connection with the local community, marginalizing the role of place in education (Gruenewald 2003). Science education has deprioritized the importance of place and its relationship to culturally mediated trajectories of practice to accommodate the push toward standardization and universalization of "what" students need to know and how they can best demonstrate that knowledge (Sanger 1998). However, although place has been silenced in the current education climate, it does not mean that place is absent in students' learning. As Jean Lave and Etienne Wenger (1991) pointed out, learning takes place whether there exists any intentional educational activity. Since place plays an essential part of youth's identity development, affecting who they are and how they learn, youth actively and purposefully *leverage* their sense of place when they engage in learning at school (Lim and Calabrese Barton 2006); thus, the point of the question becomes: In what ways does place play a role in youth's science learning?

Place matters because it orients science schooling in particular ways – it imbues the learning of science with certain expectations, practices, values, and materials. Furthermore, place matters because it positions youth in unique ways toward science learning: How youth are positioned socioculturally, politically, and geographically shapes how and why students and their teachers might choose to engage in science or in how they assign meaning or value to it. This latter point is important because it underscores that by engaging in the knowledge and practices of science in embodied ways, youth (and their teachers) can also transform the worlds they traverse in ways that matter to them.

We are interested in how place shapes the process by which youth work to transform their participation, and how youth's hybrid practices are layered into their identity development with and in a place. In particular, we explore the following question: How do youth work to transform their science learning as participation through dialectical and hybrid practices when they engage in community-based participatory research projects in a youth-based after-school program called Green Energy Technologies in the City (GET City)? We are particularly concerned with how place brings out what we refer to as tensioned dialectics, or tensions between seemingly opposing ideas of constructs (such as place versus science), which are often hidden or backgrounded in science classrooms. We are also interested in how these tensioned dialectics provide an expansive space of learning, meaning how they often function as "new ground" for further transformations of participation within the learning community.

Conceptual Background

Place and Education

Although place has been a popular topic of inquiry in diverse disciplines such as philosophy, psychology, architecture, and urban planning, it has not been a part of education discourse until recent years (Gruenewald 2003). As Matt Sanger (1998) reports, standard school practices "teach students that their relationship with their place is marginal, uninteresting, and unimportant and the quality of the environment demonstrates this marginalization" (p. 5). David Gruenewald (2003) similarly critiques the current Western education system for its disproportionate emphasis on accountability and standardization, leaving little room for diversification of educational concerns or discourses, including a concern for a local community and place. For example, today's education follows an "anywhere and anytime" general approach by establishing national (if not globalized) standards and subsequently developing curricula, which can be applicable anywhere and anytime (Smith 2002). Gruenewald (2003) argues that the idea of focusing on and including local places and their attributes in education is radical

> because current educational discourses seek to standardize the experience of students from diverse geographical and cultural places so that they may compete in the global economy. Such a goal essentially dismisses the idea of place as a primary experiential or educational context, displaces it with traditional disciplinary content and technological skills, and abandons place to the workings of the global market. (p. 7)

Alberto Arenas (1999) also points out that the current education system, which is based on standardization and universalization, disregards local histories, knowledge, stories, and languages in favor of the powerful national ones. Therefore, the importance and values of learning local knowledge and skills have been nearly eliminated in the current educational intentions.

As many researchers address the dangers of marginalizing the role of place in education (Gruenewald 2003), we believe that marginalizing place removes practice from the cultural–historical realm, reducing culture to a static set of attributes and activity only through subject–object terms. As pointed out earlier, several studies have shown that utilizing students' social and cultural experiences promotes engagement in science among urban youth (Seiler 2001). Lorie Hammond (2001) offers a particularly compelling example. In her research with Hmong-American families, she shows us how local funds of knowledge have helped to transform an elementary science curriculum when that curriculum *critically* emerged from their lived experiences. The result was that students and their family members were much more highly involved in school science. From an international perspective, Norman Thomson (2003) likewise demonstrates how the centralized and standardized national education policy has damaged place-based education in Kenya. Thomson, a science educator in Kenya, has argued that since the beginning of European influence and control of the education system through colonial exploitation, indigenous African knowledge in natural science and mathematics in Kenya has been ignored, underestimated, and depreciated. National standardized curricula and tests that are insensitive to local knowledge have desensitized students' knowledge and value of their immediate local environment. In short, science education has deprioritized the importance of place and its relationship to culturally mediated trajectories of practice to accommodate the push toward standardization and universalization of "what" students need to know and how they can best demonstrate that knowledge (Sanger 1998). The result is science schooling has become generalized, abstracted, and thus, disconnected conceptual delivery.

Therefore, if we are to challenge science schooling, which marginalizes place, and to conceptualize connected science-learning perspectives with and in a place, situated learning theories offer useful directions. As Lave and Wenger (1991) noted, we believe that learning occurs regardless of intentional educational activities. While "here and now" seem to hardly matter in current science schooling, meaningful connected science learning can and will occur when "situatedness" of a place is brought into a learning context (Lave and Wenger 1991).

Learning as Participation Through Hybridity

We draw upon Kris Gutiérrez and Barbara Rogoff's (2003) definition of learning as changes in forms of participation and the ways in which such participation is "culturally mediated, historically developing, involving cultural practices and tools" (p. 21). Central to their thesis is the idea that culture is dynamic and activity-based. Gutiérrez and Rogoff argue that such an activity-oriented understanding of learning suggests that culture can only be understood through its context development, and never as a set of definable, measurable traits. As they cite Michael Cole and Yrjö Engeström, "Culture is experienced in face to face interactions that are locally constrained and heterogeneous with respect to both 'culture as a whole' and the parts of the entire toolkit experienced by any individual" (Cole and Engeström 1993, p. 15).

Sociocultural theories point toward how changes in forms of participation are the products of both shifting cognitive and social functions. Cultural-historical approaches point toward how such education practices "are constituted through the junction of cultural artifacts, beliefs, values and normative routines known as activity systems" (Gutiérrez 2002, p. 313). Equally important, this framework intertwines the role and importance of cognitive, social, and emotional processes in sense-making.

For example, Carol Lee and Yolanda Majors (2003) argue, “Success and failure in school is contingent upon one’s ability to regulate and situate identities, utilize culturally-developed semiotic tools and negotiate models of meaning in shared social activity” (p. 49). Thus, from cultural-historical perspectives, learning is conceived of as a process occurring within ongoing activity and not divided into separate characteristics of individuals and contexts. Cultural-historical approaches are particularly helpful in moving researchers beyond cultural regularities and the assumption that general traits of individuals are attributable categorically to ethnic group membership, by paying attention to variations in individual’s and group’s histories of engagement in cultural practices (Gutiérrez and Rogoff 2003).

The centrality of race and culture within a cultural-historical activity theory makes it a particularly productive framework for understanding the hybridity and heterogeneity inherent in cultural activity, cultural artifacts, and their participants. Elizabeth Moje and her colleagues (2004) referred to three views on third or hybrid space: hybrid space as a supportive scaffold that links traditionally marginalized funds of knowledge and Discourses to academic funds and Discourse; hybrid space as a “navigational space” (New London Group 1996) in gaining competency and expertise to negotiate differing discourse communities; and finally, hybrid space where different funds and Discourses coalesce to destabilize and expand the boundaries of official school Discourse (e.g., Moje et al. 2001). We draw from all three views of hybrid space with particular emphasis on the third view, in which “everyday resources are integrated with disciplinary learning to construct new texts and new [scientific] literacy practices that merge the different aspects of knowledge and ways of knowing offered in a variety of spaces” (Moje et al. 2004, p. 44). Third space, or hybridity, therefore, sheds light on science learning because it offers a way of understanding how learning science involves learning to negotiate the multiple texts, Discourses, and knowledges available within a community as it is learning particular content and processes (Moje et al. 2004). Brokering for such hybrid spaces in science class is therefore imperative when envisioning a science education that draws from students’ out-of-school knowledges and expertise.

Research Design and Context

Green Energy Technologies in the City (GET City) program adopts a place-based, youth participatory action research (PAR) approach. The program provides opportunities for urban youth to investigate science issues in their own community and actively participate in change-making processes in their own place as “community science experts” (Calabrese Barton and Tan 2008). The PAR approach provided an opportunity to closely observe (1) how youth leverage their identities as they try to participate in community science projects as community science experts and (2) in what ways a place-based community science project could facilitate and support youth learning as participation.

Green Energy Technologies in the City: GET City

GET City is an after-school, "voluntary" science/technology/social club for youth aged 10–14 years located in a Midwest urban center called River City. GET City is funded by the National Science Foundation, and holds as its dual goals to foster deep and meaningful learning among urban youth in the areas of advanced information technologies (including data acquisition, management and analysis tools, and communication tools) and the science and engineering of green energy issues. As a weekly after-school program at the Boys and Girls Club, it is also a social space for youth to congregate and talk about friends, music, school, and other social experiences that matter to them. The club largely serves youth from minority (about equal distribution of African American and biracial children) and low-income backgrounds (most of the children are on free or reduced lunch program in schools). Because GET City also revolves around the use of an advanced wireless laptop cart, the youth who participate use their access to the computers to gain status among club youth as well as to foster the social nature of the program by using the program space to afford access to email, You Tube, Jam Glue, and other youth-oriented e-spaces.

While GET City is a formal after-school program, where attendance is structured and there are rules for conduct and participation, it is a hybrid space that skews more toward the youth's worlds with different stakes. Youth do not receive grades as they do in school. They are not ranked and their success is not metered by high-stakes exams, as is common in their schooling experience. As teachers, we work to forge a more collaborative relationship with youth than is often found in schools. Also, GET City has the freedom from standards and district curricular requirements such that if student interests dictate, it spends more time than intended on a particular area without worry of penalty.

The program began in the summer of 2007 with 20 students (roughly equal distribution of girls and boys, both African American and biracial) and enrolled three cohorts of about 30 youth by summer of 2010 (similar demographics as before). The study focuses on three activities that youth participated in as part of GET City during 2007–2008, (1) investigation of urban heat island (UHI) phenomenon in the River City (Summer 2007), (2) production of public service announcements (PSAs) about energy supply and demand in the past, present, and future (Fall 2007–Spring 2008), and (3) survey research for River City's "Go Green" program (Spring 2008–Summer 2008). These activities supported youth to engage in close contact – through science – with members of the public. Each of these units is described briefly later.

Urban Heat Islands

The urban heat island phenomenon was explored with the GET City youth during a 5-week unit in summer of 2007. The urban heat island unit was first introduced to students by asking them to consider whether River City is an urban heat island, and how they might find out. Urban heat islands are urban and suburban regions that are

1–6°C hotter than nearby rural areas. Elevated temperatures can impact communities by increasing peak energy demand, levels of air pollution such as ozone, and heat-related illness (Environmental Protection Agency [EPA] 2008). The youth investigated the causes of heat islands and how they are related to energy usage and health-quality indicators such as ozone levels. The youth developed their Geographic Information Systems (GIS) skills by producing and managing data and drawing upon EPA databases to study the relationship between environments and local air temperatures. The participants also mapped temperature and ozone levels using both thermal and chemical probes to relate heat islands to air quality, and explored the impact of urbanization on heat island formation by relating various surfaces (concrete, asphalt, vegetation) to surface temperature under identical conditions. Finally, the youth produced three 8-min youth-centered scientific documentaries on the UHI phenomenon.

Energy Supply and Demand

Following the UHI unit, the youth investigated the issue around the "Energy Crisis" and what it would mean to generations down the road, should energy consumption continue to escalate. Using the framework of the carbon cycle and the carbon footprint, students investigated and modeled where and how River City area energy is produced, how it is distributed and used, and the implications of overuse (i.e., energy consumption patterns from supply and demand perspectives). They conducted energy audits at the Club and at their homes, documented the appliance explosion in their families and communities, and generated graphs depicting supply and demand issues for future generations. They created 30-s and 60-s Public Service Announcements (PSAs) using i-Movie, and their PSAs have been televised on their local CBS affiliate station.

Go Green

Two of the GET City youth learned about the *Go Green River City* initiative while conducting research for the PSAs. Go Green is a city-wide program initiated by the mayor's office, and asks each River City resident to commit to using reusable grocery bags and compact fluorescent lightbulbs, to carpool, to recycle, and to unplug appliances more. The youth decided that they needed to do a survey for the mayor's office to figure out: (*1) how many people knew, about Go Green (2) whether, people were following the five energy practices described in Go Green and (3) hand out the Pledge to adopt those green energy practices.* The youth shared the survey with the city's director of Go Green, and she offered feedback from the mayor's perspective. The youth further conducted the survey with members of the community in four different locations, analyzed the data, and wrote a report with recommendations to the mayor's office on how to increase the public's awareness on "green" issues as well as suggestions for concretely supporting members of their city in taking action to be more environmentally conscious.

Data Acquisition and Analysis

We have relied on critical ethnography (e.g., Trueba 1999) to frame our research. Critical ethnography is a methodology for conducting research focused around the goals of participatory critique, transformation, empowerment, and social justice (e.g., Calabrese Barton 2003). Critical ethnography is rooted in the belief that exposing, critiquing, and transforming inequalities associated with social structures and labeling devices (i.e., gender, race, and class) are consequential dimensions of research and analysis. Given that urban education is marked by layers of inequalities from how schools are staffed and funded to the kinds of courses and resources available to students, the analysis and transformation of inequalities is particularly important in urban science education research. Critical ethnography also calls us to search for and use tools, which will enable us to examine and transform inequalities from multiple perspectives, and in particular from the "perspective of the oppressed" (Trueba 1999, p. 593). This point about perspective is consequential because the majority of youth in urban schools live in poverty at some point in their childhood and more than half belong to ethnic minority groups. Critical ethnography also demands that the purposes, tools, and outcomes of research be co-imagined and produced by the researcher/researched, in order to break down such a binary and to allow the toils and fruits of research to be informed by a range of perspectives.

We are researchers involved in this setting to varying degrees. Edna and Angie, as researchers as well as teachers in the setting, worked closely with youth who also participated in planning and research while Miyoun served as a distant researcher. Our different roles and involvements in the setting allowed us to bring multiple perspectives into the analysis. We met with youth to discuss the goals of our project and to work toward new and different spaces for youth to author our research with us. For example, while we went into this study wanting to understand the role of agency in learning, the youth pushed us to consider video ethnographies as the primary outcome of our work together. While we were interested in how youth took up certain science ideas and IT practices such as UHI explanations, digital probes, models, and graphs, the youth prompted us to consider other IT media that involved more socially oriented practices. Data analysis involved multiple stages and levels of coding (Strauss and Corbin 1998). We developed coding schemes on various aspects of GET City, which seemed to be particularly relevant to engaging youth in energy issues and in advanced IT. We have paid attention to the quantity and quality of youth engagement, including documentation of which youth participates in what ways, on how science meanings have been negotiated by youth, and on how youth talk about science, noting how the language they use positions them with particular roles and expertise.

Uncovering Tensioned Dialectics in Place-Based Education

As we stated earlier, from critical sociocultural perspectives, we have to be concerned with learning as movement – that meaningful learning among youth can be observed by how, when, and why their participation transforms over time and across communities.

We have been particularly concerned with what this might look like (if at all) in a community-based science learning setting, and what role(s) place might play in affording such a movement. Our findings reveal that "place" facilitates and constrains participatory learning by the contextual scaffolds it gives rise to. By contextual scaffolding, we reference the situated cognitive stance that the contextual dimensions of meaning-making are deeply entrenched in the social, historical, geographic, and political relations of which it is a product (Brown et al. 1989).

The study suggests how place-based, participatory contexts facilitate embodied science learning and support youth learning as critical participation. In what follows, we first describe the tensioned dialectics that surfaced in our place-oriented approach to GET City: What are they, how did they surface, and how were they taken up by the youth and teachers? We discuss how these tensioned dialectics served as contextual scaffolds in support of participatory science learning because of the dialectical hybrid practices they afforded. Through hybrid practices, the youth reconciled tensioned dialectics in science learning by authoring their learning. We discuss how they reconciled (1) science versus place and (2) knowledge versus action through their hybrid practices.

Reconciling Science vs. Place Through Contextualization

One of the tensioned dialectics that became visible in GET City was the tension between science and place. The doing of science is always situated by place – individuals located in time and space investigating an observable phenomenon. Yet, "place" is often invisible in the learning context as we abstract meaning from context to develop generalized patterns and explanations of the world around us. Science schooling tends to stay as decontextualized, isolated conceptual delivery. Thus, due to its focus on generalization and abstraction, science schooling often fails to frame science teaching and learning as a contextualized and connected endeavor, situated within students' lifeworlds. Therefore, due to the abstracted, disconnected, and consequently limited scope and focus, science schooling may not address the dialectical nature between science and place as a valuable and critical component of science learning, which could facilitate meaningful, expansive learning for youth.

Yet, we noted, in GET City, place often became visible in the learning context either because place was called into question (e.g., but what about here in the downtown?), because it was a central anchoring feature of the curricular design (e.g., does your city exhibit the UHI effect?), or because place became the central context of inquiry (e.g., how can we make our city more energy-efficient?). Such purposeful and sometimes problematic visibility of place often invites a tensioned dialectic between place and science into a learning context. For us, most importantly, this tensioned dialectic fostered opportunities to frame the value-laden nature of scientific inquiry and to negotiate a more authentic – but more complex – investigation.

For example, at the very beginning of the UHI unit, we first asked students to consider whether River City is a UHI and how we might find out. Because none of the students had ever heard of this concept before (as we anticipated), we asked them to consider the question: "Where would you rather be on a hot summer day? Standing in the middle of a mall parking lot or under a shady tree?" We had hoped that the kids would respond by saying something like, "No, I don't want to stand in a hot parking lot! I would be much cooler in the shade." Rather, they exclaimed that if they were in a hot parking lot, then they must be near an air-conditioned mall, a much more desirable location! An animated debate followed raising a set of relevant issues: A mall parking lot would be hot and uncomfortable but a desired location because it meant you were heading to an air-conditioned mall to shop. A shady tree would be cooler and relaxing, but possibly boring with no proximity to air-conditioning, shopping, and cold drinks. Immediately, the youth pushed beyond the intended science question of which decontextualized spaces would be cooler and thus more comfortable, to the more complex consideration of how these spaces are situated physically and socially with everyday desires and practices.

This conversation raises questions about the complexity of framing the UHI phenomenon in locally meaningful and relevant ways. The tensioned dialectic involving place and science confronts the values individuals bring to unpacking a scientific problem. We, the teachers, had stripped away, to some extent, the cultural values of the urban planning choices we as a society have made, in our efforts to get the youth to see and discuss the temperature differentials due to the built environment. Yet, due to the visibility of place, we had to ultimately acknowledge our own values – the desire to think about science environmental sustainability, ignoring our lifestyle that seeks comfort and convenience.

Through this debate, the youth raised a question for clarification: Are we going to study UHI (i.e., study a science concept) or are we going to study UHI *in River City* (i.e., study a real problem in the city through science)? The youth seemed to express their desire to define their own science learning in a "real" context. If the question was posed in a science classroom, students might have responded to the question easily or differently. In science classrooms where the ultimate, communicated goals of science learning would be to develop conceptual understanding of science, contextualization or anchoring of science phenomena or problems are often used to serve as engaging entry points, which leads back to the learning of science concepts. Therefore, students who understand the cultural norms of science schooling – although the question is presented in a contextualized form, the answer would still have to be scientific or science-centered–would have responded to the question with the rather obvious answer of "under a shady tree." However, the GET City youth challenged the norms of science schooling and asked for their science learning experience to be contextualized within their lifeworlds, with a desire for the science they are encountering to be "real" for them.

The tensioned dialectic involving place and science also surfaced later in a more significant way in the UHI investigation. During the first four lessons, the youth built model homes of different colors and conducted experiments to determine the surface and air temperatures in and out of the houses in the sun and shade. The point of these lessons was to engage youth in understanding the relationship between building materials and heat absorption and radiation and the impact on surface and air temperatures across two contexts (sunny and shady). During the next set of lessons, we wanted to delve more deeply into the design of the environment. How much does a densely packed environment impact a neighborhood's surface and air temperature versus an environment with planned green spaces? Our original lesson design was to have the students build model landscapes, such as a simulated city with a high percentage of land space covered with buildings and streets or a simulated park with high percentages of green space, and then to repeat the experiments conducted with their homes. Our intended goals with this lesson were to help the youth distinguish the three main types of "urban" environments – urban, suburban, and rural – by learning characteristic land-cover types, and then investigating the effects of different land covers on local air temperatures.

However, when we initiated the conversation around land cover, the youth were, on the one hand, intensely interested and somewhat knowledgeable about the differences in land cover and surface temperature – indeed their talk about the heat in parking lots, playgrounds, and asphalt basketball courts framed our talk. On the other hand, they rejected the idea of building more models when these types of environments existed all over their city. Several of the youth indicated a desire to not build more models, but to investigate whether this phenomenon was actually real in their city. They wanted to do an on-site investigation of their community. Doing an on-site investigation grew out of one boy's fascination with "thermal images." A group had taken what they thought were "thermal images" of their houses in the sun and shade (using the "thermal camera" effect in their i-Sight camera). They had recalled similar thermal images of cities we had shared previously to engage the youth in conversation around thermal stratification in the built environment. They shared their pictures as part of their data set, setting off a conversation about whether any images of River City existed that revealed its thermal stratification, but no one could find any on the Internet.

We decided to listen to their pleas and engaged them in dialog around "what would they do" to figure out whether River City exhibited the UHI effect. While it may very well be that the real impetus for arranging fieldtrips was to get out of the classroom, embedded within their negotiation were indicators that they understood the content well enough to drive the investigation, but equally as important they were the ones uniquely positioned to know how and why this content mattered to them and the residents of their city. Using their suggestions, we replanned and asked students to explore the land cover of the River City using GIS systems and to predict which areas of River City may exhibit the UHI effect due to the built environment. With the youth, we negotiated an investigation that included the following: They would use Google Earth to visualize the local environment, document differences in the built and natural land cover, and hypothesize locations where they thought they might find evidence for the UHI effect. After selecting a portion of downtown that contained to them the most densely built spaces, they produced a viable scheme for gathering useful evidence, which in essence modeled our previous experiments. This included taking multiple temperature readings at various locations, measuring the square footage of the built versus natural land cover, and documenting the nature of the built and natural land cover.

We encouraged them to add another element: interviewing local residents and workers, in ethnographic fashion, to gather ethnographic evidence for human impact.

The youth took up this suggestion enthusiastically and spent time writing potential interview questions and practicing on one another. Before embarking on the field trip, the youth also practiced their interview skills with the adults at the club. This approach allowed us to introduce youth to spatial thinking through GIS (Google Earth), and to allow them voice in how we constructed our investigation. The youth essentially turned this added-on component into the centerpiece of their argument. In each of the documentaries, an average of 2:08 min was used in presenting community member interviews (of an average total of 8:23 min). In each documentary, the interviews were presented primarily in the first half and used to set the case for the UHIs, by presenting common misconceptions, showing how UHIs affected people differently due to occupation, and showing a lack of awareness on the issue. As the stories showed, the youth negotiated to reorganize or change planned curricular goals, activities, and outcomes, interjecting alternative approaches and directions. The tensions that emerged in the UHI unit between science and place provided the youth with a fairly robust, although contested, space in which to make sense of the science under investigation as just discussed. At the same time, however, it transformed their participation in ways that broadened future work within the GET City context.

The idea that science could grow out of and be responsive to local concerns led youth to critically examine, and even talk back to, local city policy. In the next example, the youth described how they conducted a needs assessment project for the city's environmental program called *Go Green River City*. To illustrate how confident and competent the youth were in the process, we present segments of their writing to convey their perspective and voice. Here is how the youth described how they initiated their project:

> [During the research] an interesting thing happened. Two of us (Ledarious and Tre) found out about a program in our city called *Go Green River City* while interviewing Josh Hovey (a staff person in the mayor's office) to gather information about what River City was doing about energy issues to include in our PSAs. Go Green is a program put out by the River City mayor's Office. Go Green asks each River City resident to commit to: using reusable grocery bags, compact fluorescent lightbulbs, and to carpool, recycle, and unplug appliances more. When Ledarious and Tre told the rest of us about Go Green we were all surprised to learn about it. We thought it was a great program that required everyone to take some real action. (From youth essay)

After having done the UHI investigation and the PSA production, the youth really considered themselves as experts. As one girl coined the term, "We're make-a-difference experts." So, when they learned that their very own city had a *Go Green River City* policy initiative, they were quite surprised, if not upset, that they didn't know about it and that the city had not made it more accessible for everyone. They quickly identified the potential value of the project, which aligned with their agenda of taking some real action. This led to the development of the Go Green survey project:

> Then one of our team decided that we needed to do a survey on what the people in River City knew about global warming and about Go Green. She conducted this survey with about 25 people during Earth Day. She learned that most people have no idea about what to do to stop global warming besides turning off the lights and walking to work and no one had heard of Go Green! When we looked at her findings, we thought that as a group we could

> do something bigger that might help make a difference. We decided that the best thing to do would be to do a survey for the mayor's office to figure out: 1) How many people know about Go Green; 2) Whether people were following the five energy practices described in Go Green; and 3) Hand out of the Pledge. We shared the survey with the director of Go Green, and she approved of our survey. (From youth essay)

Once their research plan got approved by the mayor's office, the youth systematically conducted the survey project.

> We then traveled all around River City to get our survey out. We went to: (1) River City's Diversity Day Festival on May 3; (2) Walmart on May 6; (3) Boys and Girls Club (parents) on May 6; (4) and the University on May 8. We gathered surveys from 194 adults. After each adult took the survey we gave them a copy of the *Go Green River City* Pledge and asked them to sign it. Together, we typed in all of our results, and then used Excel to help us make graphs of our results. We put our results into PowerPoint to share with the mayor of River City. The mayor and the Go Green Director, Taylor Heins, were so excited with our results that they invited us to present them to the River City Energy Policy Council, and gave us a certification of partnership with the city. We also made recommendations for the mayor to consider to help with the energy crisis in River City. (From youth essay)

Place mattered to the youth in how they framed their project. At the end of the project, the youth reported their findings grounded in empirical data they collected from their community. They communicated their suggestions on what the mayor's office could do to support people embarking on a greener lifestyle in River City. These suggestions possibly led to more ways to make real differences within the community, since the audience included staff representatives from the public transport company as well as the recycling company.

The story shows how the youth challenged norms of how to learn science and were thoughtful and strategic in how the science they learned be framed, approached, and accessed. By contextualizing their own learning experiences (through decentering of science, reorganizing science curricula, and authoring a science research project), the youth reconciled the tension between place and science in their learning.

Reconciling Knowledge vs. Action Through Participation

Another dialectical tension is between knowledge development and taking an action, which facilitated youth authentic, value-laden learning of science through participation. As the youth engaged in science learning through the community-based participatory research, they seemed to realize how the knowledge should be put into practice or used to benefit the community. The youth demonstrated strong desires for taking "real" action and making "real" differences in their community. This is how they described their stance:

> We enjoyed learning about the environment, but we wanted to take some real action. We decided to start our own project where we would create PSAs to help educate the River City community about the environment and what could happen if everyone doesn't take responsibility for making changes in how we use energy. We wanted our PSAs to do three things: 1) Capture people's attention; 2) Teach them about the environment and how their energy practices

> have environmental consequences; and 3) Reach as many people as possible. Making the PSAs was a difficult process because we had to pull a lot of information together to do this. We thought that we could make our PSAs in the form of TV commercials, and if we could not get them on TV we could at least broadcast them on You Tube. We asked the Club President and our GET City teachers if we could work on our PSAs every Tuesday and Thursday until the project was done, and everyone agreed. (From youth essay)

Here, the youth clearly pointed out the tension that they experienced between knowledge and action. Conventionally speaking, youth science learning is heavily focused on and limited to knowledge development as a goal, if not the goal. Due to its emphasis on knowledge production, it is often decontextualized, abstracted, and disconnected science knowledge. Current schooling hardly allows or affords students to make meaning of the knowledge and to envision a trajectory of the knowledge within their lifeworld. Therefore, action is rarely considered as part of conventional science teaching and learning practices. Even if it is, action is often treated as a tokenism and rarely becomes a "real" consideration in science schooling. However, the GET City youth challenged the disconnection between knowledge and action and negotiated for the opportunities to take "real" actions to make "real" differences in their own communities. Through dialogical engagement, the youth wanted to produce a tangible, community-grounded outcome from the science they had been learning.

The youth developed not only strong convictions (e.g., everyone should take responsibilities to make changes), but also embodied understanding and skills to plan, strategize, and carry out their ideas into actions. The youth further explained the process of their PSA production:

> First, we created storyboards to help us get out our main points. Some of us wrote stories that connected to what we already learned in GET City, such as why it is important to unplug appliances. Many of us did extra research and wrote stories about how the energy we use now in Michigan can cause problems all around the planet. We then wrote scripts, created pictures and graphs to represent climate change and its global impact, and selected music that would help get our point across. We really wanted to educate people in River City in a way that would catch their attention and would be fun. (From youth essay)

The youth strategically and skillfully authored this PSA production project through setting up clear goals for their actions, utilizing science understanding that they have developed, pursuing further research to support and expand their arguments, leveraging social and cultural capital at the Boys and Girls Club, and strategizing their action plans to accomplish the goals they set for themselves – to attract, educate, and reach out to community people. While all the youth in GET City participated by creating PSAs, six were selected by a local panel of judges (a science teacher, representative from the board of water and light, and a graduate student from the university) to be aired on a local television station. The PSAs were judged for their science content and visual appeal.

Returning to the *Go Green River City* project. In this example, we can witness their confidence and competence in terms of hybridizing the dialectics of knowledge and action. Here, we note how skillfully the youth navigated the dialogical relationship between knowledge production and taking an action. The youth knew how to "use" science strategically to support their agenda, i.e., dual purposes of knowledge production and taking action. They framed and proposed the problem they had identified to the mayor's office using scientific language: using their scientific pilot study findings with a well-designed research plan for a bigger survey. What we have to note here is how youth continued to address the need for real action in the research plan. The survey project was designed not only to find out what people knew about the environmental program and how people engaged in the environmental practices, but also to encourage people to act by handing out the pledge, which asked residents to commit to five simple things (recycle, conserve energy, reduce waste, replace lighting with CFLs, and use alternative transportation when possible) to reduce their environmental impact in the city. Once their research plan got approved by the mayor's office, the youth systematically conducted the survey project. At the end of the project, the youth reported their findings grounded in empirical data they collected from their community and communicated their suggestions on what the mayor's office could do to support people embarking on a greener lifestyle in River City. These suggestions possibly led to more ways to make real differences within the community, since the audience included staff representatives from the public transport company as well as the recycling company.

This description of the Go Green survey project also illustrates how the youth worked through the dialectical tension between knowledge and action, accomplishing both of them successfully through the project. As a matter of fact, the strong sense of purpose, i.e., the youth wanting to make real differences in the community through their science projects, seemed to be the motivator driving the youth's learning as participation. The youth engaged in scientific research processes, identified a potential problem to be explored, conducted a pilot study to gather baseline data, presented their research ideas with detailed plans to the mayor's office, conducted a strategically planned research project, and communicated their findings to the wider community via the Internet and local television station. The Go Green survey project was a collaborative effort by the youth. Different youth were responsible for specific aspects of the survey project. While some worked on crafting survey questions, others worked on data analysis. In the end, eight of the youth represented GET City to present their results to the mayor. As a result, the youth not only experienced scientific research processes but also produced scientific knowledge that is useful for the community. A critical outcome of this research project was how the youth took concrete actions to bring about real differences in their community through their knowledge development in socioscientific issues such as energy consumption and one's carbon footprint. The youth seemed to have reconciled the tension between knowledge development and taking a real action through their critical participation in the projects.

Discussion

The stories illustrated that youth's identity development as community science experts (CSE) was interactive and expansive with and in a place as the place scaffolded the youth's science learning as participation with and in their place. Here, we discuss how the GET City youth expanded their epistemic, place, and science identities through the dialectical, hybrid science practices as they worked to transform their participation as CSE.

From the beginning, the youth seemed very secure about their epistemic identity. It is illustrated by how the youth tried to exert their epistemic authority when they asked for clarification on their learning context (e.g., parking lot debate) and challenging and negotiating the purposes, activities, and outcomes of their science learning to be "real" for them. As a result, youth successfully negotiated going on a field trip to downtown River City to explore the UHI phenomena for real. Furthermore, youth made the added-on component of community member interviews a central component in their video documentary projects. As the youth further engaged in the program over the year, as illustrated in the stories from PSA production and Go Green survey projects, we witnessed the youth taking more ownership and fuller control over their own learning. Their epistemic identity development through authoring the nature and purpose of their own learning and positioning self as an agent of change seems to be a critical aspect of their changing participation.

Another aspect of their participation focuses on how their place identity as a member of the community became expansive through the program. Since the youth participated in the program as insiders of the community, the youth demonstrated their place identity in various dimensions. The youth developed contextualized, comprehensive, and critical understanding of the science problem as it is situated within and connected to the community. Also, they demonstrated confidence and competence in how to approach the problem as it is ecologically and contextually situated in their community, such as their skillful and strategic approaches to their projects using community's social, cultural, and political capital. Furthermore, the youth showed affective ties and commitment to the community through their strong conviction to make real differences in the community by taking responsibilities and self-assigned leadership roles (as community science experts). Their place identity, demonstrated through embodied understanding of and commitment to their community, seems to be another critical aspect of their participation.

Another critical aspect of their participation is youth's relationships with science. A trend we saw with a majority of the youth is that they resisted remaining as simple recipients of science learning. The youth stated that although they enjoyed learning about science, they really wanted to make concrete differences through science in their community with what they were learning. They wanted to apply their knowledge to better their community then, and not just in the future. Through hybrid practices, the youth managed to become critical consumers of scientific knowledge (i.e., utilizing scientific knowledge to accomplish their goals for making differences in their community) and also critical producers of scientific knowledge (i.e., producing new scientific knowledge to be used to educate and impact their community). We posit that through their critical participation in science projects, the youth have shown their ability to critique, challenge, and expand cultural norms of science teaching and learning. For example, in their continuous negotiations and efforts to contextualize science within their community, the youth critiqued science education as decontextualized and disconnected activities and demanded authentic, connected science learning opportunities. Also, by insisting on taking “real” action, thus by acknowledging science to be value-laden, purposeful inquiry, the youth challenged the norm of science as value-free objective activity. Lastly, through the dialogical, hybrid practices of genres, representations, and roles, the youth challenged and expanded norms and boundaries of science, what and how science learning should be. In short, through their practices as CSE (i.e., participation in science as critical consumers, producers, and critics), the youth have shown us and taught us how science learning *can lead to a transformation of participation.*

What Do the Theoretical and Methodological Lenses Used in This Scholarship Enable and What Do They Constrain?

The theoretical and methodological lenses employed in the study have assisted us to approach science learning as changing participation and to document how “situatedness” of a place mattered to meaningful connected science learning for youth. Thus, we approached science learning not as simply learning the content of a discipline and learning within the boundaries of the discipline, but also as learning how to challenge norms of the discipline and taking a stance through voices and practices within their communities. We employed place as a conceptual framework to examine the importance of the relationship between the individual and community and also the local and the global, which offered useful directions to conceptualize science learning with and in a place – how structures and trajectories interact in place-based ways. Cultural-historical activity perspectives allowed us to pay attention to complexity and diversity in cultural practices, thus particularly served as a helpful framework for understanding hybridity and heterogeneity inherent in cultural activity, cultural artifacts, and their participants.

Through the study, while we noted the potential of these conceptual lenses in science education research, we encountered more questions and recognized further directions to be pursued. Due to its interest and focus on changes in youth perspectives and participation within the particular context, the study is limited in its discussions of pedagogical and cross-contextual considerations. For example, our discussion is limited in terms of examining and considering multiple aspects of science learning and teaching and our inquiry is limited within this rather accommodating after-school context. These conceptual lenses will need to be further explored through various pedagogical practices in diverse educational settings to offer a fuller understanding on the affordances of “place” in science learning. We also acknowledge the difficulties inherent in engaging in such place-based science learning when we ourselves are not “native” to the space. While we were glad to have the students lead in planning the investigations and activities given their identities as authentic community members, there were negotiations and compromises we had to work through as we sought to balance our roles as science teachers and adults responsible for these students during GET City.

What Are the Ways Ideas in This Chapter Can Be Used to Inform Research, Practice, and Policy? More Specifically, What Is the "So What" for Graduate Students and New Scholars Looking for Ways to Conduct Research on Equity and Diversity? What Are the Implications of This Research for Classroom Teachers or Policymakers?

We believe critical ethnography which requires the purposes, tools, and outcomes of research to be negotiated and coproduced by the researcher/researched would be of specific interest for scholars who look for ways to conduct research on equity and diversity. With this approach, we were able to observe and document youth perspectives and practices as they tried to negotiate and interject their own learning goals, activities, and/or outcomes, which in turn shaped our research process and outcome as well. This methodological stance could assist others to break down the traditional binary and to be informed by multiple perspectives, in particular from the "perspective of the oppressed" (Trueba 1999).

As we noted before, the focus of this study was more on youth perspectives and voices with a limited discussion on pedagogical processes of the projects; however, we recognize that there is pedagogical as well as theoretical potential in our inquiry on the affordances of place for science education. We hope science educators would find the contextual relevance and concreteness of "place" useful as a pedagogical construct, thus to generate further inquiries and pedagogical practices in their science education efforts.

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Chapter 13
International Response for Part III: Reflections on Context, Place-Based Education, and Science for All

Tali Tal

While reading the four very intriguing chapters, I kept asking myself in what ways the situation studied and the realities described in these chapters apply to other cultures outside the United States. My own experience with American urban schools, underprivileged communities, and racial issues lies with my postdoctoral research at the University of Michigan in 1999–2000, which exposed me to research on equity in science education. However, issues of dominant culture, marginalized sectors, poverty, and equity are familiar to me in my own diverse and complex Israeli society as well. When discussing minority issues in my country, we generally refer to the Arab minority population. The Palestinian citizens of Israel struggle to achieve equality in all possible domains, while maintaining their care for and support of the Palestinians in the occupied territories (West Bank and Gaza) who are struggling for freedom and independence. This Arabic-speaking population is diverse as well and is composed of a Muslim majority and Druze and Christian minorities who live either in mixed or segregated communities. Other minorities within the Jewish population of the country are Jewish immigrants from Ethiopia who first immigrated as an ethnic group in the 1980s and 1990s, and have kept streaming into the country in smaller groups up until now. Additionally, there are Jews who emigrated from Middle Eastern and North African countries in the 1950s (Sephardic Jews), and who became almost half the population until the breakdown of the Soviet Union (which allowed more than a million Jews to emigrate). However, despite being nearly half of Israel's Jewish population in 1989, for many years, the Sephardic Jews were politically and socially marginalized by the European Jews' hegemony. Even nowadays, there are clear differences in the socioeconomic

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status, demographic distribution, and education between descendents of European and Middle Eastern immigrants.

In the following commentary, I will address some educational issues, such as place-based education and reflection, while referring to the above-mentioned context. Themes brought up in the four chapter-context, place-based education, reflexivity, and science for all-can evoke mutual discourse among the authors and with audiences outside the USA.

Context

Although thoroughly defined in the four chapters, it is clear the authors use the term context somewhat differently. Context has to do with place (setting), time, history, culture, and personal experiences. It can be at the background of an educational endeavor or the focus of such an endeavor. Eileen Carlton Parsons and Gillian Bayne use context to investigate teachers' practices; Gayle Buck and Cassie Quigley refer to the complex context of their involvement and research arena; and Miyoun Lim, Edna Tan, and Angela Calabrese Barton make context a central principle in the design of the educational program with which they were involved. Although Leon Walls, Gayle Buck, and Valarie Akerson do not explicitly refer to context, they situate their understandings within a social structure – context, in other words. They take research on NOS from its traditional-neutral-scientific position into the context of the minority, race, and gender intersection. In a way, Parsons and Bayne's explanation for context as layers of influence and time, both proximal and distal to their subjects, made me think of the term "ecological niche" as a metaphor. Simplistic-incorrect explanations for an ecological niche refer to a "place" or a particular location within a habitat. However, more profound explanations refer to the complex integration of conditions that make a niche unique and different from other niches in the same ecosystem. Furthermore, each organism in the habitat has a unique niche, different from those of other organisms. Going back to humans, each individual acts within a unique context, and many such individuals act in one social group that has its own history, culture, and place.

In my own work, I look as well for a few layers of context. It includes the history of the target audience of the educational program, the political context, the history of education in the community, and any relevant events in the near past or present that might affect learning. For example, in an environmental education program executed in an Arab community, which is in conflict with a governmental nature conservation agency, we needed to address different views toward nature conservation vs. exploitation, especially with respect to natural herb harvest. We made attempts to bring forward the local teachers' life histories and empower them to take a leading role in the program, and were aware of the local population's tension with regard to the official state authorities who are always connected (by them) to the Jewish–Arab conflict (Tal et al. 2011). The program's success was limited, although the environmental educator was Arab and despite the students' enjoyment and their self-reported outcomes. The facilitator maintained his power and gave almost no opportunity to discuss other views about nature that might be brought up by the students and schoolteachers. Although he spoke the "right language" (Arabic) in one domain, he spoke a different language in other domains. He hardly referred to the life experiences of the students or teachers, and attempted to "deliver an alien message" – nature conservation that remained out of context in the aforementioned aspects. Another issue in this regard was the complex background of all the adults involved in the program. The teachers were from a Muslim village, the facilitator was from another Muslim town, one researcher was a Christian Arab who lived in a city and had quite a cosmopolitan way of life, and two researchers were Hebrew-speaking Jews. In a way, all these represent a number of contexts for the educational and environmental discourse to be developed.

Place-Based Education and School-Based Curriculum

Place is a theme that came up in all the chapters. The place is the social system where the studies occur – an urban school of minority students. The place is also the idea behind a view of education as place-based and community-based, as described by Lim, Tan, and Calabrese Barton and by Buck and Quigley. Place-based education, in its various forms, acknowledges the unique relationships between individuals and their physical and social environments. David Gruenewald (2003) highlighted the significance of (critical) pedagogy to place-based education, which was evident in the aforementioned two chapters. In looking for ways to enhance engagement and meaningful learning that connects cognitive, affective, and social aspects, and that empowers learners to take an active role in their community, place-based education provides a theoretical and practical framework, particularly with respect to marginalized populations. In the studies by Lim et al. and Buck and Quigley, the *place* where students live, function, and study, and where the researchers investigated was thoroughly presented and discussed. The researchers wished to be immersed in the community as well, as one step toward understanding the studied phenomena. Moreover, they used their participants' life experiences in designing the educational experiences. This is explicitly explained in the two studies. This sense of place was not emphasized in the other two chapters; for example, I wished to know more about the schools of Ms. Vince and Ms. Neamans, to learn more about the communities they worked with, about their own teaching histories (not only in terms of teaching years), and about their schools' cultures. Similarly, I wished to know more about the science taught in the schools studied by Walls et al. and about the teachers at those schools. Demographic statistics about the percent of free lunches provided and ethnicity do not reflect the entire story of those schools and, as indicated by the researchers themselves, cannot explain some of the differences found.

My experience with place-based curricula comes from both affluent and underrepresented schools. Despite the differences, in such programs, teachers expressed ownership, were highly motivated to teach their self-developed curriculum (Tal 2004), students became more engaged, and there was evidence of improving critical and other higher-order thinking skills. The students expressed a sense of responsibility toward their community and the environment, and were especially satisfied when they were able to be active *for* the environment (Tal and Alkaher 2010).

In my country, many civic-sector organizations (also known as nongovernmental, nonprofit, voluntary, and third sector) are active in what is being termed as the (geographical and social) periphery. The term periphery is used to describe marginalized or oppressed communities within the Jewish and Arab populations. These civic-sector organizations are committed to supporting and advancing these peripheral communities, instead of the government that does not do enough. Often, these organizations give systemic support from preschool until grade 12 that encompasses formal and informal education and that escorts youth through their (mandatory) army service and higher education. Consequently, in some peripheral places, there are more science education resources than in affluent communities, and a higher percentage of these students are enrolled in AP science classes than in middle-class communities, acknowledging that a good matriculation certificate is the key to high-quality higher education and socioeconomic mobility. The problem lies in the fact that these philanthropic organizations act where formal public education fails to provide equitable education. Working across the country, such a major organization – the Rashi Foundation – adopted a place-based approach that attempted to develop local leadership, empower communities, tie future leaders to their communities, and develop their obligation to advance their own schools and communities.

Reflection

Ms. Vince in Parsons and Bayne's study is a highly reflective teacher who questions her practice and monitors her students' progress with great support and optimism. She is able to draw connections between her sociopolitical views and her teaching practice. She critiques the sources for social injustice and has solid views on how to empower her students to become better and succeed. Lim et al. expected the youth to become reflective and critical, and their students' report about GET City challenged the norms of science schooling and demonstrated youth asking for their science learning experience to be contextualized within their lifeworlds. The authors advocate the relationships between place-based education and critical and reflective thinking. Although not explicitly mentioned, reflective thinking, as defined by John Dewey, includes (1) a meaning-making process that moves learners from one experience to the next with deeper understanding of ideas and relationships; (2) systematic and rigorous ways of thinking with roots in scientific inquiry; (3) interaction with others in communities; and (4) attitudes that value the personal and intellectual growth of oneself and of others (Rodgers 2002). Reflection was evident in many of the youth essays, indicating thinking skills, such as problem-solving and decision-making, and highlighting the activity within the community.

Another level of reflection is that of the researchers. Although in the four chapters the authors strongly supported critical theory, critical ethnography, and the cultural–historical approach, all of which require considerable reflection on the part of the researchers, there were differences in the extent of reflection made by the authors. While Buck and Quigley described the personal-professional transformation that they went through, which contributed to framing their study from its very beginning to its end, Lim, Tan, and Calabrese Barton mainly described the processes the youth went through. In line with the ideas behind critical ethnography, they provided good evidence for youth empowerment, participation, and transformation, but I was curious about the possible transformation of the researchers who took part in this participatory process. In the chapter by Walls et al., there was limited reference to reflection made either by the subjects or the researchers, who were interested mainly in constructs of NOS of diverse student populations. In this chapter, the authors highlighted critical theory as the leading framework of the study, arguing that, "It is not enough to simply gain insight into what elementary students understand… it must be used to ultimately inform how and what we teach them." However, at the end of the chapter, I felt that I knew much more about the NOS of elementary students, but that we still have much to learn in regard to what to teach them. As I have already mentioned, my understanding of the school's culture and context was limited, maybe because of the limited space given to the description of each school and its teachers.

Science for All

In the last two decades, the idea of science for all has become a professional as well as political issue both in the USA and in my country, Israel. In the USA, the term is strongly connected to the publication of *Science for All Americans* (AAAS 1989) and the associated criticism over "one size (of science) fits all." However, other attempts to challenge the idea, such as Glenn Aikenhead's (2005) idea of humanistic science education, Okhee Lee and Sandra Fradd's (1998), suggestion of instructional congruence, or Elizabeth Moje and colleagues', (2001) "congruent third space," showed the existence of and (even the demand for) competing discourses around what "science for all" means in different contexts.

In my country, I find that the idea has multiple meanings as well. Science educators and policymakers use it, literally, while discussing the fact that the vast majority of Israeli students are exempt from taking any science course beyond ninth grade, because science is an elective subject. Nowadays, the discourse is mainly about ranking in the OECD Program for International Student Assessment (PISA). However, since the 1990s, scientists and science educators have urged the Ministry of Education to include a mandatory science-for-all program for students who do not major in the sciences. Such an interdisciplinary program, termed "MUTAV" (a Hebrew acronym for Science and Technology in Society), was developed to focus on teaching a selection of key scientific ideas and thinking skills, rather than covering science content. A collection of modules were designed that emphasize the relevance of science to everyday lives, and the connection of science to technology, public health, the environment, and ethics, such as "Our Air Quality" (Dori and Herscovitz 1999), "Biotechnology, the Environment and What's in Between" (Dori et al. 2003), "Treasures of the Sea" (Tal and Kedmi 2006), "Ionizing Energy and its Impacts," and "On Brain Medicine and Drugs" (Cohen et al. 2004). However, only 2–3% of the students take this MUTAV program.

Going deeper into the statistics, we see three distinct social groups engaged in the program: (a) Jewish schools from the "periphery," a term used in Israel to describe lower SES communities composed of immigrants from the former Soviet Union and descendants of immigrants from Middle Eastern and North African countries; (b) Arab schools; and (c) Jewish ultraorthodox girls' schools.[1] The first two groups are engaged in the program mainly because it provides an opportunity to include the course in the matriculation certificate, which is essential in Israel to enroll in any sort of higher education; however, unlike more prestigious subjects, the MUTAV program is associated with a lower-level certificate. The third group, the ultraorthodox, is known for its free-choice separation from general education. Only recently, education leaders of the community acknowledged that to challenge the pervasive poverty of the community, they better teach some science to the girls – who are the ones who are encouraged to support their families (while men are encouraged to keep learning Torah and Talmud all day long). The program is preferred by the ultraorthodox for two reasons: (a) the modular nature of the program allows selecting benign content in terms of the contradiction between science and religion, and (b) the teachers' background does not allow them to teach science for majors, as they themselves graduated from ultraorthodox institutes that do not teach science. In the MUTAV program, they are intensively supported to allow them to teach the modules that deal mainly with public health. The teachers, who are highly motivated and strongly support their students, participate in specially designed professional development programs and get much support from the science-for-all superintendent's staff that strongly advocates teaching this population.

To highlight the extent of the problem of teaching science for all only to the above-mentioned populations, I would quote an educational administrator in Tel Aviv (unlike the USA, the stronger educational systems are associated with the main urban centers of the country), who said "science-for-all – not in Tel Aviv," meaning that the city would not be associated with such a program that serves mainly underprivileged students. Because the Science-for-All program is associated with marginalized populations, it is not available to the majority of the Israeli population, despite its recognized merits. Although many experts point to the program's

[1] Ultra-orthodox is a term used to describe the most extreme communities of religious Jews. The boys of these communities are taught only religious studies – no math beyond basic arithmetic, no science, and no English. The girls study more "general studies" and, only recently, have begun some science courses that are selected based on "religious restrictions."

potential in encouraging youth to enroll in higher-level science courses, students who are identified as potential science majors cannot take part in this context-based integrative program.

Concluding Remarks

Leo Tolstoy opens *Anna Karenina* with the most quoted phrase, “Happy families are all alike; every unhappy family is unhappy in its own way.” In the context of this commentary, it might be argued that every underrepresented social group is unique. Agreeing with this assumption prevents any discussion of similarities between African Americans and ultra-orthodox Jewish girls, between diverse urban American youth and descendants of immigrants who live in the Israeli periphery, or between Europeans and Muslim immigrants in Europe. Taking Tolstoy’s phrase forward, I believe that despite the different places and contexts, issues of participation, empowerment, relevancy of curriculum, commitment of educators, and supporting reflective learners and teachers are common themes that apply to a variety of “unhappy families.” However, in order to thoroughly understand the unique and common characteristics, our science education research community should continue the types of international conversations that are promoted in this book. Better understanding of the working contexts will allow supporting each other as we pursue common goals.

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Part IV
Introduction: Discourse, Language, and Identity

Angela Calabrese Barton (Lead Editor) and Alberto J. Rodriguez (Co-editor)

Science teaching and learning involve a process of supporting students in becoming more central members of the communities of science and school. How students and families gain access to language, discourse, and identities in science classrooms is a powerful equity issue. Discourse and language shape science teaching and learning in a number of important ways. For example, despite the growing number of English learners in US schools, there is still relatively little research focusing on how best to address their science learning needs. This fourth part takes this challenge up, and across the three chapters, a set of conceptual tools are offered for making sense of how instructional practices impact science learning for ELLs and for building upon the language resources that children and their families bring to school science. Furthermore, the chapter set offers vivid illustrations of and models for directly taking on the challenge of designing equitable learning environments for ELLs and other students for whom the discursive practices of school science sit outside the primary language practices of their lives.

The three chapters in *Discourse, Language, and Identity* also ask us to consider how learning science is concerned not only with how students develop complex understandings of scientific ideas but also with the processes of enculturation. Science learning, when viewed as enculturation, can be understood as involving a process of making explicit and supporting learners in taking up the discourses and practices of science (Moje et al. 2001). As students learn science in their classroom communities, they are also developing certain ways of being in the science class-

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room while engaging in activities and tasks, and in relating to the teacher and their peers. Referring to the process of developing science literacy as becoming "bicultural" or "bilingual" puts the spotlight on how access to ideas alone cannot account for how or why one may opt in or out of science. It emphasizes how learning to participate in a community of practice involves more than learning content and even more than acquiring a discourse; it requires an ability to move between one's primary discourse and that of school science with relative ease. As Okhee Lee (2005) argues, "Equitable learning opportunities" occur when "school values and respects the experiences that students bring from their homes and communities, articulates their linguistic and cultural knowledge with respect to the disciplines, and offers educational resources and funding at the same levels as mainstream students" (p. 493).

For example, the chapter by Emily Kang and Julie Bianchini powerfully reminds us of how there is clearly more going on in the science classroom than mastery of ideas. Analyzing classroom interaction and student outcome data from three junior high school classrooms (grade 8) during a unit on forces, these authors show that pedagogical practices that teach science as a mastery both of ideas and of a discourse greatly enhance students from non-English language backgrounds in learning science. The authors highlight the different pedagogical strategies used to support EL students' learning of science, and they link these pedagogical strategies with particular forms of talk in the classroom. While the chapter offers insight into pedagogies that work, what is particularly compelling is what the different assessments used in the project yielded. The two ways of assessing students' science understanding reflected "different ways of conceptualizing science as a discourse community" and "led to differences in ELs' [English language learners'] perceived science competence."

However, each one of these chapters also pushes us to move beyond enculturation. Indeed, another critical focus across these chapters is attention to the "modes of interaction and sociohistorical contexts brought into play in the construction in how and why individuals within communities take up science" (Brown et al. 2005, p. 780). Such a focus helps us unpack the complex system that mediates what and how students engage in science and what and how they might learn, alongside their peers, their families, and their teachers.

For example, in their chapter, Cory Buxton, Martha Allexsaht-Snider, and Carlos Rivera offer a powerful glimpse into a professional development model intended to bring teachers, children, and their families together to learn science in ways that are emergent from the cultural location of the families but attendant to the goals of inquiry-based science and college preparation. In this chapter, these authors challenge the deeply entrenched deficit-oriented assumptions regarding Latino/a parental engagement. Buxton et al. show how involving parents, teachers, and students in collaborative science activities fosters greater interest and awareness of science careers among children and parents. The authors also point out that parents developed critical social capital about science curricula, career pathways, and how schools work – a capital that is often invisible to many parents for whom schooling represents a distant discourse community.

Lastly, discourse and language also influence and are influenced by identity development. What does it mean to take up the discourse and practices of science in terms of how one talks, engages others, recruits resources for learning, and so on? Who must one be to be recognized by others as scientific? In this part, Bryan Brown's chapter offers a conceptual argument for making sense of the powerful interaction among language and identity work in classroom interactions.

For example, seeking to shed some light on the role of culturally based communication in generating effects that are both cognitive and socio-emotive in nature, Brown suggests we must pay attention to two features that mediate such language/identity work, including the gatekeeping functions of language and the role that language-identity interactions play. Offering a plan of action to redress the inequities emergent of language practices in science classrooms, Brown offers a set of strategic moves that teachers ought to take on in their instruction and planning. Using the case of a high school student, D'Andre, the author illustrates in vivid detail the tensions that frame language practices and identity work in learning science. In class, D'Andre offered an accurate representation of metabolism but did so in a way that would typically not be recognized as scientific. Using this example, Brown reveals the power of D'Andre's explanation. Brown questions the cultural and academic possibilities allowing for a kind of "vernacular" science talk as integral to teaching and learning science – possibilities that can range from creating new opportunities for engaging his peers in deep scientific thinking unfettered by the linguistic divide of school science and positioning oneself as a powerful science learner. These questions are at the heart of how and why learning science are centrally about language and identity and not simply about the acquisition of big ideas.

These ideas – that learning is a cultural process that involves both identity work and learning to understand, take up, and transform the secondary discourses of school and science – are the central themes that cut across the three chapters in this part.

Part IV is concluded with remarks by Michael Reiss, who looks across the three chapters to think broadly about how the issues raised here speak to a more global audience. He uses the framing of each chapter to take on a range of issues regarding language, discourse, and identity that challenge the broader global community to consider the critical importance that language plays in learning science. Using examples from the teaching of evolution, sex, and biodiversity, Reiss helps us to see how the language of science is never politically or culturally neutral and that accessing science, therefore, is about much more than learning the language. It is also about how one is able to see oneself as a part of science and to learn to use the non-neutrality of science to engage in critical discourse around the cultural assumptions that shape what it means to know and do science.

Taken as a set, these chapters, along with the response, provide a set of tools and perspectives on language, discourse, and identity in science education that challenge the purposes and goals of science education for all. The authors provide empirical and conceptual models along with rich narratives for reimagining the pathways to access and success in the science classroom.

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Chapter 14
The Language-Identity Dilemma: An Examination of Language, Cognition, Identity, and Their Associated Implications for Learning

Bryan A. Brown

Introduction: The Language-Identity Dilemma

The language of classroom instruction serves a primary role in mediating students' access to science ideas (Vygotsky 1986). As students are introduced to the basic principles of physics, chemistry, and biology, they are also indoctrinated into the language norms of science classrooms (Fang 2005). As a subtext to this process of language learning, students are also introduced to the political connotations of using the academic discourse of science classrooms (Gilbert and Yerrick 2001).

Research in sociolinguistics has offered the research community a framework for understanding how academic language learning has rich sociopolitical implications (Agar 1997). Scholars recognize the way culturally rich language practices denote cultural affiliation, and therefore serve as markers of cultural membership. A prime example of this research involves investigations of the sociopolitical impact of language in South Africa (Silva 1998). In exploring the question of whether the use of English was an oppressor or liberator for Black South Africans, Penny Silva (1998) wrote:

> At this level English is a national asset and 'liberator', in that it offers international access and a tool for communication between language groups. However, this dominance is likely to result in a growing resentment of English, particularly among those who have an 'old' political agenda, or who do not have access to becoming proficient in the language. To these South Africans, English will certainly be seen as 'oppressor'. (p. 74)

Silva's analysis offers a vision of a unique language paradox. In one way, acquiring the use of English offered some Black South Africans access to an ever-expanding

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resource of international English speakers. By contrast, for some, adoption of this language also reflected the oppressive political history associated with the use of English.

Exploring such a paradox is fruitful in developing an understanding of teaching and learning in science as it recognizes how adopting a new language involves appropriating the culture and history of that language (Fishman 1997). Although the discourse of "oppression" and "liberation" are somewhat dramatic when used to explain the more subtle transition from a vernacular discourse to science discourse, the political subtext remains. Just as adopting English can signal assimilation into the cultural norms of South African culture, for some, adopting science discourse signals the appropriation of mainstream culture, and such a paradox should not be ignored (Brown 2004).

Although learning science language involves adopting a new genre of English rather than learning a new language, it does involve the sociopolitical implications of language use (Reveles et al. 2002). I contend that the intersecting influences of language-identity relationships and the intense need to acquire new science language present students with a language-identity dilemma.

The language-identity dilemma in science education is the idea that the intense need to acquire new science language presents students with a learning challenge. The challenge is of two sorts. In one way, the students must develop a clear understanding of the science phenomenon and the associated discourse. In another way, the nature of language-identity relationships presents students with a need to adopt the identity relationships associated with using science discourse. For some, adopting the language of science does not produce a conflict in identity. However, for many populations, the use of complex science discourse reflects a dramatic cultural shift that can be quite detrimental (Gilbert and Yerrick 2001). Thus, the language-identity dilemma in science involves the need to recognize that a failure to reconcile language-identity relationships and language-cognition relationships generates learning problems for many science learners.

Although research on language-identity relationships has grown over the years (Aschbacher et al. 2010), it has not been applied to cognitive outcomes. As individuals experience phenomena in their lives, they develop discourse that enables them to describe those phenomena (Sapir 1949). If this discourse does not provide an equitable transition to its scientific discourse alternative, students may either be misunderstood or develop misconceptions that are rooted in using similar terms that maintain alternative meanings. A prime example of this is found with the use of the term "force." The notion of force has a variety of contextually specific "everyday" meanings. The notion of "force" can be thought to describe a powerful entity, the capacity to compel an individual or group, the act of influencing, or the act of pushing. When teachers discuss force, they must recognize which of the varieties of this term offers the most salient cognitive representation for students. Concurrently, if students are using the term force, teachers must identify if their use of the term force is accurately being applied to the relationship of mass and acceleration.

Where this example is pertinent to the language-identity dilemma is in recognizing the twofold nature of language-cognition relationships. In one way, students' everyday descriptions of scientific phenomena that do not use science discourse may be misunderstood if teachers are not aware of the language-identity dilemma. An example of this involves a student discussing why a curveball curves. A student may describe the resulting movement to be a product of "air pushing harder on one side of the ball than on the other." This description may maintain a conceptual continuity with the scientific idea of differential air pressure that determines why curveballs curve. However, if a teacher does not listen to students' comments from a position that recognizes that students may be able to offer insightful answers using everyday discourse as well as offer incorrect answers using science discourse, the students' understanding may be misunderstood.

Additionally, if teachers use dense science vocabulary to introduce science ideas, students may not develop an accurate cognitive understanding if the teachers do not account for the numerous everyday interpretations of scientific discourse. For example, a description of hydrogen bonding may be contingent on the students' understanding of the idea of bonding as shared electrons. For some, the notion of bonding may represent an understanding associated with interpersonal relationships. As such, additional descriptions about the nature of bonding relationships may suffer from a failure to share a specific meaning associated with a term that is used in multiple contexts. Therefore, in addressing this dilemma, we must be able to prepare teachers to use everyday discourse patterns to their benefit, while assessing students' scientific understanding in light of the possible everyday language alternatives.

Although synthesized under the idea of a language-identity dilemma, science education research has offered examinations of both language-identity relationships and language-cognition relationships that help support the above contentions. The following section provides an overview of how these perspectives were synthesized to help understand how the language-identity dilemma impacts students' science learning.

Perspectives on Language, Identity, and Science Learning

Science education research has identified a significant achievement gap between Black and Latino/a students and their Caucasian and Asian counterparts (Campbell et al. 2000). Many explanations about the source of that achievement difference have focused on the role of language in mediating achievement disparities (Varelas et al. 2002). Some explanations of how science language limits students' learning involve research that highlights cultural discontinuities (Brown 2004; Gilbert and Yerrick 2001) and challenges with language limiting students' cognition (Arons 1973).

Recognizing Cultural Discontinuities

Research on the issues of cultural conflict in science implicates how using science language is often associated with being White or rejecting African American culture (Gilbert and Yerrick 2001). Scholars who have focused on this cultural discontinuity position have broadened the argument beyond conflict for African Americans alone (Reveles et al. 2002). These studies have adopted a position similar to Michael Agar's (1994) *Languaculture* framework. In Agar's sociolinguistic research, the language-culture relationship generates a need for an individual to adopt the culture of the language in order to obtain fluency. This language-culture understanding, or *languaculture*, becomes a prominent feature in providing full access to those new to a particular type of language and its associated culture.

Although scholars of science education are yet to directly adopt Agar's (1994) framework, much of the research on language and identity has identified how the language and identities of students are often involved in intense cultural conflicts (Reveles et al. 2002). For example, Ohkee Lee offered critical analyses of the language-culture relationship in science education (Lee 1999, 2005; Lee and Fradd 1998). Lee and Fradd (1996) suggested that improving science education involved preparing teachers to assist students in bridging any language-culture conflicts that may occur. Lee (2005) made the argument that one of the primary challenges in reducing potential language-culture problems involves helping teachers to develop an awareness of the potential culture conflict. Lee explained this position in the following:

> Children from nonmainstream backgrounds acquire in their homes and communities cultural norms and practices that are sometimes incongruent with those of school. Teachers therefore need to be aware of a variety of linguistic and cultural experiences to understand how different students may approach science learning. Unfortunately, science instruction has traditionally relied on cultural examples and artifacts that are often unfamiliar to nonmainstream students (Barba 1993). Teachers also have difficulties in articulating students' home language and culture with scientific knowledge and discourse. (p. 502)

Lee's argument offers an insightful analysis of the need to recognize how language and culture become critical components of teaching and learning. Her analysis is striking in its underlying assumptions. As she argued that nonmainstream students come from cultures that may be incongruent with science classrooms, the obvious assumption is that mainstream students come from cultures that are more congruent. Although this is not an empirical assumption, it does provide a clear vision of how language and culture relationships are deeply connected to cultural affiliations and thus identity.

Christine Pappas and Maria Valeras offer another example of scholarship in science education that recognizes language and culture relationships (Pappas et al. 2003). Pappas et al. applied an analysis of language-identity relationships to understand how students encounter conflict when dealing with science texts. They argued that students can either experience a sense of conflict or positive relations with the science text, given the extent to which the text reflects language-culture relationships. They used the notion of "Intertextuality" to explain how students derived a sense of self from their experiences with the science text. In the following, they argued that the use of everyday discourse in text would help students find the continuity between their academic and home cultures:

> Our view is similar to those of Lee's (1999) in that children's science learning involves their being able both to engage in alternative ways of knowing and language in their own everyday worlds and to successfully participate in Western science and its disciplinary discourse.

> Intertextual connections represent one of the major ways in which children use their home/community discourse in appropriating the discourse of science. Such everyday sense-making constitutes a continuous, ongoing practice in learning science. (p. 441)

Their analysis offers a similar position to that of Lee's (1999) as they highlighted the differential levels of continuity between the home culture of students and the culture of science. Their work broadens the discussion of discourse to include text as well as classroom talk. In their case, the text relationships reflect bias if students find the culture of the text does not reflect their own culture.

A third example of science education research that indirectly focuses on language-culture relationships is found in the work of John Reveles. Reveles et al. (2002) examined how a teacher's modeling of particular modes of discourse served as an enabling feature for minority students whose culture did not reflect that of their science classrooms. John Reveles and Bryan Brown (2008) adopted a more direct approach to analyze how teachers could broker language-identity relationships. In describing how students must be taught to adopt new language-identity relationships, they offered the following explanation:

> Others propose that educators must develop an awareness of how to access students' native ways of being as a resource for teaching (Conant et al. 2001; Rosebery et al. 1992; Warren et al. 1994). In our own view, many ethnic and linguistic minority students are not explicitly taught contextual shifting (i.e., changing their ways of speaking, acting, and interacting) in ways that lead to school success. Thus, as students learn contextual shifting within school science contexts they are better able to appropriate academic identities as science learners that will not conflict with their own cultural identities. (p. 1016)

This analysis maintains a similarity to that of Lee's (2005) position, which was also expressed by Pappas et al. (2003). Reveles and Brown (2008) assumed that the cultural conflicts and discomfort that students experience is a subtle component of interaction that students may not be aware of. They suggested, as do other scholars, that teachers must make explicit attempts to help students make the cultural transition or contextual shifts that are necessary in science learning.

Collectively, these studies share a common operational framework. They begin with the premise that a significant challenge to students' science learning involves their comfort level with using science discourse. These studies indicate that students are less willing to engage in the discourse practices of science, and therefore, their science learning is hindered. They all make the argument that improved science teaching and learning will occur in instances where teachers are aware of these potential conflicts and model ways to make the appropriation of science discourse more comfortable and less symbolic of cultural affiliation. Studies of language and science in science education, which operate from this position, commonly propose a need to recognize how language presents a cultural challenge that is associated with culture and identity appropriation. The consideration of how students' own conceptions are communicated in everyday discourse, how these ideas are assessed by teachers, and how they are used as mediators to science learning must involve a critical examination of how language serves both as a signal of cultural membership and as a mediator of cognition.

The Cognition Position

A second paradigm of research associated with science language use involves the manner in which use of science language impedes students' conceptualization (Fang 2005). These studies argue that as traditional instruction is based on science language, many students fail to gain an initial understanding of science ideas because the language used to introduce those ideas is foreign to the learner (Arons 1983). Collectively, these issues present science teaching with a language-learning dilemma. Although we need all students to become masters of science language and content, we must recognize that the language of science may limit students' conceptualization.

The nature of learning and language is well documented (Sapir 1949). Lev Vygotsky (1986) provided a rich theoretical framework for understanding how language and cognition are associated. Vygotsky offered the following description of this relationship:

> The process of acquiring scientific concepts reaches far beyond the immediate experience of the child, using this experience in the same way as the semantics of the native language is used in learning a foreign language. In learning a new language, one does not return to the immediate world of objects and does not repeat past linguistic developments, but uses instead the *native language* as a mediator between the world of objects and the new language. (p. 161)

Vygotsky offered a powerful framework to understand *learning* and its association with language. If language is used as a mediator between the observed world of inquiry, experiences, and the new science language, then we must consider what happens when students are not afforded an opportunity to mediate between the old and new languages. In other words, Vygotsky (1986) argued that the language of cognition is a mediator between experiences and new language development; however, students are often introduced to new concepts in language they are unfamiliar with. He specifically argued that cognition occurs in "native language." Thus, classroom instruction presents students with a confounding intellectual dilemma. Students must acquire new scientific understandings that are cognitively represented in new science language. However, if Vygotsky's position on language and cognition is accurate, then we must recognize that science instruction should offer students access to new understandings in students' "native language." Conversely, if students communicate a scientific understanding in a discourse that is not scientific, are teachers prepared to understand the science content embedded in their everyday discourse?

Although research in science education has not explicitly framed issues of cognition and language using the notion of the language-identity dilemma, it has offered a rich analysis of how cultural conflict can limit science conceptualization (Fang 2005; Lemke 1990; Warren et al. 1994). Many perspectives share a common framework that recognizes the complexity of science language acquisition and also how developing a scientific cognition must integrate vernacular language resources.

In Jay Lemke's (1990) groundbreaking book *Talking Language*, he examined how the structure of science discourse includes embedded thematic relationships that are often lost in the translation from teacher to students. The following offers an example of how Lemke framed this position:

> But if there is more than one thematic pattern that can be fitted to, then different meaning can be made of [science words], and those meanings can come into conflict. Everything the teacher says, and everything the students say, can mean one thing to the teacher and another to the students. (p. 28)

Lemke's research served as a transcendent representation of how significant language-cognition relationships can become in impacting students' learning. Ultimately, his research recognized the need for educators to understand the nuances of classroom discourse and its implications for teaching and learning. However, this perspective did not begin with the recognition that students arrive in classrooms with language-cognition relationships that are embedded in their vernacular discourse.

Fang (2005) offered another example of this type of scholarship by using a systemic sociolinguistic perspective to analyze how the complexities of science language can present academic challenges. Fang explained how mastering science language was a necessity by explaining, "Thus, success in mastering this 'power code,' however exoteric, will go a long way toward ensuring students' success in school and beyond" (p. 343). In continuing this argument, Fang argued that students need to be explicitly taught to recognize the complexities of science discourse. Fang explained:

> "Students need tools for unpacking and strategies for revealing 'the organization and logic of scientific ways of using language'" (Lemke 2001, p. v), so that they are empowered to effectively consume and critique the discourses of science. In this connection, Martin (1998) has argued that "schools have a responsibility to engage students in explicit learning of scientific language". (p. 343)

In light of Fang's argument, we must consider the extent to which students are taught science language versus simply allowing students to passively acquire science language as a subtext of their classroom learning. Ultimately, Fang's scholarship reflects recognition of the complexity of science language and a simultaneous recognition of the failure of science education research to prescribe practices that address this dilemma.

A third example of scholarship that recognizes the challenges of language and cognitive development is found in the work of Rosebery et al. (1992). Their research explored the possibilities of using students' everyday language practices as a medium for building accurate science conceptions. They argued for students' everyday discourse practices being recognized as ideal resources to building cognition as opposed to limiting factors in the learning process.

> We have found, for instance, in these classrooms that students, even as young as first grade, employ accounts of everyday experience not merely as a context for understanding scientific phenomena but as a perspective through which to see and encounter heretofore unnoticed aspects of a given phenomenon, to create possibilities for both seeing and encountering the

> phenomenon differently (Warren et al. 2000). Furthermore, we have found it is particularly students who are themselves otherwise marginalized in school science who are able to call on these resources in ways that prove productive for them as well as for typically academically successful students. (Ballenger 1997; Warren et al. 2000) (Warren et al. 2001, p. 532).

I agree with this claim concerning the value of identifying emergent continuities between the "everyday" and "scientific" modes of discourse. I would like to contribute to this perspective by suggesting that scholars consider synthesizing the cultural conflict and cognitive dimensions associated with learning science discourse. Linguists have long argued that an individual's ability to conceptualize is directly connected to the culture of discourse made available (Whorf 1956). As individuals come to understand the world, they develop discursive practices that enable them to organize their understanding of phenomena. I contend that it is naïve to assume that students do not experience the subtle sociopolitical tensions associated with adopting a discourse that is not a component of their normative culture. Conversely, failing to recognize the value of students' own discursive repertoires renders their voices invisible. Thus, students may fail to understand science phenomena if we do not recognize the sociopolitical nature of science language use and fail to assess what cognitive resources students maintain in their everyday discourse patterns. Ultimately, the language-identity dilemma synthesizes these two positions to highlight the need to recognize potential identity conflicts and cognitive conflicts embedded in learning science.

A Framework for Intervention

One way to think about potentially addressing these concerns is to take into account the possibilities of inverting Vygotsky's (1986) perspective on science language and cognition. By "inverting," I intend to imply that if Vygotsky argued that native language resources are the mediation devices of thinking scientifically, then teaching should invert the process by beginning with the native language of the students as opposed to scientific language. If we recognize Vygotsky's position on language and thinking as a cornerstone to building a position on language and learning, perhaps, instruction would involve a more nuanced approach to academic language instruction.

At the heart of Vygotsky's (1986) exploration of the relationship between language and science cognition, he offered an intriguing explanation of how learning is a process involving a constant exchange between words and thought.

> The relation of thought to word is not a thing but a process, a continual movement back and forth from thought to word and from word to thought. In that process, the relation of thought to word undergoes changes that themselves may be regarded as development in the functional sense. Thought is not merely expressed in words; it comes into existence through them. (p. 218)

His perspective offers some intriguing insights about how students should learn, given this assumed relationship between language and thought. First, if there is a relationship between the words used to represent an idea and the cognitive understanding, then one could assume that it is critical for instructors to offer new ideas in words that are comprehensible. If students engage in a process that involves a constant return from word to cognitive position, then failure to understand the initial representation, or words, would ultimately lead to a failed cognitive understanding. If this process of returning to the word and idea is critical to understanding, then the initial words are critical in providing students with access to the ideas.

In taking this process example of Vygotsky to the classroom, we must recognize the challenge that all science students face. Science language includes the acquisition of new terminology and concepts at a linguistic depth that is unique to science classrooms (Halliday and Martin 1993). If thinking is done in a native language that provides a precursor for an ongoing process allowing students to move back and forth between the language used and their cognitive understanding, teachers must engage in a strategy to support this process.

A true inversion would require teachers to make two primary alterations. First, teachers would need to begin instruction in a language that students understand. This would require teachers to pre-assess what their students know and what language resources they have to explain scientific phenomena. Second, teachers would need to generate opportunities for their students to acquire new science language resources to support the resources they already bring to the classroom. This could be accomplished by adopting a situated approach to learning new science discourse.

Situating Science Language

Initiating instruction in language familiar to students would certainly not be sufficient to ensure a developmental understanding. There are a number of reasons why initiating science instruction in everyday language would not suffice. First, if students were introduced to science concepts in their native genres of discourse, then the goal of ensuring that all students mastered science language would not be met, unless students were able to use the new discourse. Without transitioning from a vernacular understanding toward a discourse rich in science terminology, students would only develop partial understandings. Second, although everyday discourse includes a number of continuities with scientific modes of communication, everyday alternatives to all scientific terms do not exist. As a result, some science language allows for differentiation that is not captured in everyday vernacular and would therefore not be available if instruction remained rooted in everyday discourse. Third, being introduced to science discourse does not ensure retention of science discourse. As many individuals know, being enrolled in a Spanish or French class does not equate to mastery of the new language. In fact, one could argue that foreign language instruction is most effective when speakers are provided authentic opportunities to master the new language.

Ultimately, there is a lack of sophistication in how we teach students new science language. Research on language instruction argues for situating language in meaningful contexts (Diaz-Rico 2004), yet science education does not call for pedagogical practices that situate science language learning in meaningful situations. Although contemporary learning theory calls for the recognition and incorporation of situated teaching approaches (Lave 1991), the learning of science language is treated as a passive endeavor. How would students fare if science classrooms provided them with situated opportunities to learn new science discourse by using new language in meaningful contexts?

I contend that addressing the language-identity dilemma in science education requires science teachers to make two strategic moves in their instruction and planning. First, the identity and cognition challenges of learning science could be addressed by providing students access to new science ideas in the discourse students understood prior to instruction. By providing a more accessible pathway to develop an initial understanding, students will be able to develop science schema that are not hindered by unfamiliar language. Second, I argue that science learning ultimately requires the mastering of new language. As a result, students must be explicitly taught to use science discourse. In adopting a situated approach to science teaching, students can be allowed to learn new discourse in the same fashion as they learned their native discourse – they were required to use it to function. This approach is similar to what Stella Vosniadou (2000) called for regarding science learning. Vosniadou offered a series of recommendations about learning and described practice as a necessity for engaging learning. She explained:

> Research shows that people must carry out a great deal of practice to acquire expertise in an area. Even small differences in the amount of time during which people are exposed to information can result in large difference in the information they acquired. (p. 23)

These ideas should be applied to the acquisition of science language as well. As teachers ask students to explain phenomena, they can provide students with authentic opportunities to use their newly acquired discourse. As a result, students can use their newly learned science language in a meaningful context. The integration of these two practices, everyday language introduction in situating language learning, could have a profound impact on student conceptualization and sense of self in the science classroom.

Disaggregating Instruction

In initial attempts to explore the potential value of addressing the language-identity dilemma, I engaged in research that attempted to apply the above principles (Brown et al. 2010). We explored how students learn if science instruction is taught by separating (i.e., disaggregating) instruction into both a conceptual teaching component and a science language learning component. Traditional (*aggregate*) teaching approaches begin instruction by teaching new science concepts and teaching new science language simultaneously. I contend that this generates two problems. First, despite the fact that some science teachers incorporate word walls, introduce Latin

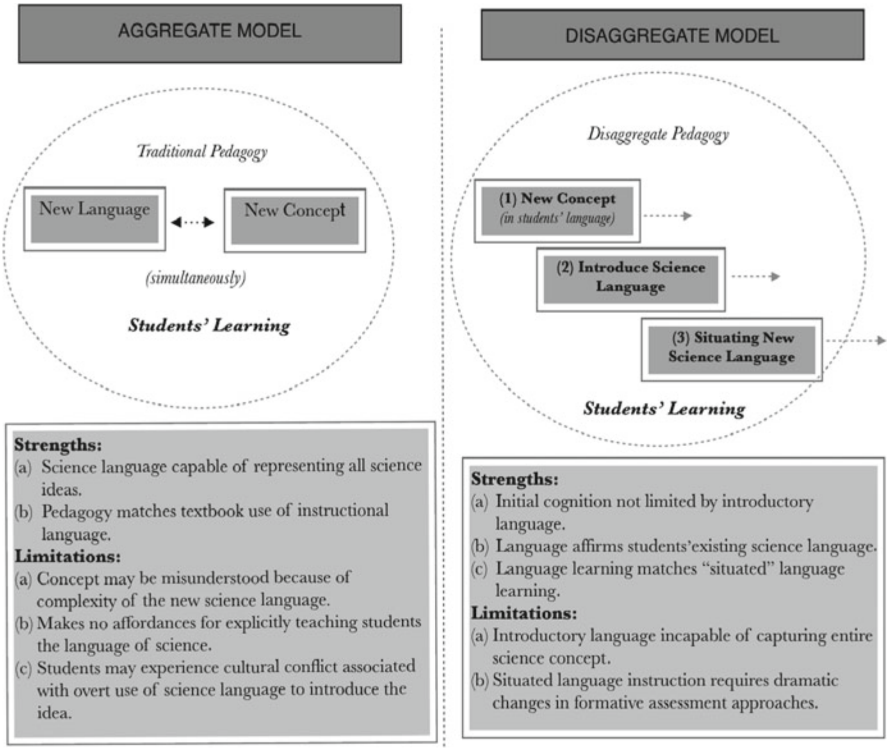

Fig. 14.1 Contrast between aggregate and disaggregate instruction

root words, and use fill-in-the-blank vocabulary exercises to teach the science language, this often causes students to be intimidated and frustrated by the language of science. Second, this approach often causes students to misunderstand concepts because the language used limits the students' understanding of the new science idea. This is because the semantic ties and basic concepts are lost as the formal science language confounds students' understanding.

In contrast, the *disaggregate* instruction approach intends to reduce intimidation and increase students' learning by altering pedagogy in three primary ways (see Fig. 14.1). First, disaggregate instruction begins by introducing new science ideas in language that students already understand. By beginning instruction this way, students are able to gain a fundamental understanding of the idea, while reducing the anxiety and frustration associated with teachers' exclusive use of science language. Second, after the basic tenets of the science idea are taught, the teacher introduces the new science language. Third, after the new ideas and new language are introduced, the teacher requires students to use their new science language to explain the phenomenon in meaningful contexts. By situating these language-learning opportunities in formative assessment activities, students are provided opportunities to learn the new science language.

Disaggregating instruction extends teaching by building on two key assumptions. First, by using students' own (everyday) language practices to introduce concepts, we assume we are able to reduce their intimidation and increase their ability to gain a fundamental understanding of the idea. Second, by altering how we teach the new language, we assume students will gain a contextually relevant understanding of the science language. By requiring them to use their new science language through formative assessment activities, the students will be able to gain a rich understanding of the science language and ideas. The combination of these features has the potential to improve students' understanding and reduce their discomfort in learning science.

The Case of D'Andre Hampton

To further explore how teaching and learning may be informed by the language-identity dilemma, I now turn to the case of D'Andre Hampton.[1] D'Andre was a senior at Jemison High School[2] in Oakland, CA. At that time, the author was engaged in professional development training and had the opportunity to participate in the classroom.

D'Andre had a unique role in this community because he was physically and intellectually imposing. D'Andre was a star athlete who stood 6′3″ tall and weighed over 300 lb. He was also a straight A student who maintained the common appearance of many of the students in the community. D'Andre wore his hair in dread locks and was often found wearing a set of removable gold teeth. He was liked by both students and teachers and maintained a high status within the school community.

Jemison High School is a typical Oakland, CA high school that has experienced a great deal of reform between 2005 and 2010. Jemison was restructured from a single comprehensive high school to two smaller magnet high schools. Jemison's academic performance index (API) score of 530 in 2008 and 546 in 2009 reflects its modest improvement. The school's API state ranking of 1 out of 10 reflects the school's need for progress.

Of the school's population of 533 students, 526 (98.7%) were African American. More than half (67%) of students were eligible for the free and reduced lunch program. The neighborhood that surrounds the school had many of the typical problems of urban schools, including high unemployment rates and high rates of crime. Overall, D'Andre reflected the Jemison high school community in ways that were both typical and atypical at the same time. Phenotypically, he reflected his environment, yet academically and athletically, he was among the best the school had to offer.

[1] This is a pseudonym used to protect the identity of the young man involved.

[2] This is a pseudonym used to protect the identity of the school.

Table 14.1 Vignette #1: D'Andre Hampton and the block of ice

	A	B
Cell #	Speaker	Quotation
1	Teacher:	So here's the deal. By the end of the day we will be able to provide a clear explanation of this problem. Here's the problem. Has anyone here ever seen a marathon runner on TV? (Hands raise.) Has anyone ever seen a fat marathon runner?
2	Ryland:	Yeah. Oprah!
3	Teacher:	She's not fat. And I am talking about people who race in marathons all the time. Has anyone ever seen a fat marathon runner? (No one responds.) So here's the question: Why is it that you will never see a fat marathon runner?
4	D'Andre	It's basically because they be sweat'in.
5	Teacher:	That's good. What does sweat have to do with it?
6	Tanisha:	It's because they always be hot. They be hotter than everybody else. My cousin always be sweat'in.
7	Steve:	It's cause they fat, Blood! (laughter) they get hot and they always be sweat'in… even if they just walk'in up the stairs.
8	D'Andre:	Naw! It's like this. It's like if you set a block of ice out. Out on the curb. The ice don't just melt. First, it just turns into water. Then, the water it disappears into steam. It's like that. It don't be no fat marathon runners because when they run, they melt the fat and they body use the fat and it burns off.

A Discussion of Metabolism

In attempting to teach the basic ideas of metabolism, the teacher began the instructional day by asking students to explain why they have never seen an obese marathon runner (see Table 14.1). In cell B-1 of Table 14.1, the teacher asked, "Has anyone here ever seen a marathon runner on TV? Has anyone ever seen a fat marathon runner?" This query led to a number of brief explanations about why students did not see obese marathon runners (Table 14.1). The comment of particular significance came in the form of the contribution of D'Andre. In cell B-8 of Table 14.1, D'Andre explained:

> Naw! It's like this. It's like if you set a block of ice out. Out on the curb. The ice don't just melt. First, it just turns into water. Then, the water it disappears into steam. It's like that. It don't be no fat marathon runners because when they run, they melt the fat and they body use the fat and it burns off.

His explanation offers an intriguing example of the language-identity dilemma in science. One must first begin by assessing the relative accuracy of his explanation. However, that assessment cannot be conducted without careful decisions being made about which types of discourse reflect accurate cognitive understanding. Although his explanation was void of critical metabolic scientific terms, such as catabolism, anabolism, glucose, and calorie, he did use an analogy that is rooted in vernacular discourse to represent the basic physical stage changes in catabolic metabolism.

Is his answer correct? If we operate on a dichotomous scale of answers being either inherently correct or incorrect, then D'Andre's answer is incorrect. However, if we apply what we know about everyday science discourse, then his use of vernacular discourse offers some intriguing insights about metabolic activity.

First, D'Andre's selection of melting ice as an analogy highlighted his understanding that fat undergoes a physical transformation that is similar to that of ice melting. His description of ice melting into water and ultimately evaporating into gas offers an intriguing continuity to body fat being catabolized into triglycerides, and then to glucose, which is used for energy. Although he did not draw the linear parallels between his analogy and the scientific alternative, his answer did offer a detailed representation of the basic catabolic process.

Second, D'Andre drew the continuity between his analogy and the scientific process of metabolism by simply stating: "It don't be no fat marathon runners because when they run, they melt the fat and they body use the fat and it burns off" (see Table 14.1). There is a great deal of ambiguity in the inherent meaning of his description. When he suggested, "they melt the fat," he could have been suggesting that fat is literally melted away through intense exercise. Or, perhaps, he did understand the metabolic use of fat for energy purposes and the relative association with the intake of calories. Either way, this exchange provides a rich example of how Lemke (1990) suggested that meanings in science are richly contextualized and reflect specific semantic relationships. As such, we cannot accurately assess D'Andre's true meaning without engaging him in a detailed discussion.

There is a pedagogical question to be asked: What can a teacher do with this description? As the conversation proceeded, were the ideas offered by D'Andre seen as a valuable resource for instruction or as useless offerings in a triadic exchange? One would hope that an effective teacher would be able to recognize the cognitive resources embedded in D'Andre's discourse and use them as a starting point for teaching. Additionally, validating his discourse and understanding may be a useful resource in eliminating any potential identity conflicts associated with using science discourse.

Ultimately, this brief vignette provides an example of the language-identity dilemma in science education. In one sense, the student offered an accurate representation of the basic premise of the phenomenon. Despite that, the ultimate goal of science learning is to understand the details of the science concept and to learn the detailed science discourse that is associated with that concept. In this excerpt, the language of the discussion was purely vernacular and therefore did not apply the language of science. Would it be reasonable to expect D'Andre, a 17-year-old African American from a crime-ridden neighborhood in Oakland, CA, to inject science discourse into his explanation without being prompted to do so? If he did this, what cultural consequences would he encounter? His selection of discourse may have offered the students listening a great resource for understanding metabolism because they were developing an initial cognitive understanding of catabolic metabolism in a discursive style that they were familiar with. If D'Andre had offered an explanation that was rich with terms like catabolic metabolism, glucose, triglycerides, and phase change, they might have lost the initial meaning. The language-identity dilemma is therefore found in the need to provide students an initial conceptualization that is rooted in an accessible discourse, while explicitly teaching the students to use the discourse of science in ways that do not represent cultural betrayal.

Conclusion: Moving Toward Identity-Based Pedagogy

Given the many challenges associated with teaching science to urban communities, a paradigm on instruction that begins by considering how language can serve as a central player in providing access to science is a growing necessity. The idea that contemporary frameworks for teaching do not take the emotive impact of language use into account calls attention to the need to engage in and design pedagogy that promotes improved conceptual understanding, while reducing the emotive impact of learning science. Ultimately, science educators must learn to use discursive identities as a resource to improve classroom environments for those who have been traditionally positioned as outsiders in the science community.

Specific strategies for language instruction in science education deserve increased research. Given the findings of some of my own early research on language, the role of language-based pedagogy becomes an important challenge to address on two fronts. First, if we are able to develop an informed perspective on teaching the language of science, we may be able to improve students' cognitive understanding of science with small alterations in the language of instruction. Second, we may be able to reduce the impact of the emotive conflicts experienced by students by engaging in additional research on how to impact students' cognitive and emotive experiences, and thus reduce the potential impact of the language-identity dilemma.

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Chapter 15
Science, Language, and Families: Constructing a Model of Steps to College Through Language-Rich Science Inquiry

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Vignette from Alka-Seltzer Rocket Lab at the Steps to College Workshop (2/27/10)

"*What's your hypothesis about this one?*" I was making my way around to each of the groups that had been assigned the job of testing one possible variable that might affect the flight of our Alka-Seltzer rockets. Each group was comprised of two or three Latino/a middle school students and two or three parents; some groups included one of the students' teachers as well.

"*So we have to test if powdered Alka-Seltzer or chunks of Alka-Seltzer works best*," Jorge, one of the students, clarified.

"*Yes*," I agreed. "*But before you test anything I want you to think about what you already know. What's your hypothesis about which one might be better and why? Then think about what evidence would support your hypothesis*."

"*The powder, it will be better*," volunteered Manuel, Jorge's father. "*It will work faster*."

"*Why, do you think?*" I asked. "*What's your evidence for that?*"

"*Because it's the same as when you grind up an* asperina *or when you use* El Polvo Goodies… *You know… the headache powder. It works faster because it's a powder. It works faster in your stomach. My mom always did that when I was a kid*."

"*I never knew why you used that powder*," responded Jorge. "*I thought it was just one of those things from México, but I didn't know there was really a science reason*."

"*Now test it*," I suggested, "*and find out if it's really faster*."

A few minutes later, there were popping sounds, a cheer, and a burst of laughter from the Gomez family table. "*It did*," called Jorge, "*the powder was much faster! We have the evidence because it popped first*."

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The above vignette highlights two key components of our Steps to College through Language-Rich Science Inquiry (STC/LRSI) project. First, it shows how we engaged families in simple science inquiry experiences that provided rich contexts for exploring the fundamental inquiry practices of coordinating hypothesis, observation, and evidence; controlling variables; and explaining cause and effect relationships. An activity as simple as constructing Alka-Seltzer rockets that requires only minimal materials can still teach important science inquiry practices when the activity is guided to highlight those aspects. We were able to support the continued development of these inquiry practices beyond our limited number of workshops in two ways: by modeling these approaches for the students' science teachers who were also participants in the project and by providing the families with bilingual home science kits (Buxton et al. 2010). We constructed these kits with an accompanying bilingual inquiry activities guidebook so that family members could continue to experiment with and talk about science inquiry ideas at home and then share what they had learned during subsequent workshops.

Second, the vignette highlights our rationale for having families participate in science together. This model allows parents to become aware of both science-specific and more general academic expectations that are being placed upon their children in middle and high school, and it allows students to see their parents (and their teachers) in an unfamiliar light, as colearners. Additionally, though not evident in this vignette, the model allows teachers to interact with their students' parents in a science learning setting where the teacher is not the authority figure with the task of delivering judgment or evaluation of the students' performance. Jorge's surprise and eventual excitement that a family practice, handed down from his *abuela* in *México*, which he apparently took to be an uninformed folk tradition, actually had a scientific basis is the kind of experience that has the potential to reshape how students and parents relate to each other about schoolwork. At the same time, Manuel (Jorge's father) was able to validate for himself, with evidence, a belief he had always held to be true but had probably never tested empirically. One can imagine future conversations about science between father and son that might not otherwise have taken place.

Conceptual Framing

With the growing numbers of English language learners (ELLs) in our schools, and continuing concerns about ELLs' high dropout rates and academic underachievement (López and López 2010), educators are seeking powerful models that unite school, family, and community resources to promote academic success, particularly in STEM (Science, Technology, Engineering, and Mathematics) areas (Litow 2008). Our decision to develop a bilingual outreach and research project focused on science, language, and Latino/a families was a response to these demographic and educational imperatives challenging educators locally and nationally.

The overall population of ELLs in the United States grew in the first decade of the twenty-first century, with the vast majority of non-English-speaking families speaking Spanish (Fix and Passel 2003). The state of Georgia, where we conducted our study, far surpassed the pace of growth of immigrant students nationwide – while the overall population in Georgia increased by 18% between 2000 and 2010, the Hispanic population increased by 96% (Ennis et al. 2011). The number of students in Georgia classified as ELLs jumped from approximately 16,000 in 1995 to approximately 56,000 in 2005, a near quadrupling in only a decade (National Council of La Raza 2008). While the ELL student population in Georgia represents numerous language groups, over 75% of these students are Spanish speakers. Georgia schools served over 120,000 Latino/a students (Pre K-12) in 2004–2005, compared with fewer than 24,000 a decade earlier in 1994–1995 (National Clearinghouse for English Language Acquisition 2008). Although most of the Latino/a students in Georgia are not currently classified as limited English proficient (LEP), the majority of students have learned English as a second language, and Spanish is still the predominant language spoken at home. These students have unique learning needs, even if conversationally fluent in English, and particularly have need for academic language development in the context of challenging content learning, such as inquiry-driven science.

Instructional strategies for simultaneously engaging ELLs in inquiry-based science learning and academic language development are just beginning to be understood (Bailey et al. 2004). Additionally, we have few examples of approaches for enhancing bilingual parents' roles in supporting their children's engagement and achievement in science (see Ash 2004 for one example). Building on previous work we have done individually in preparing science teachers to work with ELLs (Buxton et al. 2008) and supporting collaborative work between STEM teachers and ELL families (Allexsaht-Snider 2006), we began to work collaboratively 2 years ago to develop and refine a model that would support ELL students, their parents, and teachers in coming together to engage in bilingual science and academic language learning as well as in conversations about supporting academic success.

The model, which we refer to as Steps to College through Language Rich Science Inquiry (STC/LRSI), brings together three educational components: (a) engaging students, parents, and teachers together in bilingual science learning and preparation for college; (b) authentic science practice; and (c) academic language development to support language-rich science inquiry. In this chapter, we explore these components and present results from our initial attempts to implement the STC/LRSI model with groups of middle grade students, parents, and teachers through a series of bilingual inquiry-based science workshops in university laboratory settings. During these trips, the students, their teachers, and their parents, as well as Latino/a and immigrant college students, all engaged in science learning together, practiced using academic language, and held discussions about various aspects of academic success. As part of those discussions, we surveyed all participants regarding their ideas about science and schooling, and we facilitated interviews in which students and their parents interviewed each other about their experiences with science and their academic aspirations. Here, we present findings that focus on changes in the workshop participants' ideas about science, academic success, and higher education. We were less interested in studying student achievement or achievement gaps and more interested in understanding student, parent, and teacher learning as changes in understanding and especially as changes in participants' social and cultural capital for accomplishing their own goals in and out of school. We suggest that further work with this and related models of collaborative science learning could provide positive examples of successful academic engagement with Latino/a students and families.

Educational Components

Engaging Students, Parents, and Teachers Together in Bilingual Science Learning and Preparation for College

In our attempts to rethink *parent-student-teacher engagement* in science, we build on the ecologies of parental engagement framework described by Angela Calabrese Barton and colleagues (Calabrese Barton et al. 2004), new visions for family engagement outlined by the Family, School, and Community Engagement National Working Group (Weiss and Lopez 2009), and research conducted by Marta Civil and colleagues (Civil et al. 2005) with the Math and Parent Partnership (MAPPS) project. This previous work helps us to understand the interconnections between how and why parents engage in their children's education, particularly in STEM fields, and how this engagement relates to their experiences and actions both inside and outside of school. The work of Civil and colleagues especially highlighted for us the importance of providing a bilingual context for learning so that all participants could access and see the value of others' rich funds of knowledge related to schooling and science learning. We wished to explore how Latino/a parents and students negotiated common understandings, beliefs, and practices regarding science and academic success and built sustaining relationships with each other and with other actors in the school. Particularly, we valued the facilitation of student-parent talk as an important support for academic success and science learning. Recent work by Deborah Siegel and colleagues (Siegel et al. 2007) with Latino/a families in science learning environments supports our notion that engaging families collaboratively and bilingually in science learning activities can foster rich conversations both about science and about academic success more generally. Thus, the first component of our STC/LRSI model was to engage students, parents, and teachers together in bilingual science learning and activities to support preparation for college.

Authentic Science Practice

The second component of the STC/LRSI model, *authentic science practice,* has the goal of prompting science talk and action in settings that support development of practices central to scientific investigation. Specifically, we consider how interactions among students, family members, teachers, university students, and scientists (where all have access to resources in both English and Spanish) can be developed in university science settings and extended into students' homes and middle school science classrooms. Strategies for teaching rigorous science inquiry skills are essential to robust science learning and are also central to critical thinking in other subject areas (Kuhn 2005).

While the development of inquiry practices has been studied extensively both among children (Songer et al. 2003) and adults (Kuhn et al. 1995), this work has rarely focused on contexts in which students and adults engage in these practices together. Further, the study of inquiry practices is just beginning to address the unique learning needs of bilingual English language learners (Buxton and Lee 2010). There are several emerging theoretical perspectives, however, that can be used to frame an understanding of the intersection of science inquiry and language learning. These include a heteroglossia perspective focusing on the relationships between scientific practices and the everyday sensemaking of children from diverse cultures and languages (Rosebery and Warren 2008); an instructional congruence perspective focusing on cultural patterns of communicating, interacting, and ways of knowing (Lee and Fradd 1998); and a sociopolitical perspective focusing on issues of power, prestige, and privilege both in science learning and in language use (Calabrese Barton 2001). Although proponents of these perspectives share the belief that connecting students' cultural and linguistic experiences to the practices of science inquiry is central to meaningful science learning, the specific approaches proposed to best achieve this goal differ.

Research shows that ELL students have very limited access to explicit instruction focusing on inquiry (Lee and Buxton 2010), even though knowledge of inquiry practices has been shown to be important for promoting academic success across the content areas, not just in science (Kuhn 2005). Additionally, inquiry teaching practices that foster students as active problem solvers are seen as critical for promoting underrepresented students' pursuit of postsecondary schooling (National Academic Press 2009). However, it is nearly impossible to gain proficiency in these inquiry skills without repeated opportunities to engage in inquiry-based science learning (National Research Council 2007). As part of the STC/LRSI model, we focus on the development of three inquiry practices that cut across all science disciplines: *coordinating hypothesis*, *observation*, *and evidence*; *controlling variables*; and *explaining cause and effect relationships*.

Science learning opportunities in engaging settings, such as university science facilities, when carefully scaffolded in terms of both science content and language usage (including bilingual support), can provide ELL students, parents, and teachers with experiences that promote these science inquiry skills simultaneously with the development of academic language. Just as inquiry abilities provide tools for thinking in academic contexts, academic language abilities provide tools for communicating in academic contexts. As such, support for academic language development became the final educational component in the STC/LRSI model.

Academic Language

The development of competency with *academic language* and discourse is essential for ongoing academic success in science (Brown 2006) and across the content areas (Richard-Amato and Snow 2005). Despite this critical need, ELL students are still routinely taught social language in pull-out ESOL classes, while their peers are learning academic language in content classes, causing those ELL students to fall further behind their peers, not only in terms of content knowledge but also in terms of academic language (Collier and Thomas 2007).

Why is academic language development so important for successful science learning? First, academic language is used to communicate complex ideas clearly and accurately. Part of the reason that each academic discipline develops a specialized language is to allow for the discussion of details and nuances of the discipline in ways that are accurate and efficient (Lemke 2001). A second reason that academic language is utilized is that it allows members of a privileged discourse community, such as scientists, to represent themselves as authoritative and knowledgeable about a given knowledge domain. Along with physical appearance and the ability to use specific tools, it is proficiency with academic language (both subject specific and general) that identifies an individual as knowledgeable and academically successful (Carlone and Johnson 2007).

In our family science workshops, we began with a broad attention to how academic language is used in university science settings, and over time we became more focused on the inclusion of general-purpose academic vocabulary development in our activities. In other classroom-based work (Allexsaht-Snider and Buxton 2010), we found that many of the same ELL students who participated in the family workshops struggled with making meaning of expository science texts, class note-taking activities, and other typical middle school science classroom tasks. These difficulties arose less because of problems with science-specific vocabulary (which often share cognates with ELL students' home languages) and more because of difficulties with general academic vocabulary words that frequently provide little or no context for decoding their meanings.

Steps to College Through Language-Rich Science Inquiry

Our STC/LRSI model, as it evolved over the first 2 years of this project, has the goal of bringing together the three educational components of engaging students, parents, and teachers together in bilingual science learning; supporting authentic science practice; and developing academic language skills. We believe that this model can serve the dual purposes of promoting academic success in school and providing participants with academic tools that will prove useful to them in meeting their own life goals. The model presumes that engaging in authentic science inquiry activities in bilingual contexts can provide powerful opportunities for science learning, for language and literacy development, and for community building between students, parents, and teachers. Our family science workshops were designed specifically to provide such opportunities while also helping teachers conceptualize how to apply this work in their own classrooms.

The workshops also addressed a range of practical topics that we believed would facilitate conversations about science and schooling among students, parents, and teachers. These topics included past and current interests in science, experiences with science in and out of school, science-related careers, knowledge about higher education (such as college admissions and financial aid policies), and high school course-taking information. With these aims in mind, we were interested in answering questions about changes in students', parents', and teachers' relationships with each other and changes in their beliefs about science, language, and schooling. For the purposes of this chapter, however, we focus on the following two research questions:

1. How do Latino/a immigrant parents' knowledge about science and beliefs about academic success change as a result of participation in the project?
2. How do Latino/a immigrant middle school students' knowledge about science and beliefs about academic success change as a result of participation in the project?

Student, Parent, and Teacher Participation in the Workshops

During year 1, a total of 34 Latino/a immigrant middle school students attended at least one of the four sessions of the bilingual workshop series. Eighteen girls and sixteen boys participated. Starting with 15 parents, the number of parents and guardians increased at each subsequent session, an indication that the families viewed the workshops as valuable. Our goal was to have a parent or guardian participate with each student. Twenty-nine of the 34 students were accompanied by a parent or guardian for at least one of the sessions, with Latino/a university students stepping in as mentors for students whose parents or guardians were unable to attend.

During year 2, 36 students and 27 parents attended one or both workshops. Ten of these participants were new to the project, while the rest returned for a second year. Eleven of the returning students were ninth graders who had moved on from middle school to high school, but who expressed a continued interest, along with their parents, in returning for the second year of workshops.

Each of our workshops was 4 h long and was then followed by a group lunch to support informal conversation and community building. All sessions were conducted bilingually, with both English and Spanish used throughout the sessions. A majority of the parents identified themselves as either preferring Spanish or bilingual communications. A majority of the students identified themselves as either preferring English or bilingual communications. All written communications with students and parents were presented in both English and Spanish, including the family science curriculum that was created to serve as the basis for many of the science activities in the workshops and for collaborative home learning tasks. Two middle school science teachers and one ESOL teacher participated actively in all aspects of the workshops during year 1, and two additional science teachers, one from the middle school and one from the high school, joined as new teacher participants during year 2. Childcare was provided for younger siblings during each workshop to support increased family participation, and a number of parents noted that this made their participation possible.

Data Sources and Results

Surveys and interviews were conducted with all participants during the first and last workshops of year 1 and during the last workshop of year 2. All surveys were constructed as 5-point Likert scale items and were developed by the research team to align with the initial goals we had for the workshops when we began the project. Specifically, the 33-item student survey and 31-item parent survey were organized around eight topics: interest in science, experiences with science in and out of school, science-related careers, knowledge about higher education, college admissions, financial aid, high school course taking, and knowledge about the local university. The 18-item teacher survey asked teachers to rate the value of various instructional strategies for students' academic success in science and then to rate how often they had used each of these strategies in their science teaching during the previous month. During the second year, we began to develop new questions to reflect our evolving focus on specific science inquiry practices and on specific aspects of academic language development. These revised instruments will be used as we move into the third year of our work.

In addition to the surveys, students and parents conducted oral interviews in which the students and parents interviewed each other (rather than being interviewed by a member of the research team). The interview protocol addressed many of the same topics as the surveys (i.e., experiences with science, knowledge about higher education, supports and obstacles to academic success) but in an open-response format. Students and parents conducted these audiotaped interviews during the first and last workshops of year 1 and the last workshop of year 2. We hypothesized that participating together in the workshop science activities, college experiences, and discussions about science-related careers and academic success would strengthen students', parents', and teachers' knowledge about these topics and increase their desire to continue to engage in science learning. Finally, the project staff took field notes and wrote descriptive summaries of each workshop session to serve both as data for constructing vignettes and as a resource for future workshop planning.

The number of survey participants is shown in Table 15.1. Simple *t*-tests (2-tailed, type 3) were conducted for all survey questions to look for significant changes between surveys given at the start of the first year of the project, the end of the first year, and the end of the second year. Because less than half the total number of students took the survey all three times and less than a third of the parents did so, for

Table 15.1 Survey participants

	Students	Parents	Teachers
Beginning of Y1 survey	33	24	4
End of Y1 survey	18	21	3
End of Y2 survey	26	23	5

analysis purposes, we treated the survey responses as nonrandomly assigned data rather than as matching pairs pre-post data.

Interview transcripts were analyzed using a three-step, open-coding framework. First, recurring themes were identified across cases for each set of interviews (e.g., health workers as a career that involves science, or getting good grades as a requirement for going to college). Second, themes were identified within cases for each set of interviews (e.g., a parent who referred repeatedly to immigration status affecting educational opportunity, or a student who repeatedly mentioned earning more money as a goal of education). Finally, both across-case and within-case themes were explored for changes across multiple time points (e.g., parents who discussed more support structures as well as barriers to their children's academic success after attending several workshops, or students who could name more science-related careers by the end of the year).

Results

Within the topics that were addressed in the student surveys, parent surveys, and student-parent interviews, notable patterns of change emerged around four themes: interest in science, knowledge about science, knowledge about higher education, and academic success in middle and high school. We discuss each of these themes in turn.

Interest in Science

Survey and interview questions asked participants to consider their past and present interest in science (e.g., Describe anything you remember learning about science as a child in your house or with your parents? Were you curious about science as a child? Why or why not?). Based on the survey results, parents' interest in science did increase through participation in the project, but was high to begin with, so the increases were not statistically significant. In contrast, student responses about interest in science started lower but increased with participation; thus, two of five relevant items showed significant increases (Science is one of my favorite classes in school, $p < .05$; I like to learn about science when I'm not in school, $p < .005$).

The parent-student interviews further highlighted the interest that participants had in science and ways in which that interest evolved. During the initial interview at the start of the project, 10 out of the 12 parents discussed having an interest in science while they were growing up, with nearly all of the examples of this interest coming from the life sciences (i.e., plants, animals, biology, and agriculture). In the final interview, parents expressed a much wider array of current science interests, including meteorology, food science, nutrition, kinesiology, and environmental science. Parents explicitly expressed interest in topics that had been addressed during the family science workshops, and this broader interest seems important both in terms of understanding the role of science in society and in terms of knowledge about science-related careers.

Daughter: What do you remember about learning science as a child?
Mother: I liked to work with my father. He did work with trees and animals.
Daughter: What did you like about coming to the workshops?
Mother: To see all the natural science. The birds in the laboratory and the trees. To learn about the science that you are studying was very interesting.

Knowledge About Science

Survey and interview items also asked participants about experiences with and knowledge about science. On the parent surveys, responses about previous experience with science, such as science learned in school and science learned at home or through work experiences, were meant to provide background information and thus did not change significantly. Responses about science-related careers were expected to increase with participation in the project, but only one item of three (careers that involve science pay well) did increase significantly ($p<.05$). Student responses to items about science-related careers were also expected to increase through participation. Like their parents, student responses to the item "Careers that involve science pay well" did increase significantly ($p<.05$). For students, an additional item (I have gone places outside of school to learn about science) also changed significantly ($p<.01$) implying that the family science workshops provided an opportunity for these students to learn about science that had not otherwise been available to them.

The parent-student interviews pointed to additional ways that knowledge about science changed through participation in the family workshops. During the initial interview, only four parents claimed to recall learning any science outside of school, and all of these examples related to agricultural practices, such as determining proper pesticide applications and livestock care. In contrast, during the final interview, 11 parents claimed to have learned science in settings outside of school, and many of the examples they cited came from investigations conducted during the family workshops including chemical and physical reactions, food testing and production, sound, energy, biomechanics, kinesiology, and alternative fuels. When parents were asked about possible science-related careers, the variety was even greater than the number of topics they said they had learned about, including engineering, agronomy, medicine, veterinary science, kinesiology, science teaching, biology, psychology, pharmacology, food science, robotics, nursing, physics, chemistry, anthropology, geography, gardening, natural sciences, and meteorology.

Father: *What did you learn about science at the workshops?*
Son: *That there are various jobs in science and that the pay is good.*
Father: *What else did you learn at the workshops?*
Son: *That I need to apply myself in school if I want to have a good job and make something of my life.*

Knowledge About Higher Education

A third theme in both the survey and the interview data was change in participants' knowledge about higher education. While parents' responses about perceptions of the host university where the workshops were held did not change significantly on the survey items, their responses to 3 of 5 items on knowledge about college more generally did increase significantly (I have learned a lot about college from people I know or from my own experiences, $p<.005$; I know someone who has gone to college, $p<.05$; and I know what my son or daughter needs to do to get into college, $p<.005$). Similarly, parent responses increased significantly on 3 of 4 items about financial aid for college (My son or daughter can go to college even if I do not have a lot of money saved, $p<.05$; My son or daughter will be able to get financial aid to go to college, $p<.001$; and I know what my son or daughter needs to do to get a [state] scholarship when he or she graduates from high school, $p<.05$).

Like their parents, students' responses changed significantly on two items focusing on general knowledge about college (I know someone who has gone to college, $p<.05$; and I know what I need to do to get into college, $p<.01$). However, unlike their parents, student responses about financial aid for college did not change. Finally, students' perceptions of the host university changed for two of the four items. These were reverse-coded items where we expected responses to decrease (Many people I go to school with now will go to [the state university] for college, $p<.05$; There are many Latino/a students at [the state university], $p<.005$).

The parent-student interviews further highlighted changes in participant knowledge about higher education. In the initial interview, 8 of the 12 parents claimed to know very little about either the host university or about any other colleges. The other four parents mentioned that colleges had a difficult application process, that it was hard to get accepted, and that it was expensive. Most parents mentioned at some point in the interview that students need to have good grades and to put a lot of effort into studying if they are to have a chance of going to college. In the final interview, parents offered much more concrete information about college, in general, and about the host university, in particular. For example, parents discussed the large number of majors offered, the wide variety of research being conducted, the existence of campus organizations that provide support to students and the community, and the need to keep a good GPA both to be admitted and to remain in college.

Finally, when asked if their opinion about the host university had changed, seven parents said it had, noting specifically that they were now aware that the university offered a number of opportunities to community members, including opportunities targeting the Latino/a community, and that one did not need to be a university student to take advantage of many of these opportunities.

Son A: *Has your opinion of the university changed?*
Mother A: *Yes, I know now that the university has many workshops for you and for Latinos, and for continuing to study, that I didn't know about. I know that there are Latino people and that there are opportunities for you to study.*

Academic Success in Middle and High School

The final theme where we found a good deal of change in the surveys and interviews related to academic success in middle and high school. Parents' responses only showed significant changes on one of four items related to resources in the middle and high school (I know about people and programs that provide academic support for Latino/a students at my child's school, $p<.001$). In contrast, parent responses about high school course-taking patterns increased significantly for two of three items (Some students take more science and math courses in high school than other students, $p<.001$; The courses my son or daughter takes in high school will help determine if he or she can go to college, $p<.01$).

Student responses about high school course taking only changed significantly for one of three items (I have choices about the courses I take in high school, $p<.05$). However, for questions about resources in middle school and high school, student responses increased for two of three items (I know about people and programs that provide academic support for Latino/a students at my school, $p<.001$; I know about people and programs that provide support for Latino/a families at my school, $p<.001$).

Information from the student-parent interviews further clarified the parents' thinking, both about obstacles to their children's continued academic success and about support structures for overcoming those barriers. In the initial interview, many parents pointed to obstacles to academic success that included financial constraints, students' poor academic performance, and family immigration and documentation status. Parents also had concerns about their children "hanging out with the wrong people" or "taking the wrong path." Despite acknowledging these obstacles that Latino/a families faced in regard to academic success, each of the parents also talked about the existence of support structures in the family, in the community, and/or in the school that could help their children to overcome those obstacles. However, these support structures were talked about quite generally without specific examples.

Parents also talked about the need for students to persevere through adversity, saying things such as "Dreams come to those who fight for them" and "If you fight, barriers shouldn't stand in your way."

In the final interview, the barriers to academic success that parents discussed were largely unchanged; however, the support structures that parents mentioned were more specific than in the initial interview. These supports included participation in programs such as Steps To College; talking with people that have gone to college; reading science books and watching science videos; seeking information about scholarships and other workshop opportunities; being aware of tutoring, mentoring, and other support programs at school and in the community; and increased communication between parents, students, and teachers, including increased parent involvement in school programs. The following excerpt highlights the value parents saw in taking advantage of a wide range of science learning opportunities:

Son B: *What are some resources in our family and our community that can support me in learning science?*

Mother B: *By doing more programs about doing science. We as a family need to study more about science in books, videos, and everything possible. In the community, with your friends, look in books, in libraries, learn things about science.*

Discussion

The results from the surveys and interviews provide a number of points for consideration from the perspective of how family science workshops might foster students' academic potential, parents' abilities to support their children academically, and teachers' enhanced understanding of their students and their students' families. The results also provide insights into how participation in family science workshops might lead to changes in students' and parents' interest in and knowledge about science.

First, several important changes were expressed regarding participants' interest in science. Students expressed an increased interest in science both in school and out of school. If students become more interested in science generally, they may be more motivated to perform well in science class. Further, if they begin to see connections between their in-school science classes and their interests in science-related topics outside of school, they may become further engaged in academic science. During informal conversations with participants during the second year, students enthusiastically told us that they had covered ideas or used inquiry practices in science class that they had learned about during the family workshops. A second important change in terms of interest in science was that parents began to express interest in a broader range of science topics. While initial interests focused almost exclusively on a fairly narrow range of life science topics, after project participation, parents expressed interest in a wider variety of science topics across disciplines. This seems important as it models for their children the notion of lifelong learning and the idea that they, as parents, are still interested in academic subjects even though they are no longer in school. This too may prove motivational for students and may lead to increased parent-student science conversations.

Several changes that emerged regarding participants' knowledge about science are worthy of further consideration. First was the attention that both students and parents paid to possible science careers. Parents and students both picked up on the idea, expressed in various ways throughout the workshops, that science careers generally pay well. Parents spoke repeatedly about their desire for their children to have more stable and comfortable lives than they themselves had, and parents came to see science as a potential path to that stability. Second, the range of science topics that parents claimed to have studied and the number of science careers that parents could name increased considerably after participation in the workshops. This increased parental knowledge *about* science (as opposed to science knowledge) seemed valuable to the parents in its own right.

Additionally, this knowledge could provide parents with necessary social capital when communicating with teachers and other professionals as advocates for their children's educational opportunities. As we became more interested in the role of the workshops in increasing participants' science knowledge, and especially their thinking about the science inquiry practices, we became aware that our surveys and interviews did not prompt participants sufficiently to talk explicitly about the science knowledge they had gained through participation in the workshops. We are revising our instruments to better elicit this information in the coming year.

Parents and students also expressed several potentially important changes regarding their knowledge about higher education. First, participants felt an increased level of comfort with and connection to the university after attending multiple workshops on campus. A number of participants commented that they had never been on a college campus before these workshops and did not even know anyone who had attended college. After the experience with this project, however, various participants said that they would now feel comfortable looking for opportunities to come to campus for other events and programs. This seems quite important as participating in a university community is an excellent way to build social and cultural capital that will foster further academic success.

Parents also expressed a great deal of attention to and an increased understanding of the financial aid system for higher education. Their attention to this aspect of the workshops seemed to be a clear indication that parents were committed to supporting and encouraging their children to attend college. Our continuing longitudinal research with parent and student workshop participants will yield valuable data for better understanding the high school graduation patterns and school-to-work and school-to-college trajectories within the local Latino/a community.

Finally, several notable changes emerged regarding participants' thinking about barriers and supports for students' continued academic success in middle and high school. First, participants expressed an increased awareness that to meet some of the longer-term goals they were discussing regarding college and careers, they first needed to focus on academic success in middle and high school. Parents gained an increased awareness that there were certain "rules of the game" that they had been unaware of and that they needed to advocate for on behalf of their children. This included the importance of high school course taking – registering for additional science and math courses and requesting their child to be placed in honors or advanced classes – and participation in enrichment (rather than remediation) programs and extracurricular activities. A second change had to do with discussions of obstacles and support structures for academic success. While participants were realistic about the obstacles that must be overcome as Latino/a immigrants, they expressed a greater awareness of and connection to support structures and strategies that could help their children succeed academically. Thus, one critical outcome of this project was that participants were gaining an increased awareness of what families that have a generational history of academic success do for their children and realizing that they could do likewise.

Conclusions

Some research on family involvement indicates that parents are less likely to participate in school-based family activities as their children reach middle school age (Hill and Tyson 2009). There is also a widespread belief in education that Latino/a families do not get involved in school activities (Delgado-Gaitán 2004). Additionally, research has shown that, in general, mothers are more likely to be involved in educational issues than fathers (Weiss et al. 2003). Drawing on longitudinal research with families (Goldenberg et al. 2001), we wished to challenge assumptions about Latino/a parental engagement while supporting parents in gaining agency and voice within traditional school structures. The active and enthusiastic participation of so many parents, and the significant number of fathers who participated in our workshops, is a clear indication that this is an untapped resource in our schools. These Latino/a middle school parents showed commitment to and engagement in their children's schooling, as well as high aspirations for their children's academic success. The parents showed a clear willingness to devote their time, even when this required financial sacrifice, to learn science with their children and to learn how to support their children in secondary and postsecondary education.

Effective support for academically motivated Latino/a students in middle and high school contexts requires a combination of academic skill development and advocacy for the same opportunities that other academically motivated students generally receive. Academic skill development for English language learners is likely to happen in enrichment programs that develop skills such as supporting science inquiry practices and academic language development, while it is unlikely to happen in the more typical "remediation" programs that aim to redress ELL students' academic "deficiencies." Participation in opportunities that White, middle-class academically motivated students generally receive requires Latino/a parents to have access to bilingual resources in order to gain social and cultural capital. Parents can activate this capital to better understand academic expectations and then to advocate on behalf of their children. Participation in projects such as the bilingual Steps to

College through Language-Rich Science Inquiry workshops seems to provide entry points for both of these aspects of support for academic success.

The theoretical and methodological lenses we adopted for this project enabled our work to progress in certain ways while constraining it in other ways. By theorizing about science teaching and learning that embraces and builds connections among English language learners, their parents, their teachers, and university-based educators, we were able to provide project participants with opportunities to pool academic and cultural resources in ways that enabled everyone to gain new insights into some aspects of science practice and academic success. Further, our framework led us to consider the need for a robust model of science learning that enhances ideas about rigorous science inquiry with ideas about academic language development in the context of science discourse.

At the same time, our theoretical framing of the issues constrains our work in certain inevitable ways. For example, while we find the need for the explicit teaching of academic language to be an expanding part of our model, we are aware that this approach sometimes leads to an implicit (or even an explicit) deficit perspective on student language. For example, Snow and colleagues (Snow et al. 2009), leading researchers in the area of academic language development, assert that language minority students "have a history of low reading ability, limited comprehension, and low investment of time in reading" (p. 329). We wonder how language-based content instruction can acknowledge and incorporate the sociocultural and linguistic interests, as well as the rich bilingual and biliterate family resources and funds of knowledge of language minority students and their families rather than portraying them as deficient linguistically and lacking in literacy skills. Our model acknowledges student interest for learning science and language beyond narrow rationales for increased test achievement but does not go far enough in terms of identifying and building on those student and family funds of knowledge and interests related to science and language.

While we believe that we have gained some valuable insights into the role that bringing together ELL students, their families, and their teachers as colearners can play in supporting science learning and academic success, there is a pressing need for work in this area, both in terms of additional scholarship and in terms of practical applications in school settings. For scholars looking for ways to conduct research on equity and diversity (in science and beyond), we need to know much more about the roles, relationships, and interactive communication that can develop among teachers, parents, and students who engage together in outside-of-school learning. We also need to know more about how (and if) the science content and academic language that are learned together in such outside-of-school settings migrate back into the classroom setting.

We wonder how (and if) parents advocate for their students in the schools once they have learned some of the "rules of the game" about academic success, as well as what happens when they do so. More research is also needed on the use and utility of bilingual home science kits as tools for keeping conversations about science inquiry and academic language alive in home contexts. Finally, from a methodological perspective, we found that our interview approach of asking students and parents to interview each other about their academic experiences and aspirations prompted more meaningful and valuable conversations than the normal approach of a researcher interviewing participants. More research using this interview approach would be a welcome addition to the literature.

Our work suggests that supporting teachers in building relationships with students and families in outside-of-school learning contexts has potential for supporting student engagement and learning in middle school classrooms. Teachers and students in our project were able to relate to each other differently in the workshop settings, which can lead to changes in these relationships back in the classroom. For example, when one of the high school teachers attended a workshop for the first time, she was mobbed by her students who hugged her and thanked her for coming. One can imagine that this led to changes in some of those relationships back at school.

For teachers of English language learners, student-parent-teacher workshops such as the STC/LRSI project represent an unrecognized professional learning opportunity. Engaging with parents as colearners shifts the interpersonal dynamics and creates a space for new relationships and discourses to emerge. Both teachers and parents in our project came to value these interactions in the workshop context, which may lead to shifts in how the parents and teachers relate to each other in the school context.

Finally, in the current policy and political climate in the USA, in which immigrants are increasingly portrayed in a negative light, teachers can send a clear message to their schools and communities by supporting enrichment opportunities for ELL students and their families. The outcomes of projects such as our Steps to College family science workshops can provide rational evidence in these often-emotional policy debates. At the same time, by supporting the educational aspirations of ELL students and their families, these projects can help to educate the next generation of leaders who may be able to push such debates in more productive directions.

In middle schools and high schools, in colleges and universities, and in professional organizations and legislatures, we need to create spaces for dialogue with Latino/a immigrant youth and families. We must realistically examine together the barriers and potential supports for science learning and academic success that could facilitate Latinos/as pursuing STEM careers and taking active part in citizen efforts to solve pressing science-related social problems.

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Chapter 16
Relationships Among Science Language, Concepts, and Processes: A Study of English Learners in Junior High School Science Classrooms

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There is a pressing need to improve the teaching and learning of science for English learners (ELs) in US classrooms. In recent years, the number of EL students has grown to five million or 10% of the school age population (National Clearinghouse for English Language Acquisition 2006). In California, where science is taught only in English, ELs encounter the multiple challenges of learning new scientific concepts and processes in the unfamiliar languages of both science and English. In this study, we examined two eighth-grade teachers' physical science classrooms to better understand how ELs, reclassified ELs (schools reclassify English learners once they achieve a target score on a standardized test of English proficiency), and students fluent in English negotiated relationships among language, concepts, and processes. More specifically, during a 5-week unit on forces, we investigated (1) teacher participants' views of effective instruction for EL students, (2) the kinds of learning opportunities teachers provided and their students took up during whole class and small group instruction, and (3) the science language, concepts, and processes students learned as a result.

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Conceptual Framing: Teaching Science to English Learners

Our study is framed by the idea that a science classroom is a discourse community with its own history, habits of mind, and ways of talking and acting (Yerrick and Roth 2005). As with any community, students need to master the language of science, including scientific vocabulary, to fully engage with and understand the scientific concepts and processes taught (Snow 2008). Mastery of scientific language is not limited to speech; it includes particular ways of writing as well (Bazerman 1988). Further, scientific language mastery requires understanding both the structure of the language (its phonemic, morphemic, syntactic, and semantic components) and the functions that the language can perform (Diaz-Rico and Weed 1995). Language functions are defined as what a language can do – the ways a language can be used to achieve particular communicative purposes. In science, language functions include "describing, hypothesizing, reasoning, explaining, predicting, reflecting and imagining" (Lee and Fradd 1998, p. 14). In brief, for EL students, learning science involves learning a third language – one different from their first language and from conversational English (DeLuca 2010).

Researchers have proposed a wide range of instructional approaches for ELs learning science. One way to organize these many recommendations for EL instruction is by sides of a debate among science educators: Scholars disagree over how similar or different the cultural and linguistic resources of EL students are to those of the scientific community (see discussion in Warren et al. 2001). We discuss only one side of the debate here. Ann Rosebery, Beth Warren, and colleagues, for example, encouraged teachers to view everyday and scientific ways of knowing and talking as fundamentally continuous and to "allow students to talk about their [science] experiences using the full range of their linguistic abilities" (p. 539). As another example, Lori Hammond (2001) documented how treating EL students' language, everyday experiences, and cultural knowledge as continuous with scientific ideas and practices benefited teachers, students, and parents at an elementary school in California: Such benefits included a flourishing community garden, a series of heavily attended family science nights, and recordings of indigenous science knowledge. We return to this debate in our discussion of findings below.

A second way to organize science education research on ELs is by kinds of students served; research makes clear EL students bring diverse personal experiences, learning preferences, and language proficiencies with them to the science classroom. Elizabeth Moje and colleagues (Moje et al. 2001), for example, investigated seventh-grade students who spoke either Spanish only or both Spanish and English with varying degrees of fluency. Some of the student participants in our study were similar to those of Moje and colleagues; others were different. We studied eighth-grade students who spoke either English only or both Spanish and English at different proficiency levels.

As a third alternative, research on EL instruction can be organized around key teaching strategies used to promote student learning. Given the views and practices of the teacher participants in our study, we used this third approach to help make sense of our data. More specifically, our data analysis was informed by research on instruction in science language and scientific inquiry. Bryan Brown and Kihyun Ryoo (2008), for example, recommended teachers make explicit connections between the language of science and students' everyday language. They suggested teachers introduce new scientific concepts using everyday language and then later transition to the use of scientific terms. Okhee Lee and colleagues (Lee et al. 2008a) argued for the integration of instruction in science inquiry with language instruction – in this case, the English language rather than students' everyday language – to reach EL students in elementary classrooms. In their model of culturally congruent instruction, to promote science learning, teachers are asked to move from teacher-directed to student-initiated inquiries and to use students' experiences in their homes and communities as intellectual resources integral to the learning of school science. At the same time, to encourage English language and literacy development, teachers are asked to implement a wide range of both linguistic scaffolding strategies and reading and writing activities. As did Brown and Ryoo, in our study, we examined secondary classrooms and interrogated the relationship between science vocabulary terms and conceptual understanding. As did Lee and colleagues, we investigated the implementation of inquiry instruction and assessed student learning in more than one way.

Research Design

We posed three sets of questions to investigate the ways our two experienced junior high school teachers supported ELs in learning science: (1) What instructional strategies did these teacher participants identify as promoting ELs' understanding of science language, forces concepts, and inquiry processes? (2) What did teachers and students say and do during classroom instruction? What successes and struggles did they encounter in talking and doing science? (3) What science language, concepts, and processes did students learn as a result? Did students at different levels of English language proficiency learn different things?

School and Classroom Context

This study was conducted at West Coast Junior High School during the spring semester of 2008. Approximately 800 seventh-and eighth-grade students were enrolled at West Coast that academic year: 65% were Latino/a, 28% were European American, 2% were African American, 2% were Asian American, 1% were American Indian or Alaska Native, and 2% were other. Further, 29% of West Coast students were English learners, and 14% were reclassified proficient in English. Almost half (45%) of the students received free or reduced lunch (California Department of Education [CDE] 2010).

West Coast students attend six 45-min periods each day. They are assigned courses in one of three tracks based on their English and mathematics standardized test scores from the previous year. In science, those who pass the test for Gifted and Talented Education are enrolled in the GATE science courses. Students who are identified as mainstream learners and who do not qualify for language support or special education services enroll in Honors science. Many of these Honors students also receive support from special programs; one such program provides an extra period during the school day for study skills and individual tutoring. The college prep classes contain a mixture of English learners, special education students, underperforming GATE and Honors students, and students who scored below basic on English and mathematics standardized tests. College prep class sizes are typically smaller in subjects such as English and mathematics yet remain around 30 in science due to scheduling constraints. While assignment to a particular track is not based on ethnicity, it is common to see a majority of Latino/a students in the college prep classes and of European American students in the GATE classes. Finally, West Coast students new to the English language do not take science at all; rather, they receive an extra period of language support.

We observed three eighth-grade physical science classes taught by two teachers during a 5-week unit on forces. Ms. Li taught periods 1 and 5; Ms. Kahn, period 2. We invited these teachers to participate in our study because they were well known among local educators for implementing inquiry instruction. Ms. Li and Ms. Kahn were part of a multiyear project funded by the National Science Foundation (NSF): Science graduate fellows came into their classrooms twice a week to help teach science as inquiry. The study was conducted near the end of the year, after teachers, fellows, and students had had substantial time to construct a community of scientists. Further, Ms. Li was clearly committed to learning about and implementing inquiry instruction: She had participated in numerous professional development projects, including a 2-year Research Experience for Teachers, and had helped to conceptualize, write, and implement the NSF grant for graduate fellows discussed above. Indeed, 2 years after this study, Ms. Li was awarded Teacher of the Year by the local county office of education.

Our two teacher participants co-planned the forces unit and implemented the same investigations, assignments, and assessments. Only the structure of their lectures and the questions they posed to students during whole class and small group instruction differed. Ms. Li, for example, engaged students in discussions during her lectures, soliciting responses and questions. Ms. Kahn's lectures, in contrast, included few requests for student input.

In 2006–2007, the year before our study, West Coast students had achieved the highest eighth-grade science standardized test scores in the school district. The California Standards Test in Science, or the Science CST, is closely aligned to the state's science standards (CDE 2000). Both Ms. Kahn and Ms. Li felt pressure to maintain and/or increase these scores in 2007–2008. When asked what she hoped students would learn from the forces unit, for example, Ms. Li began by stating: "First and foremost, I hope that they can draw force diagrams and answer the appropriate questions on the standardized test." Ms. Kahn agreed student performance on the state science test was integral to their planning of the eighth-grade science curriculum. In recent years, across the USA, high-stakes testing has become a reality for science teachers and their students, including EL students (see Lee et al. 2008b).

Participants

Our two teacher participants were women. Ms. Li, a Chinese American, was a native speaker of English. Ms. Kahn, a European American, was also a native English speaker. Teacher participants were assisted in periods 1 and 2 by six fellows, graduate students in the sciences from a nearby university. Three of these fellows were women: Lisa and Kelly, European Americans, spoke English as their first language; Lauren, an Asian American, spoke Korean and Spanish as her first languages. The other three graduate fellows were men: Trevon, an African American, and Adam, a European American, were native English speakers; Toby, an Asian American, spoke Chinese as his first language. Also participating in this research were 77 eighth graders – 40 girls and 37 boys. Sixty-six of these student participants were Latino/a, seven were European American, two were African American, one was Native American, and one was other. Twenty-seven were classified as EL, 12 were reclassified as English proficient, and 38 were native or fluent English speakers. Students of different genders, ethnicities, and language proficiencies were distributed evenly across the three periods studied.

Data Collected

Across the forces unit, four types of data were collected. First, the first author interviewed our two teacher participants, a subsample of 14 students, and all six graduate fellows. These interviews were digitally recorded. Each teacher interview was conducted after school for approximately 1 h. Teachers were asked to discuss their goals for the unit, the science content and instructional strategies they intended to implement, and the ways they modified their instruction on days the fellows were present. Fourteen students from across the three periods were interviewed either individually or in pairs during class time for approximately 20 min at the end of the unit. Five were English learners, two were reclassified proficient in English, and seven were fluent in English. In these semi-structured interviews, students were asked their understanding of concepts tied to forces, scientific investigations, and the cultural and social norms of the classroom. Finally, graduate fellows were interviewed in groups of three during their teacher's preparation period. While fellows' interviews informed analysis of classroom interactions, they were considered tangential to the research reported here. Only findings from teacher and student interviews are presented below.

Second, teachers provided researchers lecture notes and lab handouts from their forces unit. The first author also attended and recorded four teacher planning sessions. These sessions were held for 1 h once a week after school. Teachers' plans and notes were used to inform analysis both of teachers' interviews on intended instructional strategies and videotaped classroom instruction.

Videotape records of teachers, fellows, and students engaged in learning about forces constituted our third kind of data. Two video cameras captured whole class events and small group interactions. In total, the first author recorded approximately 60 h of instruction in the three classrooms over the 5-week unit.

Students' lab reports, homework assignments, quizzes, and tests constituted a fourth source of data. These written documents served to trace students' understanding of science language, content, and inquiry processes. Students completed a forces unit test constructed by the teachers at the unit's end; a pretest was not administered because teachers thought their students would score uniformly low. The forces unit test included ten questions, each with multiple parts: Nine queried students about forces content and one, about inquiry.

Data Analysis

The first author began data analysis by transcribing all interviews in full. To answer our first question, researchers examined teachers' interviews to identify intended instructional strategies to promote EL student success in science. We organized these intended instructional strategies along two dimensions: one, science language supports through forces vocabulary terms (the specialized academic words used in the study of forces) and language functions (e.g., formulating hypotheses, describing phenomena, interpreting graphs, and using evidence to support claims); and two, the teaching of science concepts and processes through lecture/demonstrations and inquiry investigations.

To answer our second set of research questions, we examined how strategies identified by teacher participants in their interviews played out in their classrooms. The first author constructed event maps (see Brown and Spang 2008) of all lessons videotaped from the forces unit. Once completed, event maps were studied for patterns in student-teacher, student-fellow, and student-student interactions as they constructed contexts and activities in everyday life (Green and Meyer 1991). Patterns identified were organized along our two dimensions discussed above (see Table 16.1).

The forces unit test and student interviews served as the primary sources of data for our third set of research questions. We attempted to determine what students learned about science language, forces content, and inquiry processes from completing this unit. We began by testing for differences in forces unit test scores by student language proficiency status (ELs, EL students reclassified as proficient in English, and students fluent in English). Student interviews were used to augment written test findings. Because of the smaller number of interviews, in our qualitative analysis of these data, we combined the categories ELs and reclassified ELs.

Table 16.1 Organization of data along two dimensions: language supports and concepts/processes

		Science concepts and processes	
		Lectures and demonstrations	Inquiry investigations
Science language supports	*Forces vocabulary*	Teachers and students consistently connected forces vocabulary and concepts by defining and repeating terms.	Teachers and fellows' reinforcement of forces terms was inconsistent. Students' use of these terms was inconsistent as well.
	Science language functions (describing, hypothesizing, explaining, and reflecting)	Students often performed the language functions defining, describing, or conveying factual information; they rarely formulated, explained, or defended arguments. Students were usually told by teachers or fellows what to write down.	Teachers and fellows encouraged students to hypothesize, explain changes to their design, defend their explanations, and reflect both orally and in writing. At times, teachers and fellows carefully structured students' use of these science language functions.

Findings

Teachers' Intended Instructional Strategies

In their interviews, our two teacher participants discussed ways they attempted to guide their students, particularly their EL students, in making connections across science language, concepts, and processes. As stated above, we organized our teacher participants' intended instructional strategies along two dimensions: one, supporting students in learning the language of science by emphasizing both vocabulary terms and language functions; and two, conveying science concepts and processes by engaging students in both lectures/demonstrations and inquiry investigations.

Science Language Supports

In their interviews, our two teacher participants explained that they promoted students' science language development both by emphasizing science vocabulary terms and by providing students opportunities to practice science language functions. To help students master vocabulary terms specific to the study of forces, Ms. Kahn and Ms. Li consistently introduced, defined, and repeated forces terms. Catherine Snow (2008) noted that secondary science teachers spend a substantial amount of instructional time teaching students the specialized academic words of their particular discipline. Ms. Kahn and Ms. Li also placed these terms on multiple formative and summative assessments, including homework assignments, quizzes, and tests. Ms. Kahn explained that the more often students practiced using forces vocabulary terms, the better they would score on the end-of-year standardized test. Learning these specialized vocabulary terms, she continued, would enable students to perform the science language function explaining – to explain forces-related phenomena in their everyday lives.

> I hope one of the things they'll [the students will] learn is some of the academic vocabulary that goes along with this area of physics [forces]. I think that's pretty important because that's key to doing well on the [standardized] tests for one thing. But it's also the key in them being able to explain what's happening – having the language for it. So I think picking up the language [of science] is very important.

These two teachers also went beyond the teaching of new vocabulary; they explicitly supported students in taking up science language functions such as making predictions, describing phenomena, formulating explanations, using evidence to support claims, and interpreting graphs. Support for science language functions, the teachers clarified, was central to building student understanding of science concepts and processes. Ms. Li hoped her students would learn to master the language function describing – to describe phenomena they saw out in the world the way scientists do. She stated: "I want them [students] to think about the world around them so that any motion that they see they realize they can describe. They can see it [the motion] in terms of speed and direction." Equally important, Ms. Li continued, she intended to help students learn how to better use evidence to support claims: "It's just recently I've noticed that when they draw conclusions, they just write, 'Yeah' [or] 'Nah.' I do want them to go back to their data.... 'Cite evidence from your data.'" Ms. Kahn saw the investigations implemented during the forces unit as one of many opportunities during the school year to help students learn to perform the language function interpreting graphs. Students "don't really know the tool that a graph can be to them yet," she explained. "That's why they always say, 'Is it [a] bar or line [graph]?' They think it's this arbitrary teacher-decided thing.... [They do not understand that graphs] come from data."

The Teaching of Science Concepts and Processes

Also during their interviews, our two teacher participants stated that students needed both direct instruction through lectures and demonstrations and engagement in inquiry investigations to learn science. Across the 5-week unit, teachers dedicated 15 of 24 days to lectures and demonstrations. In lectures, teachers attempted to front-load forces vocabulary terms and definitions as well as to provide examples of forces. Demonstrations were most often used when teachers did not have time to engage students in investigating a particular concept. Even in her ideal classroom, Ms. Li explained, she would "present a new topic, discuss the history [and provide] some core content knowledge" before beginning an investigation. "There has to be some content delivered," she emphasized.

Ms. Kahn and Ms. Li thought that presenting science content through direct instruction was necessary for students, particularly EL students, to more fully engage in inquiry investigations; they also saw inquiry investigations as an opportunity to reinforce science vocabulary and concepts introduced in lecture. Four investigations were implemented during the forces unit. The curling (a sport played on ice) for Kisses (small chocolate candies wrapped in foil) investigation ran one period. Students measured the distance a Kiss traveled across a table when pushed by rubber bands, graphed their findings, and attempted to explain the relationship between force applied and distance traveled.

The other three investigations – land sailboats, parachutes, and bottle rockets – each ran two to three periods in length. During the land sailboat investigation, for example, students investigated forces by attempting to design a boat that both captured as much air in its sails as possible and minimized the amount of friction between its bottom and the track. Students first constructed a boat with a paper bowl, paper sails, plastic straws, tape, and clay. The boats' travel time across a 2-m-long track was then measured and recorded for several trials. On the second day, students modified their boat designs and retested them. The two teachers thoughtfully planned each of these three longer investigations so that students engaged in an iterative design process. Students design and build an initial structure and then test and analyze their results, Ms. Kahn explained. Students then "look at the setup and see how to change it and then change it and see what happens."

All four investigations implemented by Ms. Li and Ms. Kahn fell on the teacher-directed side of the National Research Council's (NRC 2000) inquiry continuum: The two teachers posed the inquiry questions for their students as well as structured the ways students generated hypotheses, presented findings, and justified their ideas. This differs from Lee and colleagues' (Lee 2008a) model of cultural congruence that encourages teachers to move from teacher-directed to student-initiated investigations over time. The investigations were structured, Ms. Kahn explained, because they had found from experience that students did not learn when simply asked a question and invited to explore: "They just make a mess of things and play. They don't remember what they did." Students lacked sufficient background knowledge, she continued, to conduct open-ended investigations.

> We have to approach it [inquiry] in a little more structured way. I think inquiry assumes that the kids have a little bit of background knowledge to apply to things and a lot of these kids don't have [the] background.... They haven't had much science, or the science they've had has been little once-a-week sessions.

Ms. Kahn's response speaks to the debate over discontinuities between underrepresented students' linguistic and cultural resources and the knowledge and skills needed to learn science noted in our conceptual frame above (see again Warren et al. 2001). Unlike Hammond (2001), at least in this context, Ms. Kahn saw her students' prior knowledge and experiences as contributing little to their present science learning. We side with researchers like Hammond in this debate.

Investigations were structured for other reasons as well, Ms. Li added. She could "barely teach the [state science] standards" even with structured investigations. Structure helped students keep on task and complete the inquiries on time.

> There's a time limit. The reality is when I send kids off to work on something in a group, they don't always work.... And so our labs are very structured. "You need to get this done. You need to collect these data."

Ms. Li did express some frustration with implementing what she herself called "cookie cutter" labs. Ideally, Ms. Li elaborated, investigations would be more open-ended. She would pose students a question and "just let them go." Students would "solve it in their own way. We come back and we share – that's the important part – so that we can all figure [it] out." At the very least, she continued, she would like more "focus on the 'explain'" part of an investigation.

Classroom Interactions

We compared teachers' intended instructional strategies to their actual classroom implementation. From our close examination of videotape data, we found that consistent implementation of vocabulary support and language function practice across both lectures/demonstrations and inquiry investigations proved challenging.

Repetition of Forces Vocabulary Terms in Lectures and Demonstrations

As stated above, in their interviews, our two teacher participants emphasized the teaching of forces vocabulary words by introducing, defining, and repeating terms. From our examination of videotape data, we found teachers introduced and repeated forces vocabulary terms during lectures and demonstrations much more frequently than in investigations. For example, across several days of lecture, Ms. Li consistently encouraged her students to define the term force. Below are excerpts from lectures on days 1, 3, and 5.

Excerpt #1: forces lecture on day 1

Ms. Li: "A force is a push or a pull exerted." Do you know what exerted means? What do you think it means?
Boy 1: It means magnitude. Speed, speed.
Ms. Li: What does that mean?
Boy 1: Thrown.
Boy 2: Put.
Ms. Li: A push or a pull put upon an object. So am I exerting a force? (She pushes on the overhead projector.)
Boy 2: Yeah.
Ms. Li: I'm exerting a force. So I actually pull and that's a force too.

Excerpt #2: forces quiz review on day 3

Ms Li: All forces have?
Alex: Magnitude.
Ms. Li: What does it mean?
Girl: Weight.
Ms. Li: Weight? It's a size. You may have a small force or large force. A small force may be poking your partner with a pencil. What would a large force be?

Excerpt #3: Newton's laws lecture on day 5

Ms. Li: (to whole class) What did we study last week?
Chris: Forces.
Ms. Li: Very good, Chris. We learned last week that force is defined as a push or a?
Class: Pull.
Ms. Li: And all forces have magnitude and?
Girl: Density.
Ms. Li: Not density. All forces have magnitude and?
Several: Direction.

Readers should note that Ms. Li asked students to define both force, a specialized academic term, and words like exerted, magnitude, and direction, nonspecialized academic ones (see again Snow 2008). In the graphing excerpt below, Ms. Li also supported a student in using the nonspecialized academic word further. Snow (2008) argued that science teachers commonly provide support for EL students in learning specialized science terms. They should – but rarely – support EL students in learning nonspecialized academic words as well.

Forces Terms in Investigations: Inconsistent Reinforcement

Forces terms, while heavily reinforced during lectures and demonstrations, did not play as substantive a role during investigations. Across the four lab worksheets provided to students, only the forces terms distance, speed, force, and air friction were included. During small group and whole class discussions around these four investigations, students routinely described phenomena using everyday language and were infrequently asked to restate their ideas using scientific terms. Rather, teachers focused on providing students opportunities to experience concepts firsthand by manipulating, experimenting with, and redesigning physical objects.

At the beginning of day 2 of the land sailboat investigation, for example, Ms. Li and a graduate fellow, Adam, asked the whole class to think about how to redesign their boats based on findings from day 1. In the excerpt below, even though Ms. Li and Adam used the term friction four times, they did not prompt students to speak, define, or record this term. One student did, however, offer the word friction without prompting.

Adam: Another thing to think about. Do [you] want a really big bottom to the boat? Or is that going to slow it down [on the track]?

Moises: We put straws on the bottom [of our boat].
Adam: That'll be good. That will reduce the bottom of the boat and that will mean less friction. You can also think about the materials we gave you.
Evan: I used the paper that you gave us [to put on the bottom of the boat].
Adam: Yup, you can use paper to put on the bottom.
Evan: Or tape, because it's really smooth.
Adam: Tape is really slippery so that might have less friction.
Ms. Li: Those are excellent ideas.... So we are a community of engineers right now and we would like to share our ideas. You don't have to do exactly what we suggested, maybe you can come up with your own designs. Now I'd like you to spend some quality time just talking only about the design [in your small group]. Please focus on the sail and the bottom of the boat where there's too much friction. It's really dragging. Throughout the day, we saw some different designs. Not everybody had the boat sitting like this. (She holds up a boat and flips it upside down.) What's the advantage of flipping it over?
Evan: Wind gets under it.
Moises: Hover.
Girl: Less friction.
Ms. Li: Less friction, because why?
Boy: It's only hitting at the corners.
Ms. Li: Right. That was a really interesting idea. And it was pretty stable.

Language Functions in Lectures and Demonstrations: Limited Practice

Across the 5-week forces unit, during lectures and demonstrations, students were rarely asked to practice language functions beyond defining, describing, and/or conveying factual information. Performance of many of the language functions specific to science – hypothesizing, explaining, or defending ideas – was rare. During the egg drop demonstration, for example, Toby, a graduate fellow, placed a raw egg on top of a toilet paper core sitting within a pan. The egg, core, and pan rested on top of a beaker with water. When he hit the pan forcefully off the beaker, the egg dropped into the water below. This demonstration was used to illustrate the law of inertia (Newton's first law) in which an object at rest remains at rest unless acted upon by an outside force. The removal of the pan and toilet paper core eliminated the normal force keeping the egg in place; the egg fell due to the now unbalanced downward force of gravity.

Toby: So what happened? (Evan quietly states that the egg stays in place. When you move the pan, the egg still stays in place and drops into the beaker. But Toby did not seem to hear him.)
Alex: Could I try [the demo]?
Toby: The egg went straight down. What Newton's law is this?
Boy 1: The first one.

Alex: Can I try [the demo]?
Toby: We have to write down the law first. Newton's first law says that an object at rest [stays at rest,] object in motion stays in motion. What was the outside force that I applied? I applied a force that was a straight horizontal force. It did not act on the egg. What forces act on the egg?
Boy 2: The pan.
Toby: The pan didn't really affect it. The TP roll [toilet paper core] was holding it up. Gravity was also pulling down. The pan goes this way [to the side], but the only thing pulling down on it [the egg] was gravity. When these [pan and core] are knocked out, the egg dropped out because of gravity. Write that down.

Toby told the students exactly what happened and what to record during this demonstration; he did not encourage student performance of the language functions predicting or explaining. More specifically, Toby might have pushed Evan to move beyond describing what he saw during the demonstration to providing a possible explanation. Toby also failed to encourage Boy 2 to explain his answer: Why did he think the pan acted on the egg?

Structured and Informal Opportunities to Practice Language Functions in Investigations

In contrast to direct instruction, many language functions specific to science were consistently reinforced across investigations. In a discussion at the end of the curling for Kisses investigation, for example, Ms. Li asked students to interpret a graph – a language function clearly tied to scientific inquiry. She put a line graph of class data on the overhead; the graph displayed the amount of force exerted on an object versus the distance it traveled. Ms. Li then carefully walked students through its interpretation.

Ms. Li: What is the relationship between force applied and the distance it [the Kiss] traveled? What do you notice about this graph?
Girl 1: It [the line] goes up.
Girl 2: Higher.
Ms. Li: It's going higher. So if I increase force, my distance goes higher. It [the distance] also increases. Let's write this down. "When force is increased, the Kiss will"
Girl 2: Go higher.
Ms. Li: It won't float up, right? It will travel further. "The Kiss will travel further."

Teachers and fellows also encouraged students to practice language functions in more informal contexts. For example, during the land sailboat investigation, while working in their small groups, teachers and graduate fellows consistently asked students to explain why their redesigned structure worked better or worse rather than just asking them to describe how they redesigned it. Below, Ana, an English learner, and Holly, a student fluent in English, finished building their first boat for this investigation. Ms. Kahn arrived at their desk and silently read their answers on their lab worksheets. For design logic/special feature, the girls had written: "It's gonna work! Because I designed it!"

Ms. Kahn: Try to think of a scientific reason for your design that made your boat go fast. I noticed your sail [in your drawing], is this tape around it?
Ana: No. It's just folded like this.
Ms. Kahn: Okay. So why did you fold the sail like that? What's your purpose?
Ana: So that air can hit this [the sail] and push it that way [forward].
Ms. Kahn: So it captures more air? So put "captures more air" here [under Design Logic/Special Feature]. The sail captured more air. This looks good. Anything else about the boat that you think is good, a special feature? I noticed you put these [straws] here like that. What are these about? To make it?
Holly: Bend.
Kahn: To make it bend so it catches more air? Okay. That looks good. When you're ready, you can test it out.

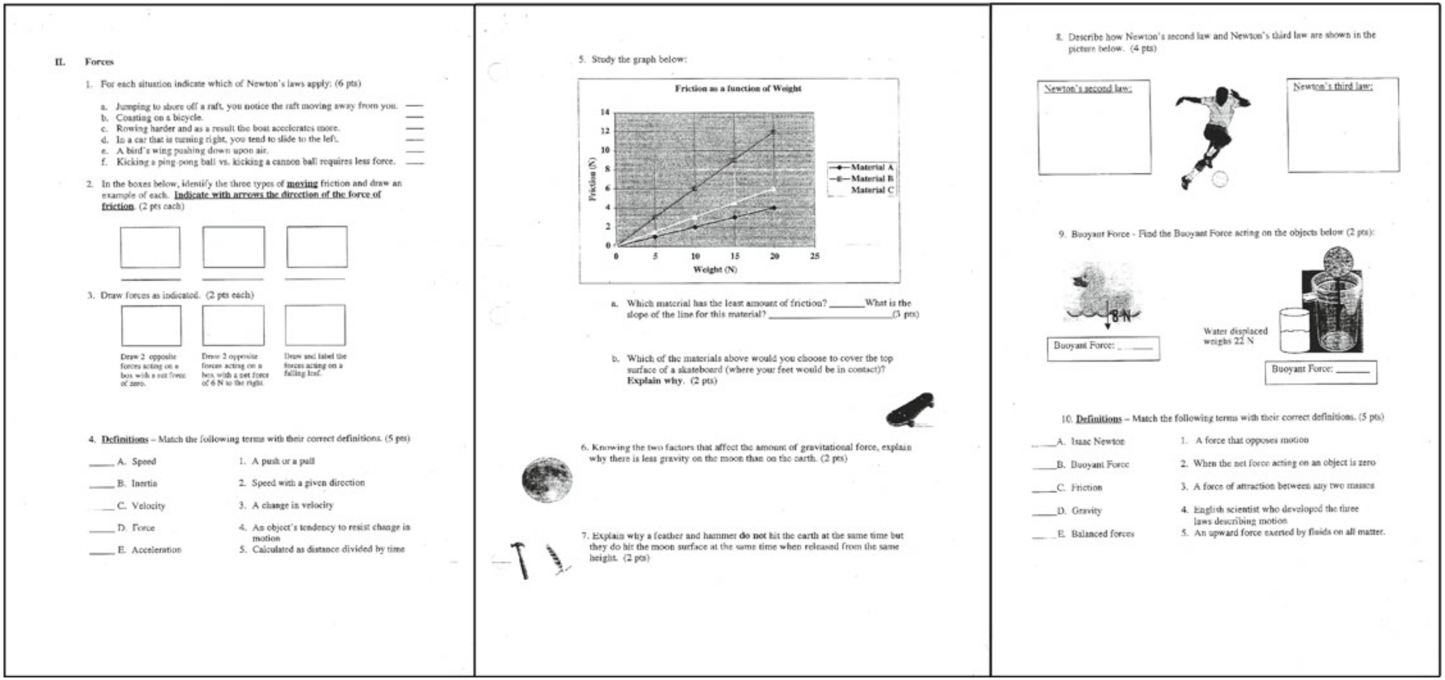
Ms. Kahn recognized that the girls' written responses under design logic were inadequate. In her interview, Ms. Kahn had noted that students often had difficulty with the language function explaining. Through questions, Ms. Kahn guided the girls to explain their boat design: They folded the sail a certain way and bent the straws so that the boat could capture more air. She then urged the girls to record "captures more air" on their paper. She did not, however, encourage the girls to explicitly connect the idea of capturing more air to the concept of force. Prior to this exchange, the girls' conversation was limited to whether or not their boat pieces would stay in place during the trial.

Student Learning

For question 3, we investigated what students learned about science language, forces concepts, and inquiry from their 5-week unit. We began by statistically analyzing students' scores on the forces unit test. We triangulated quantitative findings with qualitative analysis of students' written test responses and end-of-unit interviews. We remind readers that students in these three classrooms did not represent the full range of students enrolled at West Coast.

Forces Unit Test

Ms. Li and Ms. Kahn constructed and administered a common forces unit test consisting of ten closed- and open-ended questions (see Fig. 16.1). Sixty-seven of the seventy-seven student participants completed this three-page written test. Students' mean score was 21.12 (SD = 5.74) out of 35 points. This mean is rather low – students


II. Forces

1. For each situation indicate which of Newton's laws apply: (6 pts)

a. Jumping to shore off a raft, you notice the raft moving away from you. ___
b. Coasting on a bicycle. ___
c. Rowing harder and as a result the boat accelerates more. ___
d. In a car that is turning right, you tend to slide to the left. ___
e. A bird's wing pushing down upon air. ___
f. Kicking a ping-pong ball vs. kicking a cannon ball requires less force. ___

2. In the boxes below, identify the three types of **moving** friction and draw an example of each. **Indicate with arrows the direction of the force of friction.** (2 pts each)

3. Draw forces as indicated. (2 pts each)

Draw 2 opposite forces acting on a box with a net force of zero.
Draw 2 opposite forces acting on a box with a net force of 6 N to the right.
Draw and label the forces acting on a falling leaf.

4. **Definitions** – Match the following terms with their correct definitions. (5 pts)

____ A. Speed	1. A push or a pull
____ B. Inertia	2. Speed with a given direction
____ C. Velocity	3. A change in velocity
____ D. Force	4. An object's tendency to resist change in motion
____ E. Acceleration	5. Calculated as distance divided by time

5. Study the graph below:

a. Which material has the least amount of friction? ______ What is the slope of the line for this material? ____________ (3 pts)

b. Which of the materials above would you choose to cover the top surface of a skateboard (where your feet would be in contact)? **Explain why.** (2 pts)

6. Knowing the two factors that affect the amount of gravitational force, explain why there is less gravity on the moon than on the earth. (2 pts)

7. Explain why a feather and hammer **do not** hit the earth at the same time but they do hit the moon surface at the same time when released from the same height. (2 pts)

8. Describe how Newton's second law and Newton's third law are shown in the picture below. (4 pts)

Newton's second law:
Newton's third law:

9. Buoyant Force - Find the Buoyant Force acting on the objects below (2 pts):

Buoyant Force: ______
Buoyant Force: ______

10. **Definitions** – Match the following terms with their correct definitions. (5 pts)

____ A. Isaac Newton	1. A force that opposes motion
____ B. Buoyant Force	2. When the net force acting on an object is zero
____ C. Friction	3. A force of attraction between any two masses
____ D. Gravity	4. English scientist who developed the three laws describing motion
____ E. Balanced forces	5. An upward force exerted by fluids on all matter.

Fig. 16.1 Forces unit test

answered an average of only 60% of questions correctly. A one-way ANOVA yielded no significant difference by class period, $F(2, 64) = 2.19$, $p = .12$. To test for differences by English proficiency status, student scores across the three periods were then combined. This second one-way ANOVA yielded no significant difference by our three levels of language proficiency status, $F(2, 64) = 1.86$, $p = .16$. It suggests that implementation of EL strategies can help EL students and reclassified EL students perform as well as their fluent English-speaking peers.

Although our two teacher participants constructed this test, we could not use the full two-by-two table (see again Table 16.1) generated from qualitative analysis of their interview data to make sense of student test responses. The test did not fully assess what students learned from investigations completed in class: Students were neither asked what they learned about inquiry processes, in general, nor how findings from their four investigations connected to forces concepts, in particular. Indeed, only one of the ten questions probed students' understanding of inquiry. The question asked students to interpret a graph comparing weight versus friction for three materials. Students were to calculate the slope of the lines and infer the materials' value as a skateboard surface. Teachers intentionally constructed this question to mirror those posed on the investigation portion of the Science CST.

We did, however, qualitatively examine student use of specialized academic words, vocabulary terms specific to the study of forces. (See the vocabulary component of our two-by-two analysis table.) We began by examining student answers to the two closed-ended vocabulary questions on the test, questions 4 and 10. For each of these questions, students were asked to match five forces terms to their definitions. We found no clear differences in performance by student language proficiency status (ELs, reclassified ELs, and students fluent in English). Overall, students were able to define these forces vocabulary terms, answering an average of 7 of 10 questions correctly.

We then turned to student responses to open-ended questions; we looked to see how students used forces terms in their responses to questions 5b, 6, 7, and 8. The language functions requested of students in these open-ended questions, it is important to note, were different than in the closed-ended ones: Students were asked to interpret, explain, and apply rather than to simply define. Again, across student answers to these four open-ended questions, we found no clear differences in performance by student language proficiency status.

We did, however, find that students experienced greater difficulty answering these open-ended questions than matching forces terms to definitions. About half of the 67 students provided correct or partially correct responses to question 5b (interpreting a graph of weight vs. friction) and question 8 (applying Newton's second and third laws to kicking a soccer ball). Twenty students used the term friction in their response to the graphing question; 28 students, the terms distance, force, mass, and/or acceleration to the Newton's laws question. No student provided a correct response to question 6: Knowing the two factors that affect the amount of gravitational force, explain why there is less gravity on the moon than on the earth. Twenty-eight students provided partially correct responses. Only three students actually used the term mass; no student, the term distance. Finally, only three students answered question 7 about air resistance on the moon versus on earth correctly. One of these three explained, “They [a feather and a hammer] don’t hit at the same time [on earth] because the moon does not have that much [air] friction and the Earth does.”

End of Unit Interviews

In a second attempt to make visible what students learned about language, forces concepts, and inquiry processes, the first author interviewed 14 students at different levels of English proficiency at the end of the unit. As stated above, some students were interviewed individually; others, in pairs. We focused our examination of interview data on student responses to three target questions. One question assessed student understanding of a forces concept taught only through lectures and demonstrations: What can you tell me about Newton’s laws? A second question asked students: What was the point of the parachute lab? Its purpose was to assess students’ inquiry skills in interaction with their understanding of forces content. A third question – How would you graph the data from the parachute lab? – solicited students’ understanding of graphs practiced only during investigations.

As with the forces unit test, students’ responses to these three target interview questions often reflected partial or incorrect understandings. However, in contrast to the written test (an ANOVA yielded no significant difference by student English proficiency level), interviews also suggested students fluent in English were able to convey ideas more completely and with greater accuracy than their reclassified or English learner peers. More specifically, of the seven fluent English speakers interviewed, four provided a correct response to one and a partially correct response to the second of our three target questions; one, one correct response; and two students, one or two partially correct responses. Of the seven reclassified EL or EL students interviewed, only one, Vera, answered two of the three target questions correctly. Four students provided one or two partially correct responses. Two EL students remained silent for all three questions. Differences in students’ performance by language proficiency between the written test and the interview highlight the importance of using multiple instruments to assess student learning.

Again, as with the forces unit test, we were unable to use our complete two-by-two table to analyze student interview data. We did, however, compare student responses to our three target questions taught by lectures/demonstrations only, inquiry only, or a combination of the two. Student responses to these three interview questions suggested they understood forces content explored in both lectures and investigations better than that examined only in lectures or only in investigations. Almost all students (12 out of 14) provided a correct or partially correct response when asked the purpose of the parachute lab. For example, Sean, a fluent speaker of English, stated: “The point of the sailboat lab was to reduce sliding friction to make the boat go faster. For the parachutes, we’re trying to increase friction, slow it down.” Students were less successful in stating Newton’s laws: Only one student stated all three laws, four were able to state part or all of one law, four provided incorrect responses, and five remained silent. For example, Jessica, a reclassified EL student, provided a partially correct response: “I know there are 3 laws. An object at constant speed stays at constant speed.” Several noted, “I don’t know Newton’s laws.” Similarly, the majority of students interviewed were unsure how to construct a graph to represent findings from the parachute investigation. Nine out of 14 students attempted responses to this question; five remained silent. Of these nine, three provided correct responses; three, partially correct responses; and three, incorrect ones. Vera, an English learner, offered the most complete answer: “I would make a bar graph and label time here and parachute 1 and 2 here. Parachute 2 is better because it’s bigger than the person, so the person falls less [slower].”

Moving Toward Equity

Findings from this study highlight the complexities of teaching science to English learners. Despite experienced teachers and the support of science graduate student fellows, teachers’ implementation of vocabulary and of language function support was inconsistent across lectures and investigations. Students experienced mixed success in answering questions on the end-of-unit test and interview; they did not perform as well on these summative assessments as teachers and researchers had hoped. Study findings also foreground the importance of using more than one method to assess student learning: The two ways of assessing students’ science understanding, reflecting different ways of conceptualizing science as a discourse community, led to differences in ELs’ perceived science competence. We close with recommendations for improving the teaching and learning of science for EL students. Understanding how to better meet the needs of EL students, we argue, will benefit all.

What Do the Lenses Used in This Scholarship Enable and Constrain?

In designing this study, we made two pivotal methodological decisions. One, we attempted to foreground teachers and students’ efforts to co-construct interesting and meaningful science at the classroom level. As such, our study’s sample size was small: two teachers, six fellows, and 77 eighth graders. Teachers were not involved in a large district or state professional development effort; rather, they implemented their own version of EL support and inquiry instruction. Had we conducted our study at the school level, we might have been able to speak to issues of tracking (Oakes 1990): We might have examined how the experiences of EL students in the lowest track differed from those in higher ones as well as compared student performance on assessments across a larger number and wider range of students. Had we conducted this study at the district level, we might have been able to speak to ways state standards and high-stakes testing differentially shaped the teaching and learning of science at different kinds of secondary schools (see Lee and Luykx 2006). At the very least, at the district level, we might have included complex statistical analysis of Science CST data.

A second pivotal methodological decision was to analyze our data from an emic perspective: We used what the teachers counted as effective EL and inquiry instruction to organize our analysis. Starting analysis from the teachers' perspective mirrors how we expect teachers to teach science for all – to start instruction from their students' lives (Warren et al. 2001). However, teachers' emphasis on vocabulary and language functions did not neatly align with recommendations to bridge everyday and scientific language (Brown and Ryoo 2008); their adherence to structured inquiries, with descriptions of open-ended, student-directed investigations laid out in larger reform efforts (Lee et al. 2008a). Our analysis and results also would have been different had we examined our data through the lens of students or parents rather than teachers. Calabrese Barton et al. (2008), for example, grounded their analysis of classroom data in the lives and experiences of their student participants.

What Is the "So What" for New Scholars Interested in Equity and Diversity?

Our discussion of methodological strengths and limitations above should serve as food for thought for new scholars interested in researching issues of equity and diversity. Clearly, a study's grain size enables and constrains the kinds of claims a researcher can make and the practices or policies a study can inform. Researchers should carefully consider which aspects of science education they intend to shape before deciding on their study's scope and sample.

We found making sense of data from our two forms of assessment a challenge as well. Because we constructed our analysis scheme after all data were collected, we could not ensure the teachers' written test or our end-of-unit interview protocol neatly mapped on to the four squares of our analysis table. Gaps in the test and interview questions constrained what we could learn about students from these summative assessments. Equally important, because student understanding was assessed in different ways and at different levels in these two assessments, we expected and indeed found differences in how groups of students performed. Specifically, EL and reclassified EL students performed as well as their fluent English-speaking peers on the teachers' test; however, they did not perform as well in interviews. In the end, as researchers, we were uncertain how to craft a coherent and compelling story from this limited and contradictory set of student outcome data. To really make sense of student learning, we needed to go beyond the scope of our study: to perform a more thorough analysis of student responses in these two assessments and to compare students' oral and written responses in formative assessments to patterns found in summative ones. We encourage new scholars to more thoroughly explore how different kinds of assessments can be integrated into studies of classroom interactions to yield a richer and more complete picture of the teaching and learning process.

What Are the Implications of This Research for Classroom Teachers?

Teachers, particularly secondary science teachers, can use lessons learned in this study to inform their own instruction. We begin by underscoring two successes. First, our two teacher participants did not relegate their students – those traditionally underrepresented and underserved in science – to remedial tasks or individual seatwork. Rather, they offered their students multiple opportunities to engage in inquiry investigations – to routinely work with more knowledgeable others (fellows and teachers), design and test structures, collect data, present their findings, and argue their claims. Second, teachers did not throw out state science standards or eliminate the teaching of science as inquiry to provide students learning English academic language support. Even though they taught science at the secondary level, they did not need to sacrifice traditional science instruction to teach the languages of English and science.

Challenges to the teaching of science to English learners also emerged, however. Although our two teacher participants did indeed provide students with academic language supports, these supports were inconsistent: They failed to consistently connect ideas to science terms during inquiry instruction and provided few opportunities for students to practice language functions other than defining, describing, and conveying factual information during lectures. Emphasizing both science vocabulary and diverse language functions across all kinds of instructional strategies might better support students in developing proficiency in the languages of both English and science and deeper understanding of scientific content and processes. Similarly, although our two teachers implemented inquiry instruction, their unit test did not fully assess students' understanding of the inquiries they conducted. Graphing, the one inquiry process tested, constitutes only a narrow slice of what counts as inquiry in reform documents (NRC 2000). For students to develop a robust understanding of inquiry and to make tighter connections between science content and inquiry processes, tests might include a wider range of inquiry prompts and problems as well.

On a related note, our teacher participants found balancing the multiple and sometimes competing demands on their instructional time difficult. They attempted to attend to students' needs and interests, implement inquiry with help from science graduate fellows, meet expectations from their school for high scores on the Science CST, and address all state science standards. As suggested for professional development efforts (Loucks-Horsely et al. 2010), closer alignment across teachers' instructional practices, school goals, and larger reform initiatives might improve teachers' professional lives.

What Are the Implications of This Research for PolicyMakers?

Ms. Li and Ms. Kahn's instructional decisions were substantively influenced by the Science CST, in particular, and the California science standards, more generally. Their emphasis on science vocabulary is one example: In both their interviews and lectures, teachers underscored the need for students to know and use science terms to perform well on the end-of-year standardized test. Teachers' sustained focus on graphing is a second example of the influence of high-stakes testing on instruction. One of the reasons Ms. Li and Ms. Kahn included the skateboard materials problem on their forces unit test was to give students practice solving graphing problems. As a third example, teachers structured their inquiries, in part, to keep to a timeline – to ensure that they covered all state science standards during the academic year.

The question remains: To what extent should high-stakes testing shape what teachers teach and students learn in science classrooms? Okhee Lee and Aurolyn Luykx (2006) suggested high-stakes testing might lead to too much uniformity in instruction. "The goal of maximizing… overall student outcomes [through standardized assessments] conflicts with the goal of optimizing… individual student outcomes through contextualized modifications of educational interventions." This tension, they continued, is most acute in "classrooms where student diversity is greater and educational resources and opportunities are more limited" (p. 153). High-stakes testing might also unnecessarily narrow the kinds of investigations implemented in science classrooms. Although the investigations Ms. Li and Ms. Kahn designed included more than the mere collection and graphing of data, for example, they did purposefully highlight graphing across investigations, assignments, and assessments. Indeed, their one inquiry question on the forces unit test asked students to interpret a graph. As the USA moves toward implementation of a second wave of national science standards and a new set of standardized tests, it is difficult to tell if gaps between science and engineering practices as conceptualized by science education researchers and inquiry as implemented by classroom teachers will widen or narrow. Researchers will have even greater impetus to provide evidence-based answers to questions of standards, high-stakes testing, and equity issues.

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Chapter 17
International Response for Part IV: Discourse, Language, and Identity in Science Education

Michael J. Reiss

Us

Most of us who work in science education did well at science in school and enjoyed it sufficiently to carry on with it after school. And yet ‘science’ is not a single entity. If I think of myself, although I did reasonably well in chemistry at school, my heart was not in it and while my vacillation between physics and biology is indicated by my changing from the former to the latter during my first year at university, I never, so far as I can recall, consciously considered studying chemistry beyond school level. Looking back now, I can see it was the organic chemistry that was the problem. While I enjoyed the inorganic chemistry – those elegant rules for balancing equations, calculating heats of reaction and determining whether an endothermic reaction would proceed or not, not to mention the attractiveness of the practical work – much of carbon chemistry was a mystery to me. I realised subsequently that the problem was my poor powers of three-dimensional visualisation. To this day, I have to use a map when driving to visit my sister several times a year despite the fact that neither she nor I have moved homes for nigh on 30 years.

Is it valid to say that I had a problem with the language or discourse of organic chemistry? At first sight, the answer might seem to be ‘no’ – I knew what an alkane and an alkene were (I can still remember) and I was comfortable with the idea of chemistry, even organic chemistry. Indeed, I managed adequately to avoid having to rely on visualisation to just about cope with most of the questions my teachers or the examinations posed. And yet the sub-discipline felt ‘like a foreign language’ to me.

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I start thus partly because starting where we are is never a bad idea in education (it can be easier to understand one's own problems than those of another) and partly because the above raises for me questions about what we mean by 'language' and 'discourse', let alone 'identity'.

The Chapters in This Part

The three chapters in this part complement each other well. Two of them, by Cory Buxton et al. and by Emily Kang and Julie Bianchini, present original data and then use these data to draw more general lessons about language, particularly lessons about how rich approaches to science teaching can enable bilingual learners to be successfully included in science. The third, by Bryan Brown, proves a more conceptual analysis of how language and identity relate and ends by providing a clear model to suggest how students' learning in science might be helped.

Cory Buxton, Martha Allexsaht-Snider, and Carlos River a analyse findings from their work to develop a bilingual outreach and research project focused on science, language and Latino/a families. They employed a model of instruction that drew together three strands: the mutual engagement of students, parents and teachers in bilingual science learning and preparation for college; authentic science practice; and academic language development to support language-rich science enquiry. Encouragingly, the project resulted in increases in student interest in science and a greater realisation among both students and their parents that they did, in their out-of-school activities, engage in science. For instance, during the initial interview at the start of the project, nearly all the examples parents gave of their having an interest in science came from the life sciences. In the final interview, parents expressed a much wider array of science interests including meteorology, kinesiology and environmental science.

Emily Kang and Julie Bianchini examine two eighth-grade teachers' physical science classrooms to explore how English learners and students fluent in English negotiated issues among language, concepts and processes. Each of the teachers was well known among local educators for implementing inquiry instruction. However, all four of the investigations implemented by the two teachers were teacher-directed. More positively, students did not spend their time undertaking remedial tasks or individual seatwork. Instead, they had opportunities to work with more knowledgeable others (science graduate fellows and teachers), design and test structures, collect data, present their findings and argue their claims. Although some of the research findings were contradictory, there were encouraging signs that English learners benefitted from the inquiry approach.

Bryan Brown begins with 'the Language-Identity Dilemma' in science education, namely, the idea that the need to acquire new science language presents students with a learning challenge of two sorts. On the one hand, students must develop a clear understanding of science phenomena and their associated discourse. On the other hand, the nature of language-identity relationships presents students with a need to adopt the identity relationships associated with using science discourse. For some students, this works well. However, for many student populations, the use of complex science discourse entails a substantial cultural shift that can produce identity conflicts. Brown's proposed solution, the 'Disaggregate Instruction' approach, begins by introducing new science ideas in the language that students already understand. Students are thus able to gain a basic understanding of the ideas and experience less anxiety and frustration typically associated with teachers' exclusive use of new science language. Once the basic tenets of a science idea have thus been taught, the teacher introduces the new science language. Finally, the teacher requires students to use their new science language to explain the phenomenon in meaningful contexts.

I would like to use these three chapters as a springboard to allow me to explore a range of issues about language, discourse and identity. I do so as someone whose first language is English but who has never lived for any length of time in the USA. At the same time, I shall try to keep in mind that language (even if narrowly restricted to words, eschewing other sounds and issues of multimodality) is concerned with what is said, heard, written and read.

Language

What issues does language raise for science education? Perhaps the longest established is that science generally has a very precise use of language. If one thinks of high school physics, we expect students to appreciate the difference between words such as 'force', 'power' and 'energy'. Yet these words are used in everyday language as near synonyms. Of course, science isn't alone in this regard (the new Director of the Science Museum in London told me last week how, as an art historian, he had been ticked off for referring to a deposition as a pietà). Most subjects have a specialised vocabulary that needs to be used with precision. And yet science is distinctive in a number of ways. For one thing, as indicated by the force/power/energy example, it often takes everyday words and invests them with a very particular meaning. Of course, if you are an undergraduate studying an option in nuclear physics, you aren't going to be confused by the distinctive use of words like colour and charm when talking about quarks but earlier in one's science learning career this is more of an issue. The same point arises with the precise use of words like 'melt' and 'dissolve', with less familiar words such as 'assimilate' and 'reactant', and with phrases such as 'dependent on' and 'in proportion to'.

How does this connect with equity? For a start, and as indicated by Buxton et al. and Kang and Bianchini, those whose first language is not that of the science classroom (including, I would add, those who are Deaf, hard of hearing or disinclined/unable, for whatever reason, to listen or read attentively) are likely to be disadvantaged, as in any language-rich subject – which includes most school subjects and all those valued as academic, though perhaps less in the case of mathematics where a smaller vocabulary may suffice and where much communication is through the use of numbers and the explicit use of symbols, such as $+$, $-$, $=$, ∞, $\pm$, $\geq$, x, y, π, θ, $\therefore$, $\cup$, Σ and $\int$.

This, of course, connects with the notion of cultural capital. If I have never seen a gyroscope, looked down a microscope or played with a chemistry set outside of school, I will be disadvantaged when I am first introduced to such experiences in school even if I initially find such school experiences as interesting as someone who has already met these scientific artefacts.

But deeper considerations of how language in science can marginalise and exclude are better explored through the notion of discourse.

Discourse

Science is full of powerful discourses. As with most discourses, these are most influential when unexamined. A particular problem with some who teach or research science is that the seductive benefits of a scientific approach are such that science is seen as all encompassing so that other ways of understanding are rejected. I'll illustrate this, and suggest more positive ways forward for school science, by reference to teaching about evolution and about sex.

Teaching About Evolution

Teaching about evolution is becoming something of a battleground in an increasing number of schools, and not just in the USA. There are a number of relevant issues. First is the fact that, as someone with a PhD and post doc in evolutionary biology, I am of the view that it is important that students in high school are taught that to the overwhelming majority of scientists, the theory of evolution is extremely well established. There is only one scientific story in town and that is that the Earth is of the order of 4.6 thousand million years of age and that all species have descended from simple ancestors, indeed, ultimately inorganic precursors.

But how are science educators who accept this scientific consensus to react to those, whether students, their parents or others in the community, who do not accept the scientific account? For a start, I would argue that science educators must do nothing to ridicule or denigrate those who understand the world very differently from them. Not only is this discourteous and inappropriate for someone in a position of educational authority, it is counterproductive from a pedagogical standpoint. Indeed, for all that teaching about evolution makes additional demands on a teacher when some in the class are creationists or accept intelligent design theory, it can provide an opportunity for high-quality science teaching. After all, if a student can argue for a young Earth or that very different species do not share a common ancestor, that can provide an opportunity for a teacher to encourage the scientific evidence on these matters to be examined.

I suppose I should add that this does not mean 'teaching the controversy'. Rather, the point is that it is (at any rate should be) in the nature of science to be open to critical examination. No student is being disruptive, let alone sacrilegious, by questioning evolution. Nor, in my view, is it the job of a science teacher to attempt to convert (my use of language here is intentional) their students to an acceptance of the theory of evolution. Rather, a teacher's objectives should include getting his or her students to appreciate what the theory of evolution is, what the evidence in favour of it is and how scientists counter some common objections concerning it (e.g., that mutations are always harmful, that the fossil record fails to show intermediate forms and that the second law of thermodynamics disproves it).

So, the theory of evolution is part of the mainstream discourse of science, but it is also part of the discourse of science (or should be!) to encourage debate grounded in empirical evidence and supported by valid reasoning.

Teaching About Sex

Sex in school science is mostly taught through the topic of reproduction (though it may also appear in the topic of disease via sexually transmitted infections). Immediately, sex is presented as binary and through a heteronormative lens. That sex exists as a binary – each of us is either male or female – is so obvious a 'truth' that it cries out for school science education to trouble such a notion. I am not arguing here that high school students should be introduced to Judith Butler's texts (though some would benefit from reading *Undoing Gender*), but there is great opportunity when introducing standard biology to provide a richer understanding (and questioning) of sex and gender than is usually the case.

For a start, not all of us are unambiguously XX or XY (plus 44 autosomal chromosomes in each case). In my experience of teaching biology to 16–18-year-olds, many are fascinated by the range of chromosome conditions that some humans have (XO, XXY, etc.). In addition, learning about mosaicism (where one individual has cells of more than one genotype) can be illuminating and make what is otherwise a rather dull lesson on the stage of mitosis (remember the scene in *Twilight*?) of far more interest.

Then, it is good for students to understand that in early development, there are no discernable differences between males and females. It is only towards the end of the second month of pregnancy that the action of sex hormones results in sexual differentiation. Indeed, a whole range of factors can lead to intersexuality, something many people are now more comfortable with than was the case a few decades ago in the West when so-called 'corrective' surgery was typically unquestioningly employed – sometimes with what seems to have been successful outcomes but sometimes with what were undoubtedly not.

Moving on to the teenage years, the great majority of school textbooks make little or no reference to any sexuality other than heterosexuality. Such omissions are difficult to defend. Of course, I realise that teaching about anything that is sensitive or controversial can be difficult for educators, but it can also be profoundly affirming for some of one's students. And science has a very particular part to play. Even if one adopts a fairly conventional notion of science that sees it as ethically and politically neutral, science can still play an emancipatory role by enabling people to ask factual questions that demand objective answers. Is it the case that all people are either male or female? Is everyone heterosexual (in few societies now do all people answer affirmatively)? Does sexual orientation exist in discrete forms or sit on more of a continuum? And so on.

Identity

I began by pointing out that science is not a single entity. At one level, this is a trivial point. Even at school level, physics and biology are different in terms of how they are perceived by most students and whether or not students find them engaging. Among professional scientists, there is rather little in common between a theoretical physicist, a molecular biologist, an epidemiologist, and someone who tests for water quality before we even start to consider whether physical geographers, psychologists, and anthropologists are scientists or not.

And yet, there is a powerful discourse within science, backed up by a common language and appeal to that mythical notion of 'the scientific method', that conveys an image of science as a monolithic beast, relentlessly advancing and devouring other, older, more local, more subjective forms of knowing.

Such a discourse is attractive to some and yet excludes many. But there is another way. Science, precisely through its commitment to the use of experimentation, its spirit of open-ended enquiry and its attempt to remain above party considerations, has the potential to serve as a tool of emancipation. Given the near inevitable tendency for societies to marginalise and stigmatise those who are in minorities and positions of little political power, science offers hope for those of us who do not fit comfortably into 'the majority'.

And by the time one adds up all the minorities (the term being used to include those in unequal positions of power as well as in numerical minorities) – women, those with a minority religious faith in religious societies or with no faith in religious societies, those with disabilities, people of colour, the young, the old – one finds that the great majority of people belong to at least one minority camp.

It is vitally important therefore that school science indicates its value for those of minority identities. This, of course, is not to essentialise or rigidify identity. Most of us can accept that identities are fluid (without being entirely shapeless). The point, rather, is that science is big enough to provide a comfortable place for a very wide range of students. When students say, as many of them do in the richer countries of the world, that they find science 'boring' or 'irrelevant', what they are saying is that they cannot see the connect between what they are taught as science in schools and the issues they face or who they want to be. School science thus often has an identity problem: it fails to relate adequately to students' evolving identities.

My point is that good science teaching should enable students to realise that far from needing to reject science, science can provide a space for them to grow into who they want to be. Science can problematize cultural assumptions about what is desirable without minimising the strength with which these assumptions can operate.

Consider, for instance, race/ethnicity. Perhaps unsurprisingly, race/ethnicity is rarely considered in school science. And yet they are often core to how we see ourselves. School science could provide an opportunity (though I appreciate such teaching can be difficult) for students to explore what biology has to say about race (we are into locally adapted genotypes and genetic drift here) and whether or not differences between groups are large or small. They are small, despite what some conservatives hold, but not, despite what some liberals hold, trivial: there are important medical correlates with race/ethnicity and denying this or, more typically, failing to address this in school will help no one, particularly as personalised genome studies, and perhaps therapies, become more widespread.

More generally, students, whether conceived of as minority or majority students, should be encouraged and supported to think, read, write, listen and talk critically. 'Critically' here can be understood in two senses. First, meaning that the evidence for an assertion is to be examined rigorously. Science, fundamentally, is not about rote learning but about knowing how to test certain claims about the world. There is little point in learning that the Earth goes round the Sun rather than vice versa unless one can adduce evidence in support of this claim. It is one thing to know that proteins are an essential component of our diet; it is another to know how this was established and to understand why nucleic acids (despite being essential for life) are not.

The second sense of 'critically' is more to do with equity. A critical examination of biodiversity might include looking at which countries have lost in the past and are now losing the highest proportions of their native fauna and flora. A critical study of health in a US state might include examining data on mortality and morbidity by gender, ethnicity, age, occupation, home language and residential area.

Finally, students are most likely to develop an understanding of science, an ability to use the languages of science and an appreciation of the discourses of science when they are given some autonomy in their learning so that at least some of their efforts in their science work can be devoted to issues of personal significance. Curriculum developers and teachers sometimes seem to shy away from this, perhaps fearing that boys will spend all their time writing projects on explosive chemicals and girls all of theirs on issues to do with health.

I would respond to this perception in three ways. First, gender and other student differences in topic preferences are not as absolute as is sometimes presumed. Second, I am only talking about some time being given over to students to choose on what they work. Third, given that the great majority of school students drop science once they can, it might be wiser to do what one can to engage students, rather as teachers of fiction nowadays seem comfortable with a greater range of authors and genres than when I, at any rate, was in school. Furthermore, giving students more choice on what they work often leads to greater cooperation between interested students, to greater involvement of their families in their science learning, and to a better connect between formal and informal sources of learning in science.

Part V
Introduction: Leadership and Social Networking

Valarie L. Akerson (Lead Editor) and Angela Calabrese Barton (Co-editor)

To move the equity agenda forward will take leadership, social networking with those leaders, and mentoring new leaders. The chapters in this final part take up the problems with underrepresentation in science education generally and in NARST specifically. Given that NARST is a research organization, the authors recommend research-based practices for developing leaders in NARST, as well as designing social networking practices that support scholars of underrepresented groups at all levels. These recommendations go beyond simply making NARST more diverse. They look forward to making NARST a place where equity and diversity are hallmarks of the structure, scholarly work, and ways such work is used for interaction among members, as well as to influence policy decisions.

More specifically, Gail Richmond makes recommendations for how to develop leaders, Maria Rivera Maulucci and Felicia Moore Mensah describe ways to mentor new leaders and scholars of color, and Mensah shares ideas for using social justice as a guiding framework for both teaching and research. Richmond shares how developing a network for promoting leadership and equity requires a model of engagement that surpasses deficit notions and encompasses learning communities and leadership, development of professional identity, and use of third spaces. Mensah shares how the guiding framework for our work within science education as well as NARST should be both social justice and social action.

Rivera Maulucci and Mensah state that often scholars of color feel silenced and mentoring can help them find an authentic voice within the academy. Both formal mentoring, in terms of programs to support new scholars, and informal mentoring, in terms of more senior scholars supporting new scholars, can sustain new scholars

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in their development as leaders and successful members of the academy and NARST. Rivera Maulucci and Mensah further share the ongoing work that the Equity and Ethics Committee has undergone in order to transform the face of NARST, providing a historical account of the kinds of formal mentoring that have taken place through NARST in the recent past.

Richmond shares insights on helping scholars of color develop a professional identity by promoting an intellectual community. Her chapter asks us to consider how conversations and interactions within NARST can promote such an intellectual community, which would not only foster leadership and social justice but also make it commonplace at NARST. She notes that for change to be made, we must be dissatisfied with current practice, have a desire to transform situations, and acknowledge that there may be awkward conversations that will ultimately lead to equity.

All three chapters ask us to consider voice and context in developing leaders and designing social networks for supporting new scholars. Rivera Maulucci and Mensah suggest the use of voice and context to "honor identities, values, choices, hopes and dreams" of all scholars. All chapter authors also suggest ways for helping all scholars find authentic voice rather than choosing silence, in the hopes of encouraging development of leaders in NARST and in science education, at large.

Of course, the suggestions for developing leadership and structures for social networking are not all encompassing and raise further questions. One such question is, "Where do we go from here?" Despite the ongoing work of the Equity and Ethics Committee, there are certainly other ways to transform NARST into an organization that operates through social justice. Rivera Maulucci and Mensah describe how those who organize and deliver the Equity and Ethics Committee-sponsored preconference workshops desire to do more to help new scholars who attend, and help NARST become more progressive and diversified. Yet they struggle with pressures of their own university positions and work that must be done in the culture, at large, as well as for other organizations.

Indeed, for NARST to better attend to social justice issues, Mensah states that equity needs to cut across strands, not just be relegated to Strand 11 (cultural, social, and gender). Those who are interested in promoting social justice through NARST are encouraged to present their work in other strands beyond Strand 11, infusing best social justice practices and research throughout NARST strands and, thus, throughout NARST research.

Another question that is raised across chapters is, "What more can we do?" Though it is recognized that there is more diversity within NARST, more can be done in terms of supporting all new scholars in understanding and navigating pathways to success within the academy. Indeed, beyond the important task of supporting new scholars, there is a need to influence policy in terms of science education as social justice which, although a continuing role of the Equity and Ethics Committee, could be of greater emphasis in the future as we work toward broadening and building upon the equity work that has already begun.

Melina Furman's commentary pushes these questions further, by raising the idea that equity and social justice issues must be examined from an international perspective. She adds socioeconomic status to the picture, describing how in the international community those of lower socioeconomic status have difficulty in getting access to spheres of power. Indeed, in recent conversations on the NARST listserv, this problem has been highlighted: The cost is prohibitive for researchers from developing countries to travel to annual conferences to share their research, which leaves a gap in the international research disseminated at NARST. We argue that making science education research equitable for all will surely provide a more global perspective on science education and will facilitate movement toward a more equitable science education for all students as well.

Chapter 18
NARST Equity and Ethics Committee: Mentoring Scholars of Color in the Organization and in the Academy

Maria S. Rivera Maulucci and Felicia Moore Mensah

In this chapter, we analyze the ways in which the "problem" of underrepresentation gets framed, the challenges and possibilities scholars of color navigate, and the possibilities of using organizations like NARST to support the career trajectories of scholars of color in the academy. In particular, we describe our work as members of the NARST Equity and Ethics Committee in developing and facilitating the preconference workshop and explain how this work contributes to building a community of scholars.

Underrepresentation in the Academy

We recognize that labels such as marginalized, underrepresented, minority, diverse, and scholars of color can be problematic for how we frame identity issues in the academy. Furthermore, we challenge the typical framing of the "problem" of underrepresentation as a lack of individual persistence within institutions and highlight some of the structural, social, cultural, and symbolic barriers that often impede the progress of scholars of color in the academy. In our discussion of mentoring and

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Table 18.1 PhDs awarded in science education in 2008

Category	Number	Percentage (%)
All	94	100
Temporary visa holders	18	19
US citizens and permanent residents	75	80
American Indian/Alaska Native	0	0
Asian	3	3
Black	6	6
Hispanic	3	3
White	63	67

support for junior faculty[1] and scholars within the NARST organization, we specifically advocate for explicit programming designed to support faculty of color in the field of science education research and in the academy. We take this view in light of our personal journeys as women of color in the academy, placed within the national context of faculty of color in academia, and the numbers of faculty of color who do not receive tenure and promotion.

For instance, according to the National Center for Education Statistics report, the percentage of faculty with tenure has declined in recent years, dropping to about 49% of full-time instructional faculty earning tenure in 2007–2008, compared with 56% in 1993–1994 (Snyder and Dillow 2010). About 51% of the instructional faculty at public and private for-profit institutions had tenure, compared with 45% of faculty at private not-for-profit institutions. In addition to this, according to Thomas Snyder and Sally Dillow (2010), in fall 2007, the number of college and university faculty identified as Black was 7%, Asian/Pacific Islander was 6%, Hispanic was 4%, and American Indian/Alaska Native was 1%. Across gender and racial lines, there was a difference between the number of male and female faculty with tenure: 55% of males had tenure in 2007–2008, compared with 40% of females. In science education, out of 94 PhDs awarded in 2008, only three (3%) were awarded to Asian students, six (6%) to Black students, and three (3%) to Hispanic students (see Table 18.1). Slightly more PhDs were awarded to males ($n=48$) than to females ($n=46$) (National Science Foundation 2009).

From these brief statistics, one sees that the support for faculty of color and women is critical to their representation in the academy and their advancement along the career trajectory. At the same time, it is important to note that underrepresentation of scholars of color is not a new or recent problem. In 1989, James Blackwell noted that we seemed to have lost the commitment to diversity and that we had abandoned strategies implemented in the 1960s and early 1970s that

[1] We use "junior faculty" to include postdoctoral students and early career faculty in tenure and nontenure track positions. This phrasing is also inclusive of graduate and doctoral students who may hold instructor positions at colleges and universities.

increased representation of minority groups. In order to sustain faculty of color in the academy, most institutions offer mentoring as the vehicle of support for faculty as they progress toward tenure and promotion. In the following section, we review some of the literature on mentoring scholars of color.

Problematizing Formal Mentoring Relationships and Programs

A look at the history of the word "mentor" situates its origins in Greek mythology as the name of the friend that Odysseus placed in the role of teacher and protector of his son, Telemachus. A mentor can be "a wise and trusted counselor or teacher" and "an influential senior sponsor or supporter" (mentor 2010). Drawing on the understanding that words such as mentor carry cultural meanings forward in the form of unexcavated root metaphors, including patriarchy, anthropocentrism, individualism, and progress (Bowers 2001), we ask ourselves, "What does it mean for us as women faculty of color to be mentored and to mentor others?" How do our positionalities as women, as scholars of color concerned with social justice, as teachers, and as researchers frame how we initiate and sustain mentoring relationships? What are the implications of our experiences for formal and informal mentoring programs for scholars of color through NARST, similar organizations, and academic institutions?

The literature on mentoring describes many aspects of the mentor-protégé relationship. For instance, Blackwell (1989, pp. 10–11) outlines ten roles that mentors may fulfill, including (1) providing training; (2) stimulating the acquisition of knowledge; (3) providing information about educational programs; (4) providing emotional support and encouragement and helping the protégé develop coping strategies during periods of turmoil; (5) socializing protégés regarding the role requirements, expectations, and organizational imperatives or demands of the profession; (6) creating an understanding of the educational bureaucracy and the ways one can maneuver within that system; (7) inculcating, by example, a value system and a professional work ethic; (8) providing informal instructions, again by example, about demeanor, etiquette, collegiality, and day-to-day interpersonal relations; (9) helping the protégé build self-confidence, heighten self-esteem, and strengthen motivation to perform at one's greatest potential; and (10) defending and protecting the protégé, correcting mistakes, and demonstrating techniques of avoiding unnecessary problems.

In this case, mentoring takes place in the context of close, personal relationships between mentors and their protégés. Julia Jordan-Zachery (2004) discusses the particular experiences of Black women in academia, noting common threads evident from interviews, such as the need for departments to be "proactive in creating networks that would open up lines of communication between untenured and senior scholars" (p. 876). Other scholars discuss that "whether the mentor is Black or White, male or female is unimportant. What is more important is that the mentor is genuine and seeks to assist the protégé in having a successful academic career"

(Holmes et al. 2007, p. 121). Nevertheless, Blackwell's (1989) list promulgates the typically hierarchical and patriarchal form that mentor-protégé relationships often take, without recognizing reciprocity and how mentors may also be mentored by their protégés.

Beyond the one-to-one forms of mentoring available through mentor-protégé relationships, Sharon Fries-Britt (2000) explains that new faculty of color need multiple levels of support spanning formal and informal systems. Formal systems may include the assignment of senior scholars as mentors and institutional mentoring programs, such as new faculty seminars that help them acclimate to the institution, research and writing groups, and grant-writing seminars. Yet, institutions tend to focus on issues of recruitment of faculty of color, including salary and benefits packages, workspace, and research start-up funds, rather than on retention (Turner and Myers 2000). Reports on institutional mentoring programs for scholars of color are limited and typically document "the pervasive racial and ethnic bias that contributes to unwelcoming and unsupportive work environments for faculty of color" (Turner et al. 1999, p. 28). Their study of retention of faculty of color in the Midwest found that only 6% of participating institutions ($n=487$) had professional development offices for faculty of color and only 9% funded mentoring programs. On the other hand, informal systems have a more emergent character and consist of the "personal and professional connections that faculty have with other colleagues on campus and in the discipline" (p. 43). Fries-Britt (2000) notes:

> National conferences provide an excellent opportunity to network and meet other minority faculty who understand what you are experiencing, and who can provide a source of support and motivation. These relationships often serve as the foundation for building a very strong informal support system. (p. 43)

Although the membership of NARST is becoming more balanced in terms of gender and more diverse in terms of representation of scholars from different ethnic, racial, and national backgrounds, it is important to note that most mentors or senior advisors of new scholars in science education are likely to be White and male. As Latina and Black females and early career faculty, we often found ourselves in the role of mentoring newer scholars when, in effect, we were on a step just above or even lateral to those we were mentoring. Nevertheless, informal support systems can be "instrumental in providing the day-to-day motivation that minority faculty need to survive the challenges of the profession. They offer access to new sources of information and provide a network from which to build opportunities for collaborative research" (Fries-Britt 2000, p. 43). Furthermore, in opposition to historically hierarchical and patriarchal notions of mentors, we ascribe to a notion of mentoring that includes support and encouragement (a nurturing role) as well as receptivity, being open and responsive to the needs, interests, cultures, and hopes of our mentees. Rather than forcing young scholars into institutionally defined or preferred roles, we hope to assist them in fashioning ways of navigating the academy that honor their identities, values, choices, hopes, and dreams.

Why Scholars of Color Need Special Mentoring

In a review of the literature on mentoring, Zellers et al. (2008) trace the evolution of mentoring programs in the United States in business and academe. They suggest that "more rigorous investigation of this practice in higher education is warranted" and that "understanding faculty mentoring programs within the context of their academic cultures is critical" (p. 552). In this section, we develop five arguments for why scholars of color need special mentoring, including the need to (a) excavate silenced discourses, (b) help scholars navigate issues of representation, (c) support activism and nonmainstream scholarship, (d) help scholars accommodate the norms and discourses of the academy, and (e) assist scholars in finding an authentic voice in the academy. Although we address each of the above arguments as separate issues, we recognize the complex and varied ways in which they intertwine in the lives of scholars of color.

To Excavate Silenced Discourses

Scholars of color face the particular challenge of "a silenced discourse" (Reyes and Ríos 2005). Out of fear of "appearing weak, confrontational, self-pitying, or unscholarly or for fear of numerous other labels," scholars of color refrain from "discussing issues that need to be examined" (p. 378). For example, Xaé Reyes and Diana Ríos explain that a common theme in their experiences as Latina scholars included "low expectations," or "underestimation." In describing her graduate school experiences, Reyes wrote, "The discourses of other Latinos are filled with commentary on the numbers who had to leave or could not take the pressure of being different and expected not to do well" (p. 381). Similarly, African American female scholars experience "alienation, feelings of isolation, experiences of prejudice and discrimination, lower salaries, low professional ranks, and lack of tenured status" (Jordan-Zachery 2004, p. 875). Yet, such feelings and experiences are often concealed. Issues of race, language, ethnicity, or gender remain unchallenged and unvoiced, and scholars of color may be afraid to ask for assistance or help that scholars from more mainstream groups may take for granted as their due: "[W]ithout an intentional, proactive approach to probe for existing challenges, feelings of marginalization, emotional costs and frustration may go unnoticed" (Diggs et al. 2009, p. 330). Thus, scholars of color need safe spaces to excavate the concealed stories and silenced discourses that lie beneath the surface of the stock stories of their "success" in academia (Bell 2010).

To Navigate Issues of Representation

A second challenge for many scholars of color has to do with issues of representation, which are closely connected to silenced discourses. However, representation, as we view it, relates more to our individuality as scholars of color and representations of self within our larger ethnic and racial group identities. Here, we ascribe to a view that "most faculty members, represent multiple social and cultural identities" (Stanley 2006, p. 718) related to race, gender, nationality, class, lived history, geography, and linguistic affiliations. For example, on the one hand, we represent ourselves and do not want to be seen as filling "quotas," or "diversity hires." On the other hand, we cannot help but represent other scholars of color within our home institutions and the academy. This challenge emerges in relationships with colleagues as well as students. For example, Reyes and Ríos (2005) note:

> On one hand, we may be the first educators of color they have confronted in their lifetime, and because of that we are under pressure to establish an image that may be extended to all other academics of color, to our ethnic or racial group, and to the greater Latino community. (p. 385)

As scholars of color struggle to establish an academic identity (Diggs et al. 2009), they need to hear and learn from the experiences of senior scholars of color and the strategies senior scholars use to navigate issues of representation at their institutions, including how they handle committee work and interactions with other faculty and students, how they juggle multiple roles in the institution, and how they establish and promote their research and scholarship agendas.

To Support Activism and Nonmainstream Scholarship

In addition to overcoming issues of representation, a third challenge many scholars of color face relates to their concern with issues of equity and activism in the community. A study by Astin et al. (1997) showed that African American, Latino/a, and Native American faculty at predominantly White institutions are more likely to value community service than White faculty. As an example, Ríos, a Latina scholar, explained:

> I believe that part of scholarship entails a commitment to the local and larger community. This means that as scholars, we consider our roles in uplifting the community and not simply uplifting ourselves. We have a commitment outside as well as inside the academy. (Reyes and Ríos 2005, p. 385)

Reyes agreed that "service to the broader community and mentoring are inseparable from [her] professional role as an educator (p. 384)." Even as an accomplished scholar, Reyes admitted that she had discussions about community activism with her peers in other disciplines who "cautioned [her] about the dangers in merging [her] research and advocacy agenda" (p. 384).

Yet, for many scholars of color, an activist agenda is the root of their work as they "use service to redefine themselves as scholars and activists[,] and to connect them to their racial communities in important ways" (Baez 2000, p. 388). For example, Eileen Carlton Parsons and Felicia Moore Mensah (2010) reveal in stories and discussion of life events how oppressions intersect in their lives as Black females in science education and how these stories "manifest differently and elicit characteristically distinctive responses" (p. 23). Nevertheless, their stories align with the primary aim of Black feminist thought because they devote their "lives and careers to actively resist[ing] oppressions" (p. 23). In a similar way, Maria links her scholarship to activism by making the political choice to conduct research into her own teaching practices. Her decision is rooted in the desire to continually improve her expertise as a social justice teacher educator and enhance the likelihood that the in-service and preservice teachers she works with will in turn be able to teach for social justice. Her decision also incurs risk as practitioner research is not valued as highly as other forms of research in the academy: "When senior faculty or peers marginalize research efforts or devalue the research topics that faculty, especially faculty of color, choose, the likelihood of retention is highly improbable" (Thompson 2008, p. 51). Scholars of color need to hear how others have navigated the path of choosing nonmainstream scholarship or activism, the risks and benefits they have incurred, how they strategically communicate the goals and purposes of their research, and how they find publication venues.

To Accommodate the Norms and Discourses of Academia

Like any cultural institution, academia has its own set of norms and discourses that members from underrepresented groups may not know or may find difficult to enact. For example, we both find it difficult to engage in practices that might seem boastful or competitive. The difficulties stem in part from our religious and familial backgrounds. Maria believes that all good work comes through the grace of God. As one of eight children in a family that instilled doing for others without measuring or comparing, she has resisted developing a website and putting her name forward for recognitions or awards, practices that can be important for academics. Felicia believes that her work is "mission" work and situates her works as unto the Lord. By setting standards of excellence that she feels God will be pleased with and will reward, she also finds it hard to put her good works forward for others to acknowledge. Thus, we see how we limit ourselves within academia and are often overlooked among colleagues who more readily take up the norm of self-promotion in their careers. Scholars of color need opportunities to ask questions about the norms and discourses of academia and to learn from the ways in which other scholars of color resolve conflicts between the established norms and discourses and their familial, cultural, ethnic, religious, or linguistic norms and discourses.

To Find an Authentic Voice in the Academy

Finally, scholars of color interact, negotiate, present, and represent themselves and their work within institutions that historically have not been welcoming to their views and perspectives. Many scholars choose silence or assimilation over "rocking the boat." Such decisions are neither neutral nor easy. For example, the rules and standards of scholarship often constrain nonmainstream scholars' abilities to narrate their stories in compelling, urgent, innovative, or authentic ways. As a critical narrative inquirer, Maria has struggled to find an authentic voice within the science education literature, one that accommodates her way of seeing the world through a narrative lens. For example, she wrote:

> I call what I do critical narrative inquiry, a blending of my researcher/teacher/reformer roles that takes me outside the stance of passive observer or unbiased researcher. I make my social justice stance explicit by sharing readings, engaging teachers in discussions, and modeling practices I believe will transform science teaching and learning and enhance students' opportunity to learn. (Rivera Maulucci 2010, p. 632)

To meet the standards for promotion and tenure, we had to make compromises and tell stories in more sanctioned ways. Yet, publications comprise only one way, albeit an important one, to enact one's voice. Through mentorship, conference presentations, leadership in NARST as members of the Equity and Ethics (E&E) Committee and as coordinators of Strand 11, and publication in venues such as *Cultural Studies of Science Education,* we have found authentic voices in the science education literature and our individual niches as researchers. Scholars of color need opportunities to learn how to publish their work, including how to cope with the inevitable rejections, how to make compromises among competing institutional and personal standards for scholarly work, and how to take advantage of offers from senior scholars to read their work. They also need multiple venues to enact their voice within NARST, in other similar organizations, and at their home institutions.

Though the challenges we present above are neither exhaustive of all the experiences of scholars of color nor representative of all of our personal experiences in the academy, the fact remains that being scholars of color brings with it particular issues and concerns. Yet, in combination with our own beliefs about our work and place in the academy, they serve to make the case for special mentoring of scholars of color—professionally and personally. We face added challenges and often set higher expectations for ourselves than those required for promotion and tenure in order to offset low expectations and issues of representation and voice within the academy.

Support and Mentoring Within NARST

In the last decade, NARST as an organization has been influential in supporting scholars of color in science education—graduate and doctoral students and junior faculty—through the work of the Equity and Ethics (E&E) Committee. The E&E Committee is charged with providing leadership and guidance to the NARST organization on issues of equity, including but not limited to gender, ethnicity, socioeconomic status, disabling conditions, sexual orientations, language, and religion. This charge includes both internal and external responsibilities to:

1. Encourage equity-related research in science education
2. Inform NARST members [to become conscious of] implications for their work as curriculum developers and teacher educators

3. Inform policymakers and science teachers
4. Ensure that all researchers are treated fairly within NARST (Gilmer 2005, p. 3)

The work of the E&E Committee is ongoing, transforming how the organization functions on matters of diversity and equity within it. Several new initiatives in recent years have been adopted and have become institutionalized within the overall framework of the organization. These initiatives have been critically important in building the science education community's capacity to foster research, teaching, and leadership opportunities for scholars of color, to strengthen relationships among and within the organization, and, most importantly, to support scholars of color at various levels in their career trajectories. In the following section, we highlight one initiative that has been the impetus for additional initiatives—the preconference workshop (PCW). We provide a brief history of the PCW and discuss how this initiative serves as one avenue for special support to scholars of color in science education.

The E&E Preconference Workshop

The overall goal of the E&E PCW is "to promote junior scholars (e.g., graduate students, new doctoral degree recipients, and new assistant professors) from underrepresented groups to develop as scholars" (Lee and Calabrese Barton 2006). Over the past few years that we have been members of the E&E Committee, we have planned and facilitated the preconference workshops. In this chapter, we focus on the 2007–2010 workshops for which we served as leaders.[2]

Maria attended her first NARST conference in New Orleans in 2002, attended her first PCW in San Francisco in 2006, and began serving on the E&E Committee in 2006, with the specific charge to help plan and implement the PCW. In 2007, she co-planned the workshop with Dr. Eileen Carlton Parsons (see Table 18.2). In 2008, she led the planning of the workshop alone, and in 2009, she co-planned the workshop with Felicia. Felicia attended her first E&E PCW as well as her first NARST conference in Vancouver in 2005. Since that time, she has attended the preconference workshops and open morning meetings of the E&E Committee and was recruited to the E&E Committee in 2007. In addition to her active roles during the 2008 and 2009 PCWs, she co-planned the 2010 PCW with members of the E&E Committee.

From 2007 to 2010, the preconference themes were aligned with the larger NARST conference themes (Table 18.2) and designed to make explicit our goals as conference facilitators. The first theme was "commencement"—opening or beginning conversations that will continue throughout the conference and beyond. A key goal was to help scholars dialogue about issues of equity and representation and to

[2] It is important to note that during each of these years, the planning for the PCWs was supported by the E&E Committee Chairs, Dr. Angela Calabrese Barton, Dr. Valarie Akerson, and Dr. Julie Bianchini.

Table 18.2 NARST equity and ethics preconference workshop themes

Year, attendance	Theme	Facilitators/panelists
2005, 28	Navigating the academy, Vancouver, BC	Okhee Lee-Salwen, University of Miami Alberto Rodriguez, San Diego State University Obed Norman, San Jose State University Julio E. Lopez-Ferrao, National Science Foundation
2006, 35	Scholars from underrepresented groups and the academy: necessities for success, San Francisco, CA	Eileen Carlton Parsons, University of North Carolina, Chapel Hill Moreen Carvan, Marian University Scott Jackson Dantley, Bowie State University
2007, 54	Scholars from underrepresented groups and the academy, New Orleans, LA	Maria Rivera Maulucci, Barnard College, Columbia University Felicia Moore Mensah, Teachers College, Columbia University Pauline Chinn, University of Hawaii, Manoa Mary M. Atwater, University of Georgia Bhaskar Upadhyay, University of Minnesota, Minneapolis Eileen Carlton Parsons, University of North Carolina, Chapel Hill
2008, 32	Building a community of scholars in NARST: gaining strength through diversity, Baltimore, MD	Maria Rivera Maulucci, Barnard College, Columbia University Felicia Moore Mensah, Teachers College, Columbia University Alejandro Gallard, Florida State University Line Augustin, CUNY Graduate Center Shawn Holmes, North Carolina State University Bryan Brown, Stanford University Sanghee Choi, University of Houston Bhaskar Upadhay, University of Minnesota, Minneapolis Hsiao-Lin Tuan, National Changhua University of Education Jing-Wen Lin, National Taiwan Normal University

(continued)

Table 18.2 (continued)

Year, attendance	Theme	Facilitators/panelists
2009, 40	Grand challenges and great opportunities in science education for scholars of color, Garden Grove, CA	*Reflections on the work of Jhumki Basu, NARST E&E scholar* Angela Calabrese Barton, Michigan State University Maria Rivera Maulucci, Barnard College, Columbia University Bhaskar Upadhyay, University of Minnesota, Minneapolis Edna Tan, Michigan State University Tara O'Neill, University of Hawaii, Manoa *Grand challenges and great opportunities in science education for scholars of color* Eileen Carlton Parsons, University of North Carolina, Chapel Hill Jerome Shaw, University of California, Santa Cruz Malcolm Butler, University of South Florida, St Petersburg Karen E. S. Philips, Hunter College, CUNY Wesley Pitts, Lehman College, CUNY
2010, 52	Research into practice: practice informing research for equity scholarship and teaching, Philadelphia, PA	Janell N. Catlin, Teachers College, Columbia University Felicia Moore Mensah, Teachers College, Columbia University Jomo Mutegi, Sankoré Institute Blakely Tsurusaki, Washington State University Regina Wragg, University of South Carolina Gillian Bayne, Lehman College, CUNY Rowhea Elmesky, Washington University, St. Louis Wilbert Butler, Tallahassee Community College Nate Carnes, University of South Carolina Lisa Hansen, Georgia State University Mary M. Atwater, University of Georgia Sumi Hagiwara, Montclair State University Melody Russell, Auburn University Sarah Barrett, York University

continue those conversations in sessions, committee meetings, formal and informal conference events (such as the Equity Dinner), and through electronic communication after the conference. The second theme was "difficult dialogues," which encompassed two key questions: What does it mean to navigate the academy as scholars from underrepresented groups? How can we learn from the experiences of senior scholars? Each year, we invited senior scholars, including Dr. Mary Atwater (2007), Dr. Alejandro J. Gallard (2008), and Dr. Eileen Carlton Parsons (2009), to talk frankly about their experiences, the choices they made, and their advice for new scholars. The third theme, "building relationships," focused on initiating and strengthening relationships among scholars at different points on their career trajectories and learning from each other's challenges and triumphs. Small-group sessions organized by career stages and other interactive formats, such as researcher panels, were designed to facilitate relationships between scholars at similar and different points on their career trajectories. Last, the fourth theme was "opportunities available to scholars of color and scholars who do research involving issues of equity." Our focus was on ways to develop community-based relationships and establish research agendas that promote equity in science education in local and more distributed contexts. Keynote addresses by Dr. Pauline Chinn in 2007, Dr. Felicia Moore Mensah in 2008, and Dr. Janell Catlin in 2010 as well as a panel discussion focused on the legacy of Dr. Sreyashi Jhumki Basu in 2009 addressed this theme. The goal of all the PCWs was to be inclusive of scholars of color from a broad range of experiences, institutions, and perspectives on research in science education.

The general format of the PCW has not changed over the past 4 years. The three hours of the workshop typically include an opening or a welcome from the current chair of the E&E Committee, small-group breakout sessions, a keynote address, and a question and answer session. We offer a supportive space to highlight and introduce the work of untenured and senior scholars of color to each other. Usually, one or two keynote speakers share their insights about conducting equity research. However, most of the three hours are spent in small breakout groups, usually organized by career stages and facilitated by senior scholars, past attendees, equity scholars, or members of the E&E Committee. This format allows for personal and professional interactions and access to scholars of color in science education that support all of us at various stages within our career trajectory. Finally, we also recognize current Jhumki Basu Equity Scholars (renamed in honor of a former E&E Committee member and her equity work) and highlight other E&E Committee-sponsored initiatives held during the NARST conference, such as the New Scholars Symposium (the previous year's E&E scholars present their work at the current conference), the E&E Committee-sponsored symposium, and the annual Equity Dinner, first initiated by Dr. Leslie Jones and Dr. Molly Weinburgh. We make great efforts to invite senior and untenured faculty to participate in multiple aspects of the preconference work, serving as keynote speakers, facilitating small-group sessions, and serving on panel discussions.

We use feedback from the PCW each year to improve the next preconference session and to ensure that we continue to address the needs of the attendees.

Consistently, across the 4 years, participants cited the small-group sessions and keynote speakers as strengths of the PCW. We noted patterns in responses related to some of the initial challenges we mentioned earlier in the chapter—silenced dialogues, activism, and representation. For example, attendees mentioned that being in the company of other equity scholars allowed for "multiple voices" and provided the "opportunity to express [their] opinions." Several participants noted that the "safe environment" afforded them "opportunities to share experiences with others, to speak and be heard, listened [to], and be understood for full expression of ideas." Also, attendees shared that the "breakout sessions based on career stage [were] great for networking and critically thinking about issues." The attendees appreciated the breakout sessions for the "time to talk in groups, to share information with those in similar situations and similar stages" and for the "great practical suggestions" and "very realistic issues addressed."

Finally, attendees shared that the PCW served as a "friendly" and "informative" space for "networking with individuals of similar research interests." The preconference workshops are open to all NARST members, yet the majority of the attendees are scholars of color (Table 18.3). In this particular setting, scholars of color respond that they "hear as a whole group, words of wisdom from senior scholars" and that they value the opportunity to learn from the "strengths and struggles of scholars of color" (see Table 18.4). Participants indicated that the PCW was "great to find like-minded persons" and that they valued "networking with individuals of color." Overall, the PCW allows scholars of color to interact within a safe space to share, to pose questions, and to build initial relationships with other scholars of color. The workshop facilitates the formation of a community of scholars where participants emerge with a greater understanding of their academic trajectory and meet others who may serve as future mentors in support of their career goals, as was the case for both of us.

Responding to More Challenges

With the positive messages we have received from facilitating the PCW over the 4 years, we also are confronted with a few challenges. For instance, looking over the evaluation forms, talking with past attendees of the preconference workshop, and talking among ourselves, an emergent theme that came from the 2010 PCW was a focus on NARST as an organization and understanding how it functions. As the facilitators of the preconference workshops for 2009 and 2010, we explicitly addressed how attendees can navigate the NARST conference and discussed the overall structure of the conference, including formats of sessions, role of strands, and opportunities for networking. Although we did this for the past 2 years and explicitly discussed how to become actively involved in NARST, the attendees of the 2010 PCW wanted to know more about NARST as an organization, in particular Strand 11 (Gender, Social, and Cultural issues) and its supported research, latest publications, and emergent research areas. In addition, attendees asked for more

Table 18.3 2009–2010 participant demographics

PCW 2009		
Race/Ethnicity/Gender	Number	
African Americans	3	
Black American	1	
Afro-Caribbean	1	
Hispanic	3	
Latina	1	
Middle Eastern White	1	
Mexican	1	
Filipino, Latina, Chinese	1	
Other	1	
No race/Ethnicity Response	2	
Female	12	
Male	3	
No gender response	1	
PCW 2010		
	Gender	
Race/Ethnicity	Female	Male
African Americans	9	1
Asian	2	2
Latina/o	3	1
White	1	
International/Other	4	1
PCW 2009, 2010		
Career Levels	2009	2010
Pre-proposal	5	10
Post-proposal	4	6
Early career (1–2 years)	5	5
Pre-tenure (3–5 years)	2	1

PCW 2009 completed evaluation forms ($n=16$)
PCW 2010 attendance ($n=24$)

discussion on broader issues of equity and culture in science education, including methods of conducting equity research and concrete examples of how to be successful as untenured faculty members. Finally, attendees requested opportunities and avenues for additional support both during the conference, such as another session toward the end, and post-conference. To fulfill some of these requests, after the 2010 PCW, an email was sent out to all participants (critical friends networking list), including some attendees' names and email addresses from the 2009 PCW. Yet, in starting this postconference communication, we find ourselves in a position of desiring to do more but not quite certain how to go about fulfilling the needs of our colleagues and finding the time and resources to do so, given that we also have responsibilities at our home institutions and in other professional organizations.

Table 18.4 2009–2010 PCW evaluation excerpts

What are some strengths of the workshop?
Sharing experiences, learning from others' experiences
Space to share, pose questions, raise issues
Advice
Diversity of the attendees
Opportunities for questioning and feedback
Breakout sessions (4)
Different activities, diverse
Being inclusive
Chance to connect with folks who are passionate about their work
Understanding the trajectory, opportunities, and responsibilities
The workshop facilitates the formation of a community of practice
Building relationships
Being able to talk individually with panel members
What are some suggestions for improvement?
Discussion of alternative trajectories after finishing the doctoral degree
Be more inclusive of first-time participants
What topics would you like to learn more about?
Contract negotiations
Grant writing, creating a wiki
Small grant to perpetuate mentorships established
How to achieve equity at the institutional level
How do you navigate the academy without losing your identity
Managing transitions
Include supplementary materials…how to get a job, interview questions
Develop solid foundation and diverse conceptual frameworks that address equity in science education
Give good ideas regarding doctoral students and early career
The use of scripted curriculum and how this has an effect on minorities and students of color
Issues pertaining to students and professors of color
Alternative canons within science
Culturally relevant professional development for science teachers
Research advice
Women in science education and growth of interest in sociocultural issues in educational research

Service and Advocacy as Science Education Mentors

As scholars of color, our commitment to the work that we do stems from our former teaching backgrounds and professional development experiences as public school teachers. Much of what we do in service to science education and our advocacy in the NARST community connects to our work as teacher educators and science education researchers. For instance, Felicia wrote:

> It is difficult to separate my service and advocacy from my research and teaching, as all of these areas are intimately tied together. Therefore, I do not take these aspects of my work lightly—service is not what I do, but how I live. My service and advocacy reflect once more

> my positionality and social justice framework through the organizations and activities I involve myself in and how I mentor all students. (Tenure personal statement, 2009)

As an example, Felicia was invited to participate as a faculty mentor for the first NARST Summer Research Institute 2009. Hosted by the University of Missouri, this was a week-long program for 24 national and international doctoral students and 10 faculty mentors and had a theme of "Science Teacher Learning Research." The goal of the research institute was "forming a network of emerging science education researchers" and "improving science education research through dialogue with a community of researchers." Felicia was invited to attend the NARST Summer Research Institute because of her expertise in the area of teacher education and issues of diversity. She advised, mentored, and supported doctoral students not only in her assigned capacity but also in other groups who were interested in issues of diversity within teacher education. Therefore, her service speaks to a strong sense of agency and advocacy for all students—both at Teachers College and within the NARST organization.

NARST as a Community of Diverse Scholars

From reflecting on the work that we do as faculty of color and, in particular, the work that we do within the NARST community, we have become more aware of our role as leaders. In the past few conferences, we have seen the ways in which junior scholars look to us as role models because they have read our work or they see our leadership within the organization. We entered into this space more from an invitation than from an eager approach to take up leadership responsibilities. Our reluctance did not stem from a lack of desire to engage in the meaningful work of activism and leadership within the organization but because we were positioned into leadership roles before we could develop the expertise, experience, knowledge, skills, and cultural capital we needed to be able to navigate the academy and then mentor others.

Putting this chapter together also made us realize that our colleagues of color want and need more in terms of the NARST organization. We know that we cannot put all of the responsibility on NARST as an organization, yet seemingly many of our colleagues need more because they did not receive adequate mentoring as doctoral students. Now as junior faculty, many indicate a sense of isolation and a lack of mentoring from their individual institutions for success in the academy. Therefore, NARST offers one critical form of professional development and a welcoming community that many of our untenured colleagues do not experience in their home institutions. This lack necessarily places an additional responsibility on the organization, and on us, to provide leadership, guidance, and a sense of community to scholars of color in order to ensure their success and leadership in the academy and in science education. Part of this work involves the need for scholars of color—both junior and senior—to share their knowledge and expertise in areas of teaching and scholarship in ways that not only teach and inform other scholars of color but also provide direct, informative support about thriving in academia.

Implications

Though this chapter is not written in the traditional sense of an empirical investigation, with the use of theoretical and methodological lenses to frame the analysis, it does offer much to inform research, practice, and policy in mentoring scholars of color, with particular attention to our efforts in science education.

First, the ability to mentor and support scholars of color is vital to keeping the science education community progressive and diversified. We believe there are intellectual, social, and ethical benefits of having a diverse body of researchers and educators within the organization as ways to:

- Build the community's capacity to foster a research and teaching agenda that addresses cultural, racial/ethnic, and linguistic diversity.
- Extend networks of social capital to enhance trust, sharing, and strength of relationships among the membership in building a community that is respectful and visionary within and beyond the NARST organization.
- Overcome the effects of latent discrimination within the community that threatens to limit the range of experiences and perspectives to be fostered by the community. (Calabrese Barton and Lee 2006, p. 876)

As we have traversed our own experiences as faculty of color, we have in many ways mentored and supported the next generation of scholar leaders and activists in the field of science education.

Ensuring the presence of faculty of color at institutions of higher education also has implications for graduate students: "[I]nstitutions that are successful in recruiting and retaining Black faculty do a far better job of recruiting, enrolling, and graduating Black students than those with few or no Black faculty members" (Allen et al. 2002, p. 191). The work of Allen and his colleagues suggests that the presence of African American professors, and we add faculty of color, serves as a source of validation for Black students, and all students of color, and influences their successful transition into and completion of college. Thus, we apply these ideas to science education and the NARST organization. Productive and successful scholars of color within science education and serving as leaders within the organization provide an affirming presence for junior scholars regarding their potential for success as scholars and leaders in NARST and in the field.

Second, mentoring for faculty of color through organizations such as NARST, using the PCW, provides academic acculturation into the profession. Dannielle Davis (2008) explains, "Academic acculturation refers to the idea that, in addition to being capable or talented, new faculty or graduate students must be socialized into the profession" (p. 279). This is not to say that acculturation should be a one-way process with only the individual changing to fit the institution. Rather, as we have worked with planning and facilitating the PCWs, while much of the emphasis has been on a process of enculturation for doctoral students and junior faculty as well as ourselves, we have also attended to the diverse ways in which our voices must individually and collectively point to how and why institutions must also change.

As stated earlier, we found ourselves in positions to mentor and support others who were at the same stage or just a bit ahead or behind us in our early careers as faculty. We learned a great deal, and much of what we learned happened intuitively by paying attention to the implicit and explicit rules, norms, and behaviors of others; supporting each other; and participating actively in professional organizations. If it had not been for our early involvement in professional organizations, with NARST being one of them, we would not be in the position to assist others in having an "easier" transition from being doctoral students to growing as junior faculty and to achieving tenure and promotion in their institutions. Consequently, there should be more encouragement of doctoral students of color and junior faculty members to become actively involved in professional organizations, such as NARST, and even the broader research communities of AERA and AACTE. Service within these organizations will not only benefit the scholars of color, but these organizations will also benefit from an influx of innovation, energy, and diverse perspectives.

Third, policy is a loaded word in education and to the general public. This is true of organizational structure. The NARST organization in recent years, from our perspective, is moving in positive directions to be more open and inclusive of equity issues and supportive of scholars of color, specifically pertaining to initiatives sponsored by the E&E Committee, such as the Jhumki Basu Scholars Program. The Jhumki Basu Scholars Program awards promising young researchers a financial stipend to attend the annual NARST conference and to participate in the PCW. The year following their award, these scholars are invited to participate in a symposium to present their work. Organizational policies such as these promote scholarship and leadership among scholars of color and make them visible within the organization. With the expansion of the program from its first five scholars (both Felicia and Maria are NARST Equity scholars, 2005 and 2007, respectively), the program now supports 15 scholars each year. In addition, the NARST organization supports a similar scholars program for its international members. Both of these initiatives expand the opportunities to support the work of scholars of color, nationally and internationally.

Final Thoughts

Maria: "Next year, I am thinking of inviting scholars who do research in equity issues to come and speak to participants about what it means to conduct research in equity." I proceeded to name a few prominent White scholars.

Senior Scholar of Color: "Now Maria, I am going to tell you something and you can do what you want with it. Scholars of color get so few opportunities to be highlighted. You need to make sure that you are giving them the opportunity."

The work of the E&E Committee has largely been concealed, but we can attest to its importance both for our own career trajectories and for the impact it has had on other scholars of color and their perceptions of NARST as an organization.

In many ways, the story of the PCW in its early years encapsulates a resistance story, defined as the "proactive engagement with issues of racism…to generate change" (Bell 2010, p. 62). We used the PCW to highlight scholars of color and engage in open dialogue about issues pertaining to race, gender, ethnicity, and language. More recently, the story of the preconference workshop has become an "emerging/transforming story," a story "we construct to challenge stock stories, build on and amplify concealed and resistance stories and take up the mantle of antiracism and social justice work" (Bell 2010, p. 75). As we walk the rooms and hallways of the NARST conference, we see the ways in which the face of NARST is changing.

Gains in recruitment of scholars of color to the academy are clear; however, issues of retention remain (Thompson 2008), as do issues of representation on the executive board of the organization. Thus, we need to do more to truly transform NARST, the academy, and our society. Similar to the general literature on mentor and protégé relationships in higher education (Zellers et al. 2008), we argue for the special mentoring of scholars of color with colleagues that can provide the professional, personal, and emotional support that is needed to help them thrive in the academy. In particular, we recognize the ways in which "connecting with colleagues at conferences surpasses networking to further one's career. It is a matter of emotional, psychic survival to maintain relationships with colleagues of like mind with whom one need not 'translate' experiences across racial and/or gender lines, for support and affirmation" (Salazar 2009, p. 194). Thus, we also encourage the efforts of leaders within academia, particularly those in leadership roles within institutions of higher education and professional organizations, to promote participation, scholarly productivity, and leadership among junior scholars of color.

1. What do the theoretical and methodological lenses used in this scholarship enable? What do they constrain?
   Our theoretical and methodological lenses help to excavate concealed stories about the experiences of scholars of color both within NARST and within academia. The concealed stories we tell push against "stock stories," such as meritocracy and the American Dream, that tend to portray the success of scholars from underrepresented groups as open to anyone who works hard enough, simultaneously situating the dearth of scholars of color in the academy as problems of individual or group persistence. Whereas stock stories "explain racial dynamics in ways that support the status quo" (Bell 2010, p. 29), excavating concealed stories helps to expose the "dynamics of how privilege is reproduced" (p. 45). It is our hope that excavating concealed stories builds a sense of urgency and commitment to continue the work of affirming and supporting scholars of color in NARST and in the academy as part of building a more inclusive and just society. As we work through our resistance and transforming stories, we recognize the ways in which excavating concealed stories may produce yet another silenced dialogue, in that White scholars may be afraid to participate in conversations about race and diversity in the academy. Recognizing that participation of all groups is crucial to transforming our worlds, we hope that our approach does not

constrain critical and inclusive engagement with issues of race and diversity in NARST and in the academy.

2. In what ways can the ideas discussed in this chapter be used to inform research, practice, and policy? More specifically, what is the "so what" for graduate students and new scholars looking for ways to conduct research on equity and diversity? What are the implications of this research for classroom teachers and for policymakers?

   We have highlighted some of the practical and policy implications of our work in terms of benefits and challenges of diversifying organizations such as NARST, the need for special mentoring of scholars of color, and the role national organizations like NARST can play in welcoming junior scholars and building a supportive community of scholars. At the same time, we recognize the need for more empirical approaches to studying the career trajectories of scholars of color in science education and the types of formal and informal institutional and organizational mentoring and support that ensure or impede their success. The links to implications for classroom teachers are less obvious but important to consider. One linkage mentioned above is that supporting scholars of color in the academy helps build capacity within the field of science education to conduct research that addresses cultural, racial/ethnic, and linguistic diversity. Classroom teachers have a crucial role to play in producing and using such research to inform their practice. Another linkage is that the same social forces that silence scholars from underrepresented groups and impede their progress in the academy may operate in classrooms. Teachers should consider the ways in which students might need special informal and formal mentoring to excavate silenced discourses, navigate issues of representation, engage in activism, accommodate the norms and discourses of school, and find authentic voices.

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Chapter 19
Retrospective Accounts in the Formation of an Agenda for Diversity, Equity, and Social Justice for Science Education

Felicia Moore Mensah

First day of class

It's the first day of class. This is always an exciting and nervous day for me. First, I'm excited because it is a new semester—new students with new ideas and perspectives. I wonder who they are as persons and what insights they will bring to the class. Second, I'm nervous for the same reason. I imagine how they will receive my ideas and me. The first day of class sets the tone for the rest of the semester.

I come early to class to set up the projector, arrange the tables and chairs, and set the handouts neatly in stacks on the front table. After setting up the classroom, I take a front seat and wait for the classroom to fill up. Many of the new students are nervous and not sure what the semester will bring. I know from past comments that they are "intimidated by science" and "do not like science." They enter the science methods course thinking that it will consist of "science lectures by the professor" where they expect to "learn the facts of science."

As one student enters, I say, "Hi, how are you?" and she sits. Another comes in and I smile. They think I'm a student. This continues until almost everyone is present. They look around, wondering who the science professor is. Waiting a couple more minutes, I look around to see if everyone is present. I count the number and only three students are a little late. It's time to begin the class. I stand up and say, "Hello, class, I think it's time to get started. Welcome to MSTC 4040!" I think, "Yes, an African American woman can be a science professor." I feel their immediate embarrassment. As I continue, students notice my southern dialect. "Oh, by the way, we southerners can do science, too. This is your first lesson in diversity and social justice, and I'm your example."

Later in the semester, I discuss with my preservice teachers this opening lesson on diversity and social justice and my positionality as their professor. They reveal their immediate reactions on the first day of class and having an African American, female science professor, and how important it is to think about science teaching within a social justice framework. Many comment, "You are my first African American science teacher," and for others, "You're my first African American teacher!" (Journal entry, 2005)

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As the opening vignette the *first day of class* shows, as an African American woman in science education, I have a strong responsibility, an obligation, to help preservice teachers to overcome limited notions of who can do science. I have been teaching the elementary science methods course at Teachers College, Columbia University for almost 8 years, and for the majority of my students, I am their first female, African American professor and their first example of an African American female scientist. Therefore, my positionality at a predominantly White university as a science educator serves as a powerful example for preservice teachers to see science critically through my personal narrative. As I tell them of my experiences, they value more deeply my role and their role as science teachers for diverse[1] students. Thus, I take seriously the charge that Linda Bullock (1997) affirms, "Rather than being prepared for the diverse audiences they will soon meet, teachers are prepared for a monoculture, a mythical, culturally homogeneous aggregation of students" (p. 1025). They are not prepared to deal with issues of culture, identity, and race (Sleeter 2001). As a result, I adhere to Sonia Nieto's (2000) recommendation that social justice be a "ubiquitous" part of teacher education. With these ideas in mind, I prepare preservice teachers (elementary, middle, and secondary) in my courses to teach in diverse urban classrooms with the hope that social justice education will guide their practices. Even if they choose not to teach in urban settings, the lessons learned from discourses, experiences, and interactions in the science methods courses provide a valuable framework for their learning and professional development so that they may meet the educational needs of all students, but especially those students traditionally marginalized from achieving in science. Furthermore, my positionality within professional organizations, such as NARST, is another way that I affirm who I am and act in ways that are consistent with my agenda of teaching for diversity, equity, and social justice (see Chap. 18 by Rivera Maulucci and Mensah, this volume).

I conduct research into my practice as a reflective process whereby I illuminate the challenges and growth in making social justice a part of my work. I am able to act with purpose to ensure that all children have access and opportunity to a quality education that can have an immeasurable influence on their lives and their families. I have chosen the route of teacher education to accomplish this goal. Hence, in this chapter, I articulate a vision for the preparation of teachers in science and for the NARST organization, within a social justice framework (Bell 2007). I do this in three major ways. First, I present a vision for teacher education supported by a multiple theoretical framework that addresses fundamental issues in preparing teachers for diverse urban classrooms. I make very explicit the theories I use in my methods course and provide reflective comments from former elementary preservice teachers as evidence of their learning (and mine) about diversity and equity in science education. I do this to inform science educators of the opportunity to see social justice at work within science teacher education. In this manner, I also challenge science

[1] Diverse is used in this chapter to represent students of Black/African American/African descent, Latino/a descent, and Asian descent, students of low socioeconomic backgrounds, students with learning challenges, students learning English, and girls. My consideration is for students most representative of the high-poverty urban schools in New York City that I serve.

educators to consider how explicit attention to issues of diversity and equity in science teacher education can enhance their work. Second, I write this chapter to encourage others (including doctoral students, early career, and seasoned researchers) to consider how they may incorporate multiple theoretical perspectives and strategies in their teaching and research. Finally, I urge those who are engaged in social justice work to speak more boldly and to expose our strategies more openly so that social justice understandings may move to a more central and prominent place within the science education community.

A Social Justice Framing

There are two guiding definitions in framing social justice in this chapter. First, Jamie Lewis (2001) defines social justice as "exploring the social construction of unequal hierarchies, which result in a social group's differential access to power and privilege" (p. 189). Second, Lee Ann Bell (2007) defines social justice education as "both a process and a goal," whereby "social actors who have a sense of their own agency as well as a sense of social responsibility toward and with others, their society, and the broader world in which we live" can work toward an equitable and just society (pp. 1–2). Bell further articulates social justice understandings at the level of theories of oppression, such that the pervasive nature of social inequality is woven throughout various social institutions and is embedded within individual consciousness. This creates a "complex web of relationships and structures that shade most aspects of life in our society" (p. 3). What is desirable in having an understanding of social justice is to recognize differential effects on groups caused by systems of oppression. Bell explains that the goal of social justice education is "full and equal participation of all groups in a society that is mutually shaped to meet their needs" (p. 1).

When researchers discuss social justice understandings in science education, they often speak from the perspective of empowering and effecting change for students inside and outside classrooms (Furman and Calabrese Barton 2006), developing professional development initiatives aimed at improving science and literacy achievement of English language learners (Lee et al. 2008), and establishing methods of counterresistance in the preparation of secondary preservice teachers (Rodriguez 1998). In science education, social justice also involves understanding the culture of power (Delpit 1995) in science (Calabrese Barton and Yang 2000) and deconstructing unjust and oppressive structures within science classrooms for students who are marginalized from learning science.

As I consider this research and other studies aimed at social justice, I take a step backward and consider social justice education to begin at the level of teacher education. I consider how to incorporate cultural, social, economic, institutional, and political dimensions within the context of education. These factors are highly relevant for teacher education and the science education community, as the majority of our work is in the preparation and professional development of teachers. Therefore, my teaching and research are guided by diversity and social justice understandings.

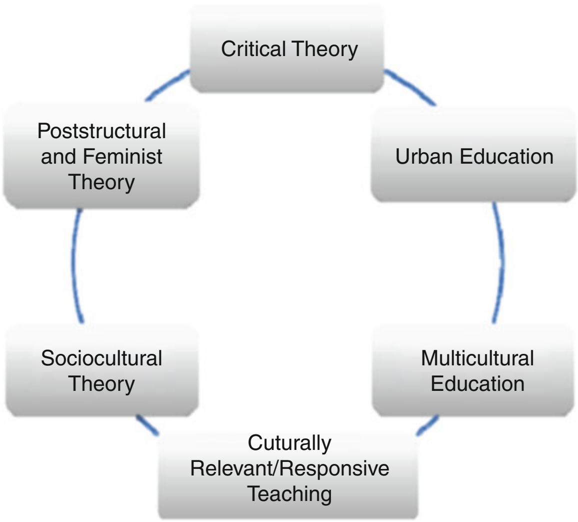

Fig. 19.1 Multiple theoretical perspectives used in science teacher education

Essentially, social justice in science teacher education is concerned with teaching and learning science as a civil right, a moral obligation, a social responsibility, and an ethical choice (Moore 2006). The science teacher embraces the belief that every child has a right to learn science, deserves free access to science, is empowered by knowing science, and is provided opportunities to advance himself or herself educationally within science. By adopting this perspective of social justice for science teacher education, I challenge preservice teachers to take on a social justice identity. This identity must become a guiding framework for teaching science so that all students, and especially students traditionally marginalized from science and students being educated in urban settings, have access and opportunity to learn science. I support preservice teachers in developing a social justice identity as learners within my methods courses. I utilize multiple theoretical perspectives that broaden preservice teachers' understandings of diversity, equity, and social justice in science education.

A Multiple Theoretical Approach

The approach I take for preparing teachers for social justice is grounded in six theoretical perspectives: (a) critical theory, (b) urban education, (c) multicultural education, (d) culturally relevant/culturally responsive teaching, (e) sociocultural theory, and (f) poststructural and feminist theory (Moore and George 2007) (Fig. 19.1). Because each of these perspectives is grounded in its own assumptions and ways of knowing, I am confronted with the challenge of applying these perspectives in ways that honor their contributions, yet acknowledge their shortcomings (Rivera and Poplin 1995). Briefly, I provide a description of each.

First, *critical theory* underscores the relationship among society, politics, social change, and power. Fundamentally committed to the development and evolvement of a culture of schooling that supports the empowerment of culturally marginalized and economically disenfranchised students (Darder et al. 2003), social justice and critical theory are closely connected; both are associated with questioning taken-for-granted notions to reveal social, political, and ideological processes that inhibit teaching, learning, and the preparation of science teachers. Within my methods courses, we discuss how schooling produces oppressive barriers for students of color, females, and students in poverty.

Although *urban* and *multicultural* have come to mean different things to different people, others use the terms interchangeably. Both give particular attention to the contextual issues of teaching in schools and diverse communities that have been challenged by larger socioeconomic and sociopolitical factors, such as underresourced schools and communities. Some additional challenges often acknowledged within urban settings are the diminished use of human and material capital and the increasing numbers of multi-racial/ethnic students. The teaching practices and classroom environments for urban and multicultural classrooms must be addressed in ways that promote learning within a culture of difference. Teachers then must give attention to issues of power, difference, and achievement gaps within urban and multicultural classroom settings.

Part of the charge in making science education more equitable for students of diverse backgrounds is getting preservice teachers to understand power dynamics within diverse classrooms and to incorporate more participatory approaches to learning. Pedagogical practices guided by *culturally relevant* and *culturally responsive teaching* are emphasized. The former empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes in classrooms (Ladson-Billings 1994). These cultural referents are not merely vehicles for bridging or explaining the dominant culture; they are aspects of the curriculum itself (Ladson-Billings). Similarly, Geneva Gay (2000) explains that for underachieving students from various ethnic groups, culturally responsive teaching endorses a "pedagogical paradigm…that teaches *to and through*" [emphasis in original] students' personal and cultural strengths, intellectual capabilities, and prior accomplishments (p. 24). Culturally relevant and culturally responsive teaching approaches have their roots in student achievement.

The personal relationships that are needed in order to foster productive and powerful learning experiences for diverse students in the science classroom must occur within communities of practice (Wenger 1998). *Sociocultural theory* acknowledges differing perspectives and voices toward personal meaning-making and shared understanding within the sociocultural context of learning environments. This theory of social learning enables multiple perspectives to be shared and critiqued among learners, as communities and participants within them "act as resources to each other, exchanging information, making sense of situations, sharing new tricks and new ideas, as well as keeping each other company and spicing up each other's working days" (p. 47). The diversity of experiences and the sharing of students' varied experiences in the science classroom allows for both active engagement and the social construction of knowledge. If we want students in our classrooms to engage in this way of learning, then our preservice teachers must also engage in learning similarly (Mensah 2009a, b).

Finally, *poststructural and feminist theories* involve challenging dominant discourses such that women and others who have been marginalized and oppressed by dominant paradigms such as gender and race/ethnicity have an opportunity to engage in science. They have opportunities to engage in classrooms where their voice is acknowledged. From an educational perspective, Elizabeth Tisdell (1998) states that feminist poststructuralism is "partially accomplished by including the work of women and people of color in the curriculum" (p. 150). When this occurs, the classroom community is inclusive and receptive to the voices of women and those marginalized by race, class, sexual orientation, and age. Their experiences and contributions are foregrounded and allowed space in the classroom. Preparing preservice teachers to recognize the varying contributions that women and people of color bring to science extends curricular possibilities for including new knowledge and approaches to teaching and learning science. A feminist poststructural view of voice is also extended to preservice teachers within the methods course. Teacher–student power dynamics are lessened, giving way to a shared community space where everyone participates.

Accordingly, these six theoretical perspectives, when considered collectively, offer a formidable approach or framework to guide the curriculum and preparation of urban science teachers. The strengths of each theory support strong theoretical and pedagogical principles for enacting a theory of social justice in science teacher education. Furthermore, the assignments within my science methods courses adhere to a structure that promotes social justice as a way of thinking and as a goal for the teaching and learning of science. For example, in Fig. 19.2, I present four core assignments[2] that are used to prepare science teachers for urban elementary classrooms. These assignments reflect a commitment to an equitable and socially just science teacher education curriculum. The assignments are typical, such as reading articles, completing lesson plans, writing papers, and teaching. However, I also include a few atypical assignments, such as reading a multicultural text in a Book Club (Mensah 2009a, b) and doing community outreach in urban middle schools. The combination of multiple theoretical perspectives throughout the course and within these core assignments has a set purpose; all the assignments address the shared goal of creating science teachers who develop a social justice identity in science education and are prepared to teach students of diverse backgrounds and abilities. As a result, the preservice teachers are able to develop for themselves "pieces of theory" in the construction of knowledge and practices as science teachers

[2] Although these four assignments are considered to be core experiences, the course incorporates additional activities, experiences, and discussions, and they do change from one semester to the next. Still, these assignments are supported by a multiple theoretical framework and connect to the overall theme of teaching science for social justice. Other assignments and activities include inquiry-based science laboratories, Science in the City Photo Albums, observation journals, placements in high-poverty schools, pre- and post-questionnaires, identity activities, student drawings, themed lectures, and final project presentations.

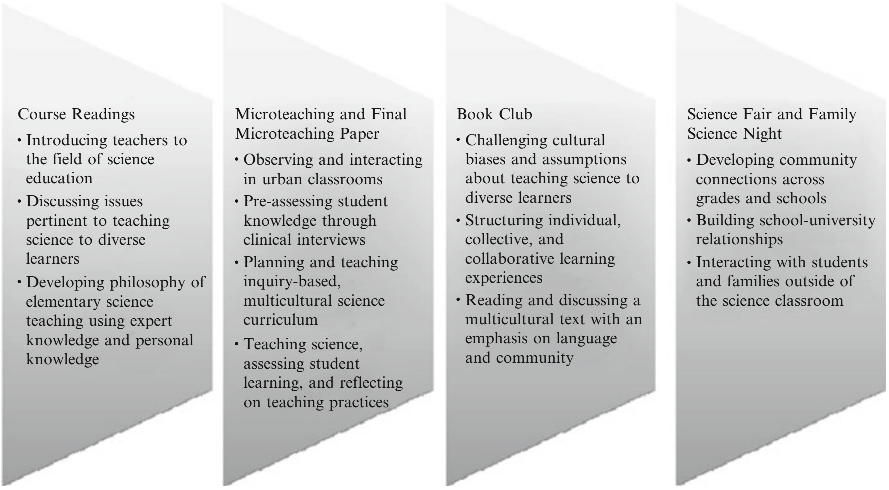

Fig. 19.2 Four core assignments in the elementary science methods course

(Moore and George 2007). The preservice teachers construct understandings of social justice and are able to articulate in real ways "what they are learning and hope to transfer to classrooms during their student teaching and future teaching" (pp. 3–4).

Process of Recoding

To think more purposefully and critically about developing a diversity, equity, and social justice agenda for science teacher education, I revisited analysis files from previous studies (2004–2010), such as student journals, student interviews, and researcher journals. I completed a careful re-reading of these previous data and analysis files and re-coded them for themes under the larger framework of *process* and *goal of social justice* understandings (Bell 2007). I also conducted cross-analysis within the multiple theoretical perspectives and assignments employed within the methods course. This retrospective coding allowed me to consider how well the ideals of social justice understandings matched the learning of the preservice teachers over the years, and how well the core assignments in the methods course adhered to the process and goal of social justice as a framework in science teacher education. Finally, I extracted narratives that represented the preservice teachers' learning about social justice from the four core assignments.

In the following sections, my analysis and students' narratives are discussed. These selections connect the multiple theoretical perspectives to the four core assignments as exemplars of social justice understandings in science teacher education. These comments highlight how social justice was framed as a process of learning for the preservice teachers (and me) in the methods course and as a goal for teaching science in urban elementary classrooms.

Science Teacher Education for *Social Justice as a Process* of Teacher Learning

Heather Hackman (2005) and bell hooks (1994) noted that critical self-reflection moves classrooms closer toward the goals of a socially just classroom. Reflection—purposed and recursive—extended through all of the core assignments in the methods course. Reflection was both an individual and collective process focused on personal development in learning and teaching science for social justice. For example, the course readings were selected to introduce preservice teachers to the field of science education. They were also intended to encourage them to reflect on the inequities in science learning, mainly from the perspective of oppression and marginalization of students of color, students of poverty or low socioeconomic status, and females. To get them to this point of realization about science education as a broad field, they were asked to reflect on how science is taught, how they had learned science as students, and to think about their views of self-marginalization as learners of science (Reaction Papers format). With social justice education as a process of teacher learning, their Reaction Papers and classroom discussions served as a means of "full and equal participation of all groups [preservice teachers]" as a classroom norm (Bell 2007, p. 3). Therefore, throughout the course, the preservice teachers were given ample opportunities to share their thinking with their peers in classroom discussions and with me in their writings (Reaction Papers).

For instance, though Ann-Marie was "uncomfortable" learning in the classroom, she disclosed how her perspectives were valued. Likewise, she had undergone a process of revealing her "naïve conceptions" about science teaching. Another point that is revealed from Ann-Marie's narrative was how she thought the methods course should be taught, specifically what my role as the instructor in the course should have been. She had gone through "conceptual change" about science teaching and learning and the role of the teacher, or instructor:

> When I began learning in this class, consisting mainly of facilitated discussions, activities, and personal writings, I felt uncomfortable. When will the teacher teach us what we need to know about science? I was operating under the assumption that the role of the teacher is to disseminate information to the students. Throughout this course, I have been asked to talk about my ideas, beliefs, and experiences about education. Even if I wasn't an expert teacher with years of experience, even if I never taught, my opinion was considered important and valid. I was able to link theories and methods of education with my own past experiences and prior knowledge. The textbooks were not the sole source of our learning; they were resources to be used in the course of our learning. Professor Moore has modeled the conceptual change approach without me even noticing. Several times I wondered, "Why isn't she teaching?" I now believe it was because she was too busy making sure we were learning. My naïve conceptions of what teaching and learning is supposed to be were confronted and expanded upon. (Ann-Marie, summer 2006, Reaction Paper)

Similarly, the Book Club was another assignment that promoted active discussion and teacher learning, reflection, and change in perceptions of science education (Moore 2008a). From the Book Club conversations, the preservice teachers became more attuned to positionality (Moore 2008b) and how it influenced science teaching. In many cases, the preservice teachers confronted self, or their positionality, in relation to science and students. One preservice teacher commented on how she could use her rural upbringing to open discussions of difference with her future students:

> I have learned that I have to be honest about where I come from, and make that information available to my students; in order to break down the misconceptions and stereotypes they have about me, in order to begin a dialog in the classroom about difference. It is important to communicate who we are as people. (Trudy, spring 2005, Final Book Club Reflection)

Preparing science teachers to view culture, language, and communities in positive ways was achieved from the Book Club assignment. This assignment encouraged critical reflection and confrontation of assumptions, biases, views of culture, language, and communities that may be detrimental to science teaching and learning (Mensah 2009a, b). It was important for the preservice teachers to confront their assumptions in order to teach science from a social justice framework. The selection of a multicultural text on the life and language of two southern, rural communities challenged many of the preservice teachers to rethink their past learning experiences in science and to reconceptualize their views of diverse learners and self. In one case, reflecting on participation in the Book Club was a learning process for Klaren, because it prompted her to consider how her assumptions about students could impact classroom teaching and student learning:

> Our book club helped to shed light on my flawed, and almost, dismissive approach to this book, and how, by extension, this could be incredibly detrimental in the classroom. Accordingly, over time, I realized how cognizant I need to be of my existing biases and be sensitive to the often subconscious effect of my ethnocentricity. Stereotypes are easy, and just as I needed to focus to find the real value and meaning in the text, I could find constructive insight and realize a mutually beneficial experience/interaction from a deliberate effort to understand my students and their backgrounds. (Klaren, spring 2006, Final Book Club Reflection)

Similarly, Len, a student teacher at the time he took the methods course, communicated how he questioned his assumptions about student behavior and race in the classroom from reading the Book Club selection. He read about teachers' evaluations of the different social and academic behaviors between Black and White students. This caused him to think about his students: "I began to think critically about why my students behaved differently. Their skin colors should not be accounted for their behaviors. The book shows me that I need to explore further than their skin colors, their background experience, communities, families, values, traditions, etc." (Len, spring 2005, Final book Club Reflections).

As previously stated, science teacher education for social justice was aimed at the process of learning about self. In the process of acquiring this view, the preservice teachers became observant of the institutional and structural forms of discrimination that hindered their participation as well as their students' participation in science. Once more, they reflected on their own marginalization as learners of science and transferred these understandings to the context of urban schools. For example, in one of her reaction papers from the course readings, Brooke spoke of tracking as a reason for her limited exposure to diverse students:

> In California, I attended tracked schools where students were divided into general education, gifted and talented, and special education. Later on at my combination junior high/ high school, I ended up in a magnet school which was populated with Whites, Chinese,

> Koreans, Japanese, and Indians. There were four students from Mexico and one Black student in my entire grade level. Even our teachers (who also served as role models) were all upper middle class White males and females; (the female teachers usually taught English, music, and art), with one math teacher of Chinese descent. With a background like this, it's no wonder that I was unaware of the needs of students from different ethnicities and students dealing with poverty until much later in life and especially with my education at The College. (Brooke, summer 2006, Reaction Paper)

As a class, we took Brooke's ideas further by discussing why there were so few Black students in her honors courses in high school and also connected this to why there are so many Black children in lower track and special education classes. For teachers to teach science from a social justice perspective, they must be critical of their education and the ways in which they were taught science and observant of forms of discrimination and racism in education. With these perspectives, they then must desire a better way of teaching and learning science for their students. Part of understanding institutional and structural forms of discrimination was making the connection between social justice and critical learning through stories and narratives of their personal experiences in learning science. For example, the personal reflections on past experiences (Course Readings Reaction format) revealed to many of the preservice teachers the overt and covert nature of who can do science and how women, in particular, were often not seen as a part of those who can do science. Not just in individual writings, but also in whole class discussions, opportunities to share personal narratives related to gender were commonplace (Book Club). Preservice teachers discussed why there are very few young men in our elementary methods course and reflected on their past participation in school science laboratory activities; for many of the females in the course, doing science was not a norm. This awareness of gender bias, which was then extended to other areas, such as race/ethnicity, inspired the preservice teachers to teach science differently from their experiences and to focus on inequities in science education.

Finally, the preservice teachers had to write a philosophy statement as the sixth Course Readings Reaction Paper. This was a summary written from re-reading their previous five reaction papers. The philosophy of science teaching statement revealed the preservice teachers' process of coming to new realizations about teaching and learning science as they prepared for their microteaching, which is conducted during the middle to end of the semester. From some statements, the preservice teachers were able to situate their understandings of self within broader views of science education in their process of learning:

> As a collective whole, these articles have clearly influenced my vision of elementary science education as well as my understanding of my place within that vision. I hope that this new emphasis on the roles of the student and the teacher rather than the material itself will remove some of what intimidates me so profoundly about teaching science and will allow me to approach it in a more creative and personal way. (Susan, fall 2005, Philosophy Statement)

To summarize, the selected narratives from various core assignments (i.e., Course Readings and Book Club) in the elementary science methods course reflect the preservice teachers' views of science teaching and learning as a process of developing social justice understandings. By becoming knowledgeable of their personal experiences in science, these preservice teachers, presented here (and many more over the years), have looked critically at self, science, and science teaching as well as education and teacher education. Consequently, the process of learning about social justice and inequities in student engagement in science education comes first from critically reflecting on their personal narratives and their education and being thoughtful about ways to improve science learning experiences for students.

Science Teacher Education for *Social Justice as a Goal* for Science Teaching

Building from the previous section, social justice as a goal for science teaching is represented by a discussion of two additional core assignments in the course—Microteaching and the Microteaching Final Paper and Outreach. From these two core assignments, preservice teachers are asked to respect students as unique individuals with perspectives, knowledge, interests, and experiences that can be used in teaching and learning science. They are also encouraged to look at themselves as diverse teachers with experiences, knowledge, and interests that can be shared with their students. For the Microteaching assignment, the preservice teachers plan and teach 2-day science lessons in an urban elementary classroom. Prior to planning, the preservice teachers conduct observations and pre-assessment interviews with a student on his/her ideas about a science topic. Topics are taken from the New York City Core Science Curriculum and Scope and Sequence. This assignment challenges the preservice teachers to develop an identity and agency for teaching science, because they are to plan an inquiry-based science lesson that would be meaningful and relevant to urban students. Janette, one preservice teacher who was placed in an East Harlem classroom, felt that the pre-assessment was "quite helpful" for her lesson planning and building upon her student's ideas. For her microteaching lesson, she planned a culturally relevant lesson on pollution:

> The pre-assessment interview was quite helpful in determining what to teach. … By drawing on the student's preconceptions before my lesson, I was better prepared to plan the topic. For example, I noticed that [Serena] already had a strong grasp on the fact that humans cause pollution and that she recognized examples of that in her life. She blamed "the garbage people" for neglecting overflowing trash cans. Yet she did not take any personal responsibility for pollution. This observation led me to plan a lesson where the children could see pollution as being everyone's responsibility—not just a select few. (Janette, spring 2006, Microteaching Paper)

When social justice guides instruction in the science classroom, it is evident in the design of curriculum materials that are also transformative. James Banks (2001) discusses that transformative curriculum should have a social action component for effecting change. A social action approach moves beyond simple adaptations to classroom practices and science content. Instead, teachers transform their practices and classrooms in order to engage students fully in science, while students make decisions and act on social issues that are relevant to them and their communities. Lewis, at the time he took the methods course, was in his student teaching placement. His first graders planned a recycling project for their school. The project originated from the students' interest and connected to the larger community as the students were learning about recycling as part of their science curriculum. The recycling project showed how knowing science can be beneficial, informative, and transformative in the lives of young students. Lewis commented, "[T]hey sparked a tremendous change that truly helps our earth. I am just happy and proud of my students" (Lewis, spring 2006, Microteaching Paper). In addition to this, the recycling project was "democratic and participatory, inclusive and affirming of human agency and human capacities for working collaboratively to create change" (Bell 2007, p. 2). As first graders, they enacted their agency in an impressive way that was rewarding to them, their teacher, and the school community. They saw the significance and importance of applying scientific knowledge in their lives and acting in a socially just way.

A social justice framework as a goal for science teaching that utilizes multiple theoretical frameworks does not negate connections to the community, but rather works with/in the community. For example, preservice teachers are encouraged to step outside the traditional relationships of teacher–student, teacher–parent, and teacher–community in order to establish stronger ties with students, families, and their communities. There are two occasions for outreach in the methods course: the Family Science Night, where preservice teachers create hands-on lessons for students and families in science (fall semester), and the Science Fair, where the preservice teachers first serve as science mentors of students working on science fair projects in the classroom and later return to the school as science fair judges (summer semester). Both assignments serve as community outreach to support university-school-community partnerships.

The outreach assignments take place at a local urban middle school in New York City; the school is located in East Harlem, only a few blocks from one of the elementary schools where I also place preservice teachers for learning while in the methods course. This cross-grade, cross-school relationship allows the elementary preservice teachers to consider their role as teachers in the preparation of elementary learners for middle school science. In both outreach programs, the preservice teachers dispel negative images of urban schools. Some views that they hold prior to spending time in the middle school are that urban families are not concerned about the science education of their students, "inner city" families are not supportive of their children, or middle school students do not like science. Many of their deficit views of urban communities are revealed and challenged. Though both Family Science Night and Science Fair take place at the middle school, alternative images of science learning in urban communities, parental engagement, and community service are the goals for these two assignments. It is important that the preservice teachers experience science learning outside the traditional science classroom of the university setting and the school classroom:

> It was really important to me to experience a night in a school that is not like the schools I grew up in or am student teaching in now. The schools that I have had most experience with are mostly homogenous, comprising of mainly [W]hite, middle class students. The [middle] school itself was in a beautiful building, but the surrounding buildings were strikingly different in design and construction. The families were warm and enthusiastic about being a part of the science night. I enjoyed seeing many smiling faces and students guiding their families through the halls while pointing out classrooms and teachers. I'm glad I got to be a part of a night that seemed to mean a lot to the school's students. (Fran, fall 2007, Family Science Night Reflection)

From participating in Family Science Night, the preservice teachers also think of ways to further engage parents and students in learning science together. This involves being cognizant of how language can be a barrier to full engagement in science:

> I had one little girl and her mother, and we were translating back and forth what was going on in the experiment from English to Spanish. It was frustrating because I really wanted to be able to explain it to the mother, but it was a great tool because the student had to synthesize the material and translate it to Spanish to her mother. … This brought up a realization for me; I should have printed the directions in Spanish and English. (Camryn, fall 2007, Family Science Night Reflection)

Evoking a social justice framework for some of the preservice teachers is frightening and, in a few cases, trepidation arises from thinking about stereotypes of urban communities and students of diverse backgrounds. One preservice teacher, Roberta, had a real fear going into the "inner city," no less a middle school classroom environment which was especially different from her upper-middle class, suburban, White background and school experiences, and across town from the university campus. As a point of analysis, Bell (2007) remarks, "Dominants learn to look at themselves, others, and society through a distorted lens in which the structural privileges they enjoy and the cultural practices of their group are represented as normal and universal" (p. 12), and consequently perceive difference as inferior and frightening. Roberta had been "socialized to fear the different, the socially outcast, the minority" [and] realized that "[her] entire rearing was isolated in a bubble of fear." Her family had "always avoided 'inner city' neighborhoods." Despite these fears and concerns, Roberta entered the predominantly African American and Latino/a middle school in East Harlem to work with the sixth graders as their science fair mentor and later as a science fair judge:

> …I thoroughly enjoyed working as a science mentor. The children had such colorful personalities and humorous imaginations. They were all so excited to interact with me and my peers, and this made our relationships strong from the beginning. I would much rather work at a school like [this urban middle school] opposed to a gifted school [I was placed at last semester] whose community consists of over worked, over anxious and over competitive families. This world [at the urban middle school] of teaching was much more peaceful [than I would have imagined]… (Roberta, summer 2008, Science Fair Journal)

Though the preservice teachers enjoy their time working with the middle school students, they still struggle to comprehend how students who are motivated to learn science also strain to understand science. Mentoring a small group of students on their science fair projects, Marianne could identify with the students' frustrations in learning science. She reminisced about the challenges she encountered in learning science as a student:

> The process that it took for the students to get to the final outcome—the moments of confusion, silence, or frustration—gave me a sense of the disconnect that students still experience in their science education. Thus, for me, I walked away from this experience wondering where, exactly, the source of the frustration lied and what I could do, especially as an elementary school teacher that could help students navigate their way through a subject that I, myself, never had the opportunity to really "get". (Marianne, summer 2008, Science Fair Journal)

In sum, as a result of thinking about inequities in science, over the years, the preservice teachers have developed an identity and agency for teaching science to students of diverse backgrounds and experiences. Of course, there are influences on urban schools and communities that pose difficult challenges and ongoing questions; yet, students and these communities deserve our attention and commitment to provide a quality education (Nathan 2010). In order to teach in socially just ways, the preservice teachers have to confront their fears, hidden assumptions, and biases that keep them from viewing urban communities, schools, parents, and students in a positive light. Regardless of their apprehension, the preservice teachers confront their fears and dispel negative stereotypes and images of "inner city" youth, urban schools, and communities and work to make science an enjoyable learning experience for students, their communities, and self. The classroom discussion, comments, and other writings from the methods courses serve as a continual body of data to access preservice teachers' narratives of learning about diversity, equity, and social justice. As an educator and researcher engaged in this work, preservice teachers' narratives provide both formative and summative assessment of what I am able to accomplish in a methods course, and what my limitations are. Still, the direction that science education must take toward social justice understandings in science teacher education is worth the effort. My efforts are explicit, directed, coherent, and couched within a multiple theoretical framework. As science educators, we too must develop broader understandings of the challenges and possibilities we face in science education to prepare teachers who are equipped with the knowledge and skills to provide an equitable science education to all students.

Theory and Policy

As the author of the chapter, I was asked to address two questions:

1. What do the theoretical and methodological lenses used in this scholarship enable? What do they constrain?
2. In what ways can the ideas discussed in this chapter be used to inform research, practice, and policy? More specifically, what is the "so what" for graduate students and new scholars looking for ways to conduct research on equity and diversity? What are the implications of this research for classroom teachers and policymakers?

I address these questions first by interjecting another personal vignette, entitled "*classroom politics,*" and taking the definition of politics as "a process by which groups of people make collective decisions; it consists of social relations involving authority or power" (Wikipedia, the free online encyclopedia). Following this, I articulate a vision for science education and the NARST community toward an agenda for diversity, equity, and social justice in science teacher education.

Classroom politics

Hi, Class! As I understand the conversation from this evening, you would like to have LESS reflective writing in the course. I view reflective writing to be the hallmark of academic learning, and the assignments are designed to guide and scaffold your learning in this way. Also, in graduate studies writing is not only expected but it is also a means of sharing and communicating your learning with the professor. For me it is a dialogue whereby it allows me to get to know you and your personal experiences. Therefore, as your professor I cannot in good conscience deny you the opportunity to learn from the diverse assignments in the course, nor do I want to be denied learning from you. Therefore, after much contemplation, I have decided to let the syllabus remain as is. However, I still have the freedom to make changes to the syllabus as the semester progresses and as I consider individually and collectively your needs and my goals for the course. With that said, you may decide individually if you want to complete the next four reaction papers as presented in the syllabus, which includes reaction number 6. (Email communication, October 24, 2006)

I admit that engaging in social justice work and utilizing multiple theoretical frameworks to accomplish this requires some repositioning on my part. The vignette discloses the challenges I encounter when I ask students to openly engage in critical reflection, to actively enlist in a process of collective learning, and to seriously consider education—theirs, mine, and their future students. My feminist and sociocultural mind analyzes the vignette as a desirable outcome: Students exert their agency, voice their concerns, and express their needs as learners. However, my critical mind arises, and I question my authoritative position as the university instructor and how much power I exert and am willing to yield in how I prepare them as teachers and what my overall expectations are of them as learners. hooks (1994) explains “that without the capacity to think critically about our selves and our lives, none of us would be able to move forward, to change, to grow” (p. 202).

When the class met the following week, several students confessed that they were not against “reflecting so much,” but that reflecting in the ways that I asked them to was new and hard. In fact, three students talked with me at the end of the class and reported that it was actually two of their classmates who were anti-reflection, and the rest of the class did not agree with them. I took that evening and the students’ comments to heart. I had awakened in some of my students a realization that learning for social justice was uncomfortable, but that “really talking about diversity” (comment from a student) was something that they wanted because they were not getting this in other courses; another student commented that I should change the course description in the academic catalog to reflect that diversity is a major focus in the course.

I have very high expectations for the preservice teachers who enroll in my courses. I want them to grow in their understandings of social justice in science education, but most importantly, I want them to change the world—or at least assist in transforming the educational experiences of their students; is this too much to ask? I articulate more explicitly in my syllabus and in classroom discussions the goals and intent of why and what I do as a science educator, my hope for them as science teachers, and the hopes I have for the students they will serve. All of the course assignments are purposed, connected, and constructed to facilitate their growth as teachers. I establish with more authenticity the idea of a learning community and the ways I am also part of this community of learners. Since that email communication (fall 2006), I continue to reflect on my practice—the assignments I create for my courses, the theoretical assumptions that guide my teaching and research, the relationships I foster within and outside the classroom with my preservice teachers, and the myriad of experiences I provide for them to voice, grow, and exert their sense of agency in their development as science teachers and social justice educators. As I grow, so do my students, and vice versa.

Teaching for social justice is a continuous process of self-reflection, accommodation, and learning. Therefore, the frameworks that are currently being utilized in science education—including the six that I use—are not adequate in transforming our students (Mutegi 2011). This does not mean that they are not worthy of use, but they definitely open up opportunities for debate and amendment. At the moment, the theoretical and methodological perspectives that I employ enable me to fit together pieces into a workable whole, which is still a partial rendering. The frameworks allow me to address some fundamental aspects of teaching and learning and what it means to teach science for social justice. Thus, theoretical and methodological frameworks do constrain me as I know there are limitations to every theory and inadequacies in every approach. Even so, the use of these frameworks helps to establish the goals and intents that comprise my work as an educator and researcher and hold abundant possibilities for the preparation of urban school teachers. It is because of the constraints or limitations that theories hold that I work to establish strong pedagogical connections among them, so that my preservice teachers develop an identity as social justice educators and feel better equipped, more knowledgeable, and more confident to teach science than they did prior to taking my course. The connections I make have implications for my ongoing efforts to advocate for social justice understandings to have a more prominent position in our work as science educators.

Implications and Future Directions

To write this chapter, I took a retrospective look at my work and the general body of research on social justice in science education. On looking back, I first revisited analysis files from several data sources I had previously coded (and a few data sources that I am currently coding) and reviewed the implications of not only my published work in diversity, equity, and social justice scholarship within the field of multicultural science education, but also within the broader field of education. This process of critical retrospection allowed me to consider how the principles and goals of social justice education in my work—embedded in a multiple theoretical framework—serve as evidence of teacher learning. In another way, it gave space for me to articulate an agenda for diversity, equity, and social justice in science teacher education grounded in my own practices.

Social justice is the missing element in much of the work in science education. The examples I share in this chapter may invite science educators to engage in dialog about how to incorporate social justice understandings in science teacher education. For those who are currently engaged in this work, I implore that we clarify what we do, how we do it, and why we do it; essentially, we need to share. Social justice educators are responsible for providing support, mentoring, and networking with other social justice scholars—new and established—to advance an agenda of diversity, equity, and social justice in science education by and large. The work of social justice educators is situated within the margins. Nonetheless, we perceive this work to be central to many of the debates involving science education reform, student achievement, and teacher learning. Thus, we must acknowledge our ongoing struggles to incorporate social justice into our teaching and research, yet give way to moments of success in accomplishing our goals and advancing our efforts toward addressing many of the issues that we face in science education reform.

As an example, given the strand structure of NARST, I encourage social justice researchers to submit their work to various strands. In this respect, we must move with intent and purpose within the organization's structure and emphasize vital connections where others may not be as perceptive. There are numerous opportunities for discussions of diversity, equity, and social justice in a variety of strands, such as science learning contexts (Strand 2); science learning in informal contexts (Strand 6); curriculum, evaluation, and assessment (Strand 10); and policy (Strand 15). For the past 3 years, in order to share diversity and equity understandings, I have participated in other strands outside of cultural, social, and gender (Strand 11), such as Strand 7, and in co-sponsored sessions of the Publications Committee, Research Committee, and External Policy and Relations Committee of NARST. I have presented papers, chaired sessions, and served as a reviewer in strands outside of Strand 11, where I have found community and acceptance of my work. Attending and participating in these "other strands," I pose questions to colleagues who do not have a focus on diversity, as a method of extending and connecting their work to issues of diversity. By engaging in dialog across the strands, social justice understandings become more central to the work of the membership and thus to the organization itself.

As we move purposefully within other strands and invite ourselves into other people's conversations, we may initiate constructive, critical dialogs with our colleagues about the importance of diversity, equity, and social justice understandings in science education. Conversations may entail expanding perspectives, collaborations, and personal research agendas; being inclusive of new approaches and methods outside of traditional frameworks and methodologies that dominate the field; incorporating multicultural frameworks within research and teaching; and discussing ways to spur national policy and reform in science education for social justice. These may include recommending new reform initiatives to address the challenges we are facing in science education regarding diversity, equity, and social justice on local, state, regional, national, and global levels. Networking and collaborating with science education colleagues across organizations, universities, and countries in support of a diversity, equity, and social justice agenda matters in all of our work, and, in particular, teacher education.

Conclusion

Many researchers have articulated their views and perspectives of social justice education. These views have been in response to the changing demographics of society and schools, such that the new approaches for the preparation of teachers are offered as one solution to address concerns at larger national and global levels. Thus, I encourage science educators and promoters of quality education to take advantage of all available resources in order to bridge long-standing gaps within our work regarding diversity issues. We must begin to develop new relationships and nurture existing relationships within and outside our research circle. Our social, professional, personal, and research networks need to expand. This may entail stepping into unknown territory and leaving our comfort zone in pursuit of larger equity goals. We also have to reorganize, restructure, and consider new possibilities for research and policy, such that diversity, equity, and social justice issues are prominent in our work and in our organization. We have to provide the necessary leadership and collaborative networks to make this happen. Collectively, we have to mobilize our efforts so that we are powerfully positioned to effect positive social and educational change—the mantra of a social justice agenda—in science education and policy (Mensah 2010). For this reason, I not only share a longstanding personal agenda, but also invite others into a collective dialog and communal space in support of a science education program that earnestly supports a diversity, equity, and social justice framework in science education reform.

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Chapter 20
What Perspectives on Community-Based Learning Can Teach Us About Organizational Support of Research and Policy Work in Equity and Diversity

Gail Richmond

A Historical Perspective: How Have We Addressed Issues of Student and Teacher Learning Outside the Classroom?

A story familiar to many in the US science education research community goes something like this: In the lengthy aftermath of the *Sputnik* launch in 1957, long before many of us were born, attention in the USA turned toward enlarging the pipeline of those who would become the next generation of scientists, engineers, and mathematicians. The primary purpose was to return the USA to the cutting edge of technological sophistication and intellectual sagacity, which would inevitably contribute to the economic growth of our country and its continuing role as an international leader. This led to the creation and support of hundreds of enrichment programs in science, mathematics, and eventually in engineering for young people across the USA. The models for such programs converged and what resulted was first the Student Science Training Programs (SSTPs) funded by the National Science Foundation (NSF) between the late 1950s boom and early 1980s recession, and then the Young Scholars Program, established at a much smaller scale in the mid-1980s through the early 1990s. These initiatives then spread to look-alike programs at other agencies across the country. All of these programs provided what was considered "authentic" scientific or mathematical experiences for precollege students.

In the decade or so after the creation of such opportunities, attention shifted away from the few who were able to take advantage of them. Two significant changes precipitated this shift. One was the cry, which has resonated and been reproduced

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hundreds of times and in many contexts, of *Science for All*, and the creation of standards and benchmarks which, if reached, would mean a more scientifically sophisticated, literate citizenry. The other was the shift in attention to those professionals instilled with the responsibility for enacting these standards—classroom teachers. This shift was accompanied by the creation of programs, such as the Teacher Enhancement Program at NSF, which would oversee hundreds of programs that provided enrichment experiences for teachers in STEM disciplines—experiences not unlike those provided to students in the SSTPs. Indeed, many had almost indistinguishable characteristics.

Two significant issues attended efforts directed at both teachers and students. The first of these was that the programs for both groups were constructed using a "one size fits all" model of relevance and engagement potential. The second and related issue was that these efforts were often grounded in deficit notions of scientific understanding and requisite technical skills. The result was that the language of science education reform documents was to provide access to necessary resources for learning for *all* students (and in the USA, the pace with which the diversity of the student population was increasing was greater than many had predicted). However, those resources did not leverage, much less recognize, the rich, nuanced experiences or funds of knowledge (Gonzalez et al. 2005) which students brought with them to their interactions with science. Nor did they recognize the power of nontraditional resources, many residing in the community itself rather than in schools, to support rich and relevant learning. Only recently have resources acknowledged the importance of contextualizing subject matter. Furthermore, opportunities for outreach and research to support student learning through school- and community-based programs have begun to be grounded in a "hybrid view" of science, one in which content arises out of critical features of language, culture, race, ethnicity, and other important dimensions of the populations served.

Similarly, early teacher-targeted programs designed to encourage more effective science pedagogy (and thus enhance student learning) were decontextualized historically. Early work from which principles for effective professional development (PD) were derived appeared to ignore unique issues arising from particular settings, such as those that are urban or rural (as opposed to the suburban settings in which much early work took place); similarly ignored were the particular political and economic structures and agendas that shape the cultures of school districts and schools themselves. Also largely ignored was the powerful impact of teachers' views of themselves as content specialists or as respected professionals and role models, and their beliefs about their students' capacities as learners. All of these influence the development of knowledge and practices for science teaching. Over the past 20 years, we have learned that, just as it is not one size fits all science, it also is not one size fits all science teaching. In recent years, efforts have shifted to a closer examination of the particular opportunities and constraints that teachers face in becoming reform-based science teachers.

Chapter Goals

In this chapter, I will focus on some of the ideas that have arisen from this recent work. In particular, I will examine how recent work on professional development and leadership (e.g., Richmond and Birmingham 2009; Richmond and Manokore 2011; Spillane et al. 2001a) and professional identity (e.g., Luehmann 2007; Richmond et al. 2011; Richmond and Passmore 2009; Spillane 2001b) have contributed to our understanding of the design and sustainability of effective professional learning communities. In addition, I will discuss how the constructs of script, counterscript, and third spaces (Gutierrez et al. 1995), originally proposed to explain the tensions that arise between teacher and students in classrooms, might be used to better understand the factors that constrain or foster sustained professional growth and create the conditions necessary for teacher leadership. Lastly, I will argue that those same factors that work to facilitate or inhibit professional growth within learning communities also are at work in organizations such as NARST; those factors that make possible the growth and empowerment of teachers of science also can make it possible for members of our NARST community—both new and established researchers—to feel individually and collectively supported in their pursuit of work in areas of equity and diversity. NARST can become a place where equity and diversity are not only hallmarks of our structure and scholarly work but also values that inform the ways we use this work in shaping our interactions with other professional organizations and in influencing policy decisions on the broader educational and political stages.

Professional Development in Communities of Practice: Understanding the Power and Pitfalls of Learning Communities

The science teaching profession fundamentally serves the public interest, has many of its elements situated in relatively public spaces, and is open to public scrutiny and debate; thus, it is somewhat surprising that teachers spend the majority of their time in isolation from ongoing collegial problem-solving and support (Little 1990, 2002). As research on student learning in classrooms and other contexts has become informed by sociocultural theory, which considers that learning is the result of interactions within communities of practice between more and less knowledgeable others (Lave and Wenger 1991), attention has also become focused on the conditions necessary for powerful and long-lasting teacher learning. Early work (e.g., Putnam and Borko 2000) suggested strongly that teachers learn best by being presented with opportunities to work through relevant problems with peers; this work has resulted in engagement by the science education community (and the education community more broadly) in the potential power of situating teacher learning in what has become called professional learning communities, or PLCs. By the late 1990s and early part of the twenty-first century, PLCs seemed to have sprung up in almost every conceivable location and at a wide array of scales. Not only did they become a focal context for research projects, but they also became the hallmark of whole district initiatives for teacher professional development. The problem was (as is often the case when curricular materials are adopted whole cloth and without relevant professional development to guide their structure, intent, and use) that surface features of PLCs were often replicated without careful examination of the functional attributes critical in fostering productive outcomes. Also ignored were the features of the particular context in which these groups would be introduced, or the experiences and needs of those who would people these groups. The mandating of school-based PLCs in districts around the country in the 1980s and 1990s often resulted in resentment among school staff, and worse, little, if any, impact on student achievement (e.g., Wilson and Berne 1999; Wood 2007). Over the past 15 years, however, as a number of investigators have turned a critical eye on the phenomenon of PLCs, we have learned about the critical elements for success, both locally and at scale, for the participants in these communities and for the students they serve.

After a brief overview of what structural analyses have revealed about critical elements of professional development programs for teachers, I will discuss contributions from several studies that have taken a closer look at such communities and which are aligned with two distinct theoretical/analytical domains. The first is social capital theory, originally developed within the disciplines of sociology and political science (e.g., Lin 2001). This theory sheds light on distributed leadership and social networking. The second is sociocultural theory, with a particular emphasis on professional identity and context. These two areas of scholarship differ in their unit of analysis; those engaged in sociocultural research typically treat the PLC as a cultural entity while those taking a social networking or distributed leadership approach consider the PLC or its equivalent as one unit within a larger entity that includes the school as a whole, as well as the larger district within which it resides. However, each of these offers intriguing insights into how teacher interactions within professional communities become established, and the factors that determine the extent to which these communities are maintained and, in some cases, flourish.

Critical Elements of Learning Communities

One of the most long-standing research projects on elements critical for the design of effective professional development for science and mathematics teachers was conducted by Susan Loucks-Horsley and her colleagues (see, for example, Loucks-Horsley et al. 2003). They found central design elements must include: (1) the knowledge and beliefs held by those providing the PD, (2) the set of contextual factors influencing PD, (3) the critical issues the PD project will face, and (4) strategies for professional learning. Attending to such diverse factors is challenging, at the very least. In his more recent synthesis of work on PD efforts in science education, Peter

Hewson (2007) aptly summarized the complexity of such efforts, pointing out the importance of considering the system of which these programs are a part. As he pointed out, this work has one of two foci—the teacher participants themselves, and those delivering the PD. In what follows, I will pay selective attention to two broad areas of research which attempt to make sense of PD efforts within different kinds of communities of practice from both of these perspectives, and propose another area of work which might contribute in significant ways to our understanding of how productive teaching and learning can take place in such communities, be they classrooms, PLCs, or even professional organizations.

What and Who I Value Is What I Learn: Social Capital, Social Networking, and Professional Development

Fueled by an interest in identifying how necessary resources are identified and utilized in supporting science education—in spite of the undervaluing and under-resourcing of this subject in urban environments, James Spillane et al. (2001a) examined the resources available for leadership within 13 elementary schools in Chicago. They identified school leadership as "…the identification, acquisition, allocation, coordination, and use of the human, social, and material resources necessary to establish the conditions for the possibility of instructional innovation" (p. 919).

These investigators found that despite science being undervalued and under-resourced, some schools were able to identify and activate resources to support organized efforts to transform science teaching. They did so by activating three kinds of resources—physical capital, human capital, and social capital—which intersected, complemented, and enhanced each other. Physical capital included financial resources, human capital included leaders with the knowledge and expertise for leading instructional change, and social capital included the trust and communication between staff within the school and networking outside the school. An example of the last of these was the creation of specific structures such as regular staff meetings with specific agendas to support communication and interaction, and the accessing of resources—human and otherwise—from nearby organizations and universities to support the school's instructional efforts. In addition, the ways in which these different kinds of capital were brought to bear on instructional issues was distributive in nature; that is, the expertise "brought to the table" by different key agents—building administrator, department chair, teaching staff, community organization president, and so on—were distinct but complementary, and the recognition of this complementarity resulted in a richer and more powerful outcome. The very fact that the activation of resources occurred as a result of structured within-school interactions and community-based networking led these investigators to consider the group as the critical unit of analysis for understanding the likelihood that resources will be activated and instructional change would not only be invoked but sustained. This work has been extended by others and elucidates necessary resources and the factors, both internal and external to the group, which can facilitate and inhibit the growth and sustainability of science teaching reform. Such factors include the situated nature of expertise, issues of accountability, and perceptions of isolation (e.g., Richmond and Manokore 2011).

In a more recent study, William Penuel et al. (2009) studied the network structure of social capital among individuals in communities within two elementary schools in California. This investigation was stimulated by the fact that while they shared certain characteristics, these two schools looked quite different in terms of both commitment and progress toward curriculum reform. Although Spillane and his colleagues thought of teacher interactions within formally recognized and structured domains (e.g., "teacher talk" groups, department meetings) as a form of distributed leadership, these investigators took a somewhat different approach, making use of social networking tools to analyze the nature of both formal and informal professional interactions within a school building and to identify critical subgroups and leaders.

These approaches are complementary; a social network analysis can examine different kinds of ties (e.g., professional, friendship), while an analysis of social capital can consider particular resources and expertise accessed through those ties (Penuel et al. 2009). The findings of both studies strongly suggest that for significant learning and lasting change to take place, two things are critical: (1) a pattern of distribution and perspectives about the value of resources, rather than the amount of resources per se and (2) the critical role of empowerment and ownership by key participants in these communities—both teachers and administrators alike. This work has implications not only for professional learning within school-based communities, more generally, but also for learning in schools with limited resources, in particular. It refocuses attention from the amount of material and human resources available to the quality of these resources, their value, and their cultivation, by teachers and administrators alike.

What and Where I Am Is What I Learn: Professional Identity, Context, and Professional Development

Studies grounded in social capital theory approach teacher learning through a lens of group interactions, and while social networking suggests the importance of analysis of individual interactions, its focus and that of researchers using a distributed leadership approach on the acquisition and distribution of resources does not allow for a close examination of more psychological or psychosocial attributes or constructs which might shape professional interactions. It has become clear from research on teacher learning over the past 20 years that despite various interpretations of what is meant by these terms, beliefs, identity, and context play critical roles in shaping knowledge and practice. The extent to which there is uptake of ideas is shaped by what teachers believe about their students' capacities as learners, how they think of themselves as educators, now and into the future, and the context in which they practice. None of these alone accounts for the extent to which learning occurs;

the terrain of the profession and its enactment in schools is too multidimensional and interactional for this to be the case.

For example, only recently have investigators in the science education community taken on the complexity of these interactions in trying to make sense of the features of the landscape that underlies professional learning; most of these efforts have been focused on the period of teacher preparation and early years of teaching. Several frameworks (Windschitl et al. 2009; Richmond et al. 2010) have been developed as a result of this work, and they have much in common. In the framework we have been using in our recent work with teacher candidates, we have taken the stance that knowledge and practices for teaching are heavily dependent upon an individual's notions of her professional identity and the context in which she practices. With respect to the former, we have built upon identity development work of others (e.g., Enyedy et al. 2006; Luehmann 2007; Sfard and Prusak 2005), as well as my own recent work (Richmond et al. 2011). Whether this research has focused on learners or teachers of subject matter, all of these investigators treat identity as socially constructed, multidimensional, subject to change as a result of experience, and composed of narratives told by the individual, to the individual, or about the individual.

Professional identity also can be revealed through perspectives individuals take on their own teaching, their students' learning, and their observations of others' instruction (e.g., Kang and Anderson 2008). In our present work, we have construed professional identity to be the result of two factors. The first of these is what one *values* most highly—for example, a teacher may value facilitating students' understanding of content, or she may value developing positive relationships with students, or receiving respect from students and peers, or maintaining classroom order. The second of these is how one *positions* oneself with respect to a particular community of practice, such as the school where one is employed or the university where one may be engaging in professional development activities or obtaining an advanced degree or endorsement (see also Moore 2008). As stated above, professional identity is not a constant, as neither values nor positioning remain unchanged. One is typically foregrounded more than the others at a particular moment in time, but may shift as the individual's experiences or circumstances are altered. How knowledge appears in practice is also influenced by the context in which the individual finds herself. For a beginning or experienced teacher, this may include contextual factors at the level of the classroom (e.g., a tracked or inclusion class, teaming or solo teaching) or the school as a whole (e.g., urban, suburban, or rural). Contextual factors interact with identity and may result in beginning teachers feeling as though the context in which they find themselves presents challenges much more real and "present" than anything offered by the university program with which they are associated. A White, middle-class student teacher in an urban high school who places high value on his students understanding the content deeply and positions himself with respect to his teacher preparation program may feel ill-prepared to face an inclusion biology class where most students' first language is not English and where there are 30 seats for the more than 45 students who are enrolled in the class. The daughter of Mexican migrant workers who values her ability to develop personal relationships with her students may find herself challenged by the seemingly regimented classroom culture established by the male chemistry teacher who serves as her mentor and by the perplexing aloofness she observes in the largely White eleventh-grade chemistry class in the suburban high school where she is placed.

Two sets of findings and related challenges arising from this work are relevant here. The first is that beginning teachers differ in significant ways in their needs and obligations, which drive their priorities in learning to teach (i.e., their values), and in their positioning with respect to the school professionals and university program with which they are associated. These values and positioning are rooted in their experiences as students and as beginning professionals, including those who find themselves in particularly challenging and unfamiliar environments, such as urban classrooms. Very few of these, unfortunately, are focused on supporting their students' development of powerful scientific practices Duschl et al. (2007), but rather are often focused on such things as maintaining order or gaining respect (Richmond et al. 2010). The second finding is that candidates who construct narratives about themselves as developing teachers that are in conflict with those told about them by others and who are unable to realign these narratives to minimize the conflict are less likely to successfully complete their teacher preparation program, no matter the kind or extent of resources made available (Richmond et al. 2011).

While these frameworks were originally conceived as guides for our growing understanding of beginning science teacher development, I believe that they also can be valuable in helping us understand teacher learning in professional communities; a PLC has the potential to become a community of practice within which a teacher positions herself and thus can shape the kind of knowledge a teacher develops and the extent to which this knowledge finds its way to her classroom practice. The narratives that make up an experienced teacher's professional identity are likely to be different from those constructed by a beginning teacher, whose experiences were accrued in the precertification period. Contextual variables are certain to change as well. For example, policies put in place by a school administrator or at the district level are not issues that affect teacher candidates, but can have major impact once that individual is teaching full-time in a school. Together, these variables serve as powerful filters on a teacher's continued professional growth—defining the kinds of experiences teachers seek, their openness to reform-based ideas and practice, and their motivation to developing their practice as science teachers.

While it is clear that professional identity and context play important roles as filters on teacher learning, neither of these findings nor those from the perspective of social capital theory as described earlier provide a complete picture of the complexity of learning within communities of practice. Particularly when the goal of work in such groups challenges one's identity as a teacher (which is often the case when the goal is associated with the knowledge and practices necessary for reform-based science teaching), understanding more deeply the dynamics, motivation, and ownership of the discourse within that community of practice is critical to better understanding how and why it is that some communities flourish and some flounder. I turn now to work which allows us to focus attention on just these issues and, I think, affords us an opportunity to apply these ideas not only to professional work within PLCs but also to scholarly exchange and professional growth within our own, much larger professional organization as well.

Professional Learning Communities as "Third Spaces"

Fifteen years ago, Kris Gutierrez and her colleagues published work based on the analysis of classroom discourse they had carried out in diverse classrooms in four different school districts in the Los Angeles area (Gutierrez et al. 1995). From the careful observations they made over the course of a school year, they described how teachers created a power differential through the construction of monological scripts, which resulted in the stifling of dialogue and of real learning; many students who refused to accede to the teachers' expectations for participation (as represented in the employed script) developed powerful "counterscripts" or scripts of their own making. For meaningful teaching and learning to occur, both teacher and students had to create constructive interactions in what Gutierrez and her colleagues termed a "third space," building upon earlier work by such scholars as Homi Bhabha (1994) and Pierre Bourdieu (1991). The challenge associated with this kind of move is that such engagement is many times unfamiliar and high-risk and often runs counter to both personal and cultural expectations. As a result, individuals typically retreat back to their original scripts. But such movement *can* happen. When it does, what counts as knowledge and as participation changes and, as a result, so does teaching practice. Such dynamics have been invoked to explain a variety of similar tensions and counterproductive practices in the classroom (e.g., Moje et al. 2004). These ideas may be equally powerful in explaining what transpires in other learning contexts, such as PLCs.

In my PLC-based work with urban science teachers with varying years of experience, I am observing a phenomenon similar to that observed by Gutierrez and her colleagues. Teachers are motivated to become part of a professional development program for many different reasons—they are dissatisfied with some aspect of their practice, they wish to strengthen their content knowledge, they want to garner resources for their classroom, and/or they feel isolated and want to interact with peers who understand their needs and difficulties. These represent rather than exhaust the motivations for engagement by teachers. Those responsible for delivering the professional development come with their own agenda, and at some point, usually fairly early in the process, what is being asked of participants (e.g., a fundamental shift in their view of student capacity to learn, or their instructional approach) finds its way to the center. These shifts can cause significant tensions to arise.

Consider the case of a teacher who places a high value on classroom order and may in fact have respect from colleagues and administrators as someone who maintains a high degree of order. If she is being asked to orchestrate an activity that involves brainstorming, collaboration, and student-initiated inquiry, then the shift in focus and approach may result in more noise and movement in the classroom. This may signal disorganization and disorder to that teacher, and may present a challenge or even a threat to that teacher's professional identity. The result may be that the teacher resists making the change, preferring her more familiar, comfortable script. If not resolved, this tension may lead to a lack of productivity for the entire group or to a member leaving the PLC, either temporarily or permanently. If the group pushes forward, circling back to the goals that brought them together, recognizing and supporting participants in their struggle toward these goals, and finding ways to accommodate the needs of each of the group's participants, then productive interactions can take place and powerful outcomes can result. The group that manages to accomplish this has created a "third space" for productive interactions, has reconstituted what counts as knowledge, and has allowed the voices of the group's participants to shape this knowledge generation.

Productivity and Sustainability of PLCs: Lessons Learned

Research and evaluation efforts directed at PLCs have revealed much about those factors that are critical in either facilitating or inhibiting productivity and sustainability. Here, I will focus on what we have learned about the features that distinguish productive PLCs, the development of productive PLCs, and the sustaining of productive PLCs.

Professional learning communities, by most scholars' definitions, include individuals who share a goal and work together to achieve it. These may be teachers, but they could also be principals from different schools across a district, or as I will argue in the last section of this chapter, representatives from different intellectual communities within an organization like NARST. However, for a PLC to be productive, there must be norms for collaboration and agreed-upon mechanisms for accountability with respect to the common goal. What also is clear from studies of PLCs (see e.g., McLaughlin and Talbert 2006) is that in every case, even when student outcomes are not an initial driving force, they become woven into the fabric of the group's work and into the system of accountability, independent of any external accountability that might exist in the form of high-stakes tests. Participants use evidence of student performance with respect to specific learning goals, as well as ways in which their own teaching practice can better address gaps they identify in this performance. A critical level of knowledge among the participants also appears to be necessary, along with the expertise to access and distribute resources in powerful ways to support learning. In addition, support by building leadership, in the form of providing time for such work, promoting the value of a collaborative and analytical approach to instructional change, interfacing with parents, and recognizing those who commit to such work, is critical. At the district level, too, there is a need for providing support for evidence-based curriculum changes and distribution of innovative changes in order to build capacity.

Research has also demonstrated that professional identity and context matter greatly as factors that can determine the effectiveness and sustainability of professional growth and leadership. Time and again, programs to support teacher learning flounder when they are not attuned to the sense that teacher participants have of themselves as professionals or to the context in which teachers practice and when they do not allow these issues to be addressed alongside those of science teaching and learning. It is like building an enormous addition onto an existing house without accounting for the size and stability of the foundation or the style and materials of the original structure. But it is also important to point out that a community of practice does not simply accommodate professional identity and context; as stated earlier, identity is a fluid construct, becoming reshaped as experiences are accumulated and sense-making occurs. Deep intellectual engagement in all facets of PLC-based work can and does reshape professional identity; when this work consists of an ongoing cycle of instructional design, implementation, and assessment, and where student performance on meaningful assessments is at the core of this work, educators are led to reconsider what they value and with what community of practice they align themselves, as well as to reconsider their beliefs about what their students are capable of doing. And as a result of this continued work, they can become leaders for instructional change.

Work within these communities of practice also must take into account the context in which its participants practice—not merely their own classrooms but also the school as a cultural institution, and the community within which the school resides. This work also has the potential to change the context in some important ways. Such change is not only accomplished through the distribution of existing resources in the most effective ways possible but also through the creation of third spaces within individual classrooms and within communities designed to support instructional reform, to fundamentally change the culture of teaching and learning, and to provide ongoing support for productive and powerful teaching and learning.

Conclusions and Recommendations

How does a complex organization like NARST support and promote intellectually rigorous and activist work on diversity and equity? In addition, how does this complex organization orchestrate but not dictate generative dialogue among its diverse members about the impact of such work? As NARST has grown, so have the number and type of smaller intellectual communities, composed of scholars who are drawn together by common interests in particular issues, often with varying goals with respect to target audiences and relationships to practice, and differing motivations with respect to activism; this is reflected in the strand structure of the organization. The pattern of growth has become increasingly evident as NARST has become ever more international in its membership and interests. This has led to an increased diversity of interests and local support for the work of NARST scholars, but it also has resulted in a lack of organizational voice for areas of scholarly work that could provide insights for those engaged in diverse research efforts.

Thus, one of the most significant challenges to the NARST organization as a whole is not unlike those faced by PLCs and the districts in which these PLCs reside—to recognize and cultivate the kind of conversations which will maintain and support the identity, as well as the commitments of its constituents, while at the same time serving the needs of the community as a whole. One strategy for doing so might be for the NARST leadership to sponsor an electronic forum across the year to encourage members to post descriptions of issues in which they have an interest but feel are not currently represented by our existing strand structure. A particularly productive set of exchanges about an area of work could be used as a vehicle for designing a special interactive session at the next annual conference, the focus of which would be to explore productive directions for research, potential target audiences, and sources of financial and additional intellectual support; those individuals who had been primary contributors to the online discussion might be asked to play a role in the design and orchestration of such a session. Situating the conversation in the annual conference venue would signal the organization's recognition of the importance of scholarship in this area, and its support of NARST members committed to such work.

Cultivating and mainstreaming these conversations and highlighting their importance to the future of NARST—in this way as well as in other ways—has the potential to provide support for shifts in professional identity along with new and productive collaborations among scholars who find mutual interests and commitments. The conversations that will lead to such changes will at times be awkward and difficult, and it would no doubt in the short term be easier to retreat to our familiar scripts—those conventions of interaction and daily work which we feel are safer, more familiar, and more comfortable. However, in the face of the increasing diversity and needs of children in schools and communities across the globe, an organization such as NARST, situated as it is in both the worlds of research and practice, is even more critical. Our organization as a scholarly community must become a third space within which productive, scholarly exchange and research can take place. And this work can provide research-informed information to the larger community for the purposes of enriching lives and preparing the world's populations to be empowered and productive citizens, who are not only responsible for their own lives, but for the lives of others.

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Chapter 21
International Response for Part V: Equity and Diversity in Science Education and Academia: A South American Perspective

Melina Furman

When seeking an international perspective, we often look to those countries where students "do well" (at least according to international exams) in science. Something apparently works in all those "successful" countries, and the challenge is to find out what works and why, in an attempt to replicate it at home. Yet, if we want to extend the conversation to other contexts and other issues, a question remains to be asked: What can we learn from other types of perspectives? More specifically, what can the analysis of experiences from countries usually considered to be at the margins bring to the table when we inquire about science education in the USA? In this commentary, I provide such an international perspective: a South American vision, particularly a view from the Argentine context, with the hope of building together deeper understandings of the issues we share as a science education community of practice.

In this commentary, I look across the work of Gail Richmond, Maria Rivera Maulucci, and Felicia Moore Mensah. I first talk about recent efforts for diversity and social justice in teacher education. In doing so, I draw on my long-standing work in reform-based science education programs[1] with teachers at schools with the highest levels of social and economic vulnerability in Argentina. Then, I discuss some tensions around promoting equity in academia in my country from a historical and political perspective.

The first topic that I would like to discuss is the importance of taking teacher identity, school context, and explicit social justice goals into account when framing teacher education programs, especially if we share the goal of making teaching for equity and diversity hallmarks of teacher preparation. In her chapter "What Perspectives on Community-Based Learning Can Teach Us About Organizational

[1]For more information on these programs, see www.ebicentenario.org.ar and www.sangari.com.ar

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Support of Research and Policy Work in Equity and Diversity," Richmond discusses recent research that shows the key roles of teacher identity and school context in reform efforts, as the "one size fits all" model of teacher education has again and again shown its drawbacks. As she points out, in teacher education, "the extent to which there is uptake of ideas is shaped by what teachers believe about their students' capacities as learners, how they think of themselves as educators, now and into the future, and the context in which they practice. None of these alone accounts for the extent to which learning occurs; the terrain of the profession and its enactment in schools is too multidimensional and interactional for this to be the case."

In our work with Argentine teachers who teach youth in poverty across the country, we have found similar tensions, albeit shaped within a different context. We have seen how school cultures of what we have called "low-intensity teaching" (especially due to the high levels of absenteeism of teachers and principals alike) start to be challenged and reshaped when programs afford teachers the possibility of building a professional identity based on personal narratives of success with students, as opposed to a deeply engrained feeling of despair and impossibility, which is often the case in Argentine disadvantaged schools. For instance, after 1 year of participation in a reform-based science program that closely helped teachers to develop inquiry-based activities by providing intensive training, teaching materials, and ongoing mentoring, 92.9% of teachers expressed that their confidence in students' possibility of learning had improved (CIPPEC 2010). As one teacher mentioned, "At the beginning of the year I thought that my students would not be capable of this. Now that I see them so connected to science, I believe I really underestimated them."

This comment illustrates a significant finding, since Argentine teachers of youth in poverty often hold a deficit model of their students, describing a significant number of their students as "abnormal" or as "children who should be placed in special education classes." What is more important about this finding is the fact that teachers' views of their students are intricately connected to their own professional identity, especially their sense of self-efficacy as teachers. In other words, as they begin to build personal stories of success (usually related to student engagement but also, sometimes, to what children can learn), teachers start to see their students in a new light. As Mensah claims in her chapter "Retrospective Accounts in the Formation of an Agenda for Diversity, Equity and Social Justice for Science Education," teacher educators have "a strong responsibility, an obligation" to help teachers overcome notions of who can do science. What we have found in our work is that revising these notions is very difficult outside an authentic teaching context and requires sustained work in the field, where teachers get to try out new kinds of pedagogies with their own students, as long as the teachers are closely scaffolded in a way that allows them to build personal stories of success, especially with those children traditionally marginalized from achieving in science (Furman et al. 2008). It is only when teachers start to see that those programs (usually brought to them by state or by university experts) work with their own students that teachers start to revise their assumptions around who is capable of learning science and about the value of scientific skills for children's lives. Equity, as one teacher said, "starts to go beyond politicians' discourse to become a reality in our schools."

We have also found that belonging to a collective of peers who are engaged in reform efforts in schools traditionally considered "at risk" is another important factor that helps teachers revise their notions about students and place equity and diversity at the center of their practice. Unfortunately, the Argentine context makes the professional learning communities (PLCs) that Richmond discusses in her chapter almost impossible to establish, since teachers usually work at two different schools every day and have almost no paid hours for meeting with colleagues. However, it becomes clear from teachers' testimonies that belonging to a collective of peers working within similar contexts becomes an important factor in shaping teachers' identities. As one of our teachers put it: "I don't feel alone anymore. We are many teachers working together, and now we know it can be done. Because doing science is our kids' right. And we have to make sure that they fulfill it." As this quote shows, belonging to a collective of peers supports teachers in starting to see themselves as political actors who have a responsibility to reach all their students and who have the tools to do so.

Second, I would like to discuss the tensions involved in bringing issues of equity and diversity to academia and the challenges that scholars of color face in advancing their professional careers as academics. Richmond proposes that drawing from research in PLCs can contribute to making it possible for members of the NARST community "to feel individually and collectively supported in their pursuit of work in areas of equity and diversity." In their chapter "NARST Equity and Ethics Committee: Mentoring Scholars of Color in the Organization and in the Academy," Rivera Maulucci and Mensah discuss "some of the structural, social, cultural, and symbolic barriers that often impede the progress of scholars of color in the academy."

As opposed to what happens in basic education, where the issues we find in working with teachers and students are in many ways similar to the scenarios we see in the USA, in higher education and academia the tensions we face in Argentina, and South America in general, are more distant. To bring some context to our own issues of diversity, during the late nineteenth and early twentieth centuries, Argentina received large numbers of Southern and Eastern European immigrants as a result of government policies aimed at increasing the country's population. These immigrants mostly formed what is now called the middle class and had access to higher education due to the strong investment in public education that created tuition-free public universities. After the early twentieth century, massive immigration ceased until recent decades when many immigrants from adjacent countries (Bolivia, Perú, and Paraguay) arrived seeking new opportunities. These immigrants have enlarged the numbers of socioeconomically disadvantaged people who currently have almost no access to higher education, let alone academia, a situation compounded by the neoconservative policies of the second half of the twentieth century that deeply weakened public education and the possibilities of social mobility. In the past decades, middle classes have moved to private education, starting from elementary school, which leaves many public schools attended mostly by students in poverty.

Given this context, it is easy to imagine that access to higher education is very scarce for what in the American context would be called "scholars of color."

However, the Argentine population is much less racially and ethnically diverse than the USA, and thus it is socioeconomic status that counts the most in terms of getting access to all spheres of power, including academia. In the past decade, access to higher education for traditionally marginalized groups has increased due to the opening of new tuition-free public universities located in underprivileged areas; nevertheless, access to academia is still a far away goal for most members of these noncentral groups. As Rivera Maulucci and Mensah point out in their chapter, “Like any cultural institution, academia has its own set of norms and discourses that members from underrepresented groups may not know or may find difficult to enact.” In that sense, we have still much more to do in terms of making academia more equitable. It is interesting to note that academia, especially in the social sciences, has paradoxically focused on trying to understand the problems of poverty and inequity of the region. Yet, at present, we might claim that academia itself is one of our least equitable institutions.

However, it is worth mentioning that even when most scholars still belong to the socioeconomic elites (or at least the middle class), the debate on how to make science education more equitable (what American scholars call “science for all”) is very much alive. For instance, very recently, the Argentine government, following similar initiatives in Latin America, decided to give every secondary student in the country one laptop computer, as long as they remain in school and do not drop out. In addition, the government has given a “universal grant per child,” which consists of a monthly stipend for families below a certain level of poverty. This initiative has significantly increased the number of students in public schools, since in order to receive the stipend, children need to attend school regularly. What is now in debate is what kind of support teachers need to use these computers in meaningful ways with their students, in order to help them develop powerful science practices and close the achievement gap that has widened over the past decades. In sum, even when contexts are sometimes very different, it is quite important to know that there is a global community of researchers whose efforts aim to put equity and diversity at the center of their practice. Hopefully, diversity in our own research communities will make us stronger, help us think deeper, and ultimately, improve our countries’ education systems.

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Chapter 22
Epilogue: Moving the Equity Agenda Forward Requires Transformative Action

Alberto J. Rodriguez

In the last four decades, we have made tremendous social, technological, and scientific advances. We have the Civil Rights Act. We have explored the moon and are now making plans to explore Mars. We have completely mapped the human genome. We have also made computers smaller, faster, and smarter. Yet, during this same period, we have not been able to close the student achievement gap. How is this possible when the science education research community has produced so much knowledge clearly describing the social, cultural, and institutional factors that obstruct and/or facilitate equal access to educational opportunities (National Academy of the Sciences [NAS] 2010; Rodriguez 2004)?

In fact, the science education research community has produced a great deal of innovation in terms of enhancing teacher professional development and student learning since the frantic race for space started shortly after the Soviets launched *Sputnik* in 1957. However, we seem to be caught in a perpetual loop of "producing innovation," without often taking the next logical and scientific steps. Such steps would include investigating the challenges to implementing those innovations in different sociocultural contexts, and then scaling up to further explore the innovations' overall impact on a larger population of teachers and/or of students. Without these steps, the end result is this ongoing production of new insights that remain underutilized. I would argue that this might very well be one of the principal reasons why the science education community's research continues to have little or no impact on what and how teachers teach, how students learn, and what policies are enacted by politicians. One need go no further than the No Child Left Behind Act (2001) to clearly see how major educational policies in the USA continue to be driven by political slogans and good intentions instead of by sound educational research.

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In this epilogue, my main goal then is to make an appeal to all reading this volume. Just like scientists around the globe organized an unprecedented collaboration to map the human genome, we should also collaboratively and purposely tackle common issues in science education. We cannot afford morally, ethically, or professionally—as privileged intellectuals—to allow pervasive educational inequalities to continue to fuel the high student dropout rate, the achievement gap, and the lack of students' interest in pursuing science-, math-, engineering-, and technology-related fields. These phenomena, in fact, are not unique to the USA. The student achievement gap between the haves and have-nots and the high dropout rate are also commonly found in Latin American countries (with an average 50% dropout rate, Jacinto 2010). In sub-Saharan African countries, the high-school dropout rates for girls continue to be higher than those for boys with a range of 63–83% (Hoffmann-Barthes et al. 1999). While these issues are extremely complex and influenced by many cultural, historical, social, and institutional factors, there is much we can do to seek transformative action. Below, I provide specific suggestions drawn from findings and insights shared by the authors of this volume, as well as from the work of others. To facilitate discussion, I address three broad questions:

1. How do we organize ourselves to share our work in ways that are congruent with the theories of teaching and learning we profess?
2. How do we conduct our research in ways that more directly address issues of power, voice, and impact (catalytic validity)?
3. How do we impact research funding, evaluation, and policy?

How Do We Organize Ourselves to Share Our Work in Ways That Are Congruent with the Theories of Teaching and Learning We Profess?

It is interesting to observe how we continue to borrow from the Western aristocratic format to share our work at conferences even though research organizations have grown so large. Each year, over 10,000 people from around the world attend the American Educational Research Association's (AERA) annual meeting. Similarly, over 1000 attend the National Association for Research in Science Teaching's (NARST) annual conference. Yet, we usually see presenters following the very transmissive, "fill in the empty vessels" approach that we tell teachers does not work when seeking to engage others in meaningful learning and collaboration. Often, at these research conferences, a large group of presenters are given 10 min or so each to quickly share findings from sometimes multiyear projects with little or no time for discussion with the participants. This industry conveyor belt-like format of "sharing" knowledge is obsolete and out of sync with the advances in technology and learning theories we write so much about.

While it is true that these professional organizations "encourage" alternate formats for presentations, I argue that they are not truly supported. I have attempted several alternate formats with colleagues at both AERA and NARST: They have been successful and productive for my colleagues and me, but these organizations have not been interested in supporting or promoting them. For example, I organized a session at AERA and invited a distinguished panel to participate. Although in reality a research workshop, the only way I thought this session would be fairly reviewed was to disguise it as an "interactive symposium." Since no special attention or points were given to innovative proposals, I did not want to decrease the chance of its acceptance. Further, although we had a distinguished panel of scholars participating, our session did not get the kind of promotion that the traditional invited "talking heads" receive. At this research workshop, the panel members spoke very briefly and then played the role of sounding board. This immediately communicated to all participants that their knowledge and expertise were valued, and that knowledge was not the domain of the panel members alone. Participants were divided into small groups, and each group sat at a table with a specific set of questions and actual research data (key quotes from interviews) to which they were required to respond. The engagement and sharing of knowledge at this workshop was rich and fluid. We could have continued the discussion for another hour, but we were ushered out of the room because another session was starting.

The results of this workshop inspired Richard Kitchen and me to edit our first book, *Preparing Prospective Mathematics and Science Teachers to Teach for Diversity: Promising Strategies for Transformative Pedagogy* (Rodriguez and Kitchen 2005). Almost all of the chapters in this book were written by colleagues who also participated in this workshop and who had similar research interests. How can alternate and innovative formats for sharing our work at research conferences be improved and promoted? I have some suggestions. But, first, I discuss another example of how alternate formats are indirectly discouraged at conferences.

At NARST annual conferences, Randy Yerrick and I organized two interactive workshops also under the guise of "interactive symposia." Both workshops (held in different years) were placed on the last day of the conference, and they were not promoted at all by the conference organizers—even though we had managed to get Apple to loan us a set of 12 desktop computers completely free of charge to the organization and participants (Apple even paid for the shipping and handling). Our goal at these workshops was to have a more twenty-first-century approach to sharing our work. So instead of talking very fast at participants for 10 min, participants at this workshop interacted freely with the researchers, visited their project's website, and watched videos of children and teachers engaged in collaborative learning. Several of the researchers brought students' products and hung them on the walls for participants to review. Again, the conversation was multidimensional, rich, and fluid. The 90 min allocated for our session was relaxed and productive unlike the tense conveyor belt format of the traditional panel sessions.

Even though those who attended commented on how valuable they found the session, and even though I communicated this to the NARST Board (since I was a member at that time), nothing changed in terms of promoting similar innovative and more twenty-first-century approaches to sharing our work. And so, we continue to see PowerPoint presentations without power. That is, even though the technology of gathering and sharing information has changed dramatically, we still continue to see text projected on a screen and a talking head beside it (just like we did when overhead projectors were the top technology).

While I realize that many might prefer the traditional, Western approach of presenting knowledge at conferences, the examples provided above indicate that there is much more we can do to share our research even with the given time constraints and sheer number of conference attendees. The next step then is to seriously promote and encourage alternate forms of presentation by: (1) giving them priority allocation of space; (2) requiring all special interest groups, divisions, and strands to include an *innovative format* category in the review process; (3) making a list of alternate formats with corresponding definitions available to presenters; and (4) reducing the number of talking head (single invited speaker) sessions and create more town hall meetings.

Town hall meetings, for example, were originally established to tackle specific issues and to seek decisive action. We can similarly hold town hall gatherings at research conferences and invite expert panels to engage with participants in the pursuit of new ways to solve common issues. While these town hall meetings will not result in immediate quick fixes, they will facilitate the sharing of knowledge and expertise and inspire new ways of thinking through purposeful discourse. Indeed, town hall meetings, as well as other alternate formats for sharing research, do not necessarily have to focus on solving issues and/or addressing current research findings. They could also be used to advance our understanding of methodological and/or policy-related issues. I deal with these two topics next.

How Do We Conduct Our Research in Ways That More Directly Address Issues of Power, Voice, and Impact (Catalytic Validity)?

With the advent of the No Child Left Behind (NCLB) Act, the so-called "golden research method" (re)gained strength. This involved the notion that for a study to be truly rigorous and scientific, it had to include the traditional control and experimental groups to make valid comparisons and to truly measure impact. This assumption is another example of how educational policies are not informed by actual advances in research. In addition, the NCLB Act also struck a blow to the kind of research scholars interested in qualitative and/or hybrid methodology were able to pursue since funding favored quantitative methods. I will discuss this policy-related topic in more detail in the next section, but here I wish to concentrate on methodological issues.

At the onset, I should make clear that I do support (and often use) qualitative, quantitative, and hybrid methodologies. In my view, these are just tools to enable researchers to investigate their specific research questions. Just like a hammer is not superior to a screwdriver, I do not think quantitative methods are superior to qualitative ones—they are simply that, tools with distinct functions. It is up to researchers, then, to choose the right tools to complete their chosen investigation successfully.

The topic I would like to discuss here has to do with the misuse of research methodologies and their corresponding tools in educational contexts. In the introduction of the *Context and Culture* section (this volume), I pointed out that culture and context are organic and always in flux. Therefore, the research methods and tools we wish to use in today's complex and culturally diverse classrooms must match this reality. In fact, the authors of the section on context and culture provide rich descriptions of how the constructs of culture, context, place-based learning, and equity interact with one another. The education researcher's goal cannot then be the same as that of a content area scientist working in a controlled laboratory environment. As educational researchers, we might as well seek to capture lightning in a bottle if we think one specific methodology or research tool will allow us to capture everything that happens in a classroom. How can we conduct research in educational contexts in ways that are more congruent with the fact that we are working with human beings in impossible-to-control contexts—school settings? Before exploring this question, I wish to explain further why the traditional experimental approach is not appropriate.

To put it bluntly, to require that all research studies have randomization and include control vs. experimental groups in order to be considered truly rigorous and/or valid is not only ludicrous, but also *unethical*, *immoral,* and *impractical* in educational contexts. First of all, in educational contexts, we can never have truly experimental studies—only quasi-experimental at best. As mentioned above, there are too many variables beyond the control of researchers to be able to make the kinds of "objective and scientific" claims researchers who work under controlled laboratory conditions are allowed to make. Most importantly, given all we know already through advances in our work, it is unethical for us to deny teachers and/or students in a control group the benefits of an intervention just to meet the illusion of "experimental" research as required by some funding agencies and their reviewers. Furthermore, this practice is also immoral because given what we know about the achievement gap and the lack of equitable opportunities for success for culturally diverse and economically disadvantaged students, we do not want to contribute to this deplorable situation again by denying some participants access to the benefits of our projects. Jeannie Oakes (1990) clearly explained how the disadvantages some students face in their education, such as low socioeconomic status, second language learning, low academic achievement, and so on, do indeed become "multiplicative inequalities" that tend to intensify and obstruct those students' chances for future success. How could researchers possibly justify contributing to this phenomenon in the name of pursuing "scientific proof" and for the sake of securing funding?

In any case, this broad and blind requirement for randomization and quasi-experimental methodology is simply impractical. For instance, what would you do if you were the parent of the child being asked to be the in the control group? The group the researcher must explain is going to play the role of "pretend guinea pigs" in a "pretend laboratory condition," thus the group that receives no access to the intervention. While in the same letter of consent, the researcher must also explain how wonderful their proposed study is and why it is needed.

I have had to argue many times with proposal reviewers and funding agency directors, either as another member of a proposal review panel or as the principal investigator of a research project, to explain that we could do better. We could indeed carry out a modified version of quasi-experimental research using either quantitative, qualitative, or hybrid methodologies as needed. Therefore, again, I must clarify; it is not that we should not use quasi-experimental methods. Rather, the problem is when one method is held above all others as superior and/or blindly required regardless of the educational contexts and/or research questions under investigation.

On one hand, depending on the project, we could conduct rigorous studies without having formal control vs. experimental groups just by simply developing strong baselines and measuring growth comparatively across classrooms/grade levels. I have found in my own research projects that there is so much variability in the contexts in which teachers work—even from the same schools and grade levels—that comparison groups often emerge naturally (and realistically). By having a strong baseline (data gathered via surveys, interviews, academic achievement records, personal and professional/educational histories, etc.) before the intervention, it is possible to measure changes in growth over time. This of course requires longitudinal projects (at least 1–3 years) with field-based observations to measure significant change. The benefit of this approach is that all participants have access to the intervention.

On the other hand, if we must carry out a quasi-experimental study, we need to avoid the unethical, immoral, and impractical traps described above. This can be accomplished by ensuring that the control group participants eventually receive the benefits of the intervention. I have successfully argued two ways to accomplish this with funding agencies. The first I call *phased-in intervention*. This research design allows for the gradual integration of control group participants into the intervention (experimental) at appropriate intervals during the study. For instance, if a project is investigating the effect of a professional development intervention on student achievement on three grade 4 and three grade 5 classrooms, in Year 1 of the project, 2 classrooms per grade level could be randomly assigned as the intervention classroom and 1 classroom per grade level could play the role of control. If the project is a multiyear study, as the grade 4 control group students move to grade 5 the following year, they could be assigned to the intervention (experimental) group so this time they get exposed to the benefits of the intervention. If the project is for 3 years, all grade 6 students and teachers should be exposed to the intervention. The second approach is called *compensatory intervention.* If the project is only for 2 years, the students in the grade 5 control group who move to grade 6 and miss the intervention can be offered special after-school workshops to at least expose them to the benefits of the program. I have done this when it comes to integrating learning technologies with inquiry-based science teaching. In this way, no student is denied at least some exposure to the benefits of the program under study just because of the requirement to have traditional control groups by funding agencies. Since we are not working with animals in a controlled laboratory environment, we must be respectful, inclusive, and attentive to the complex demands of teaching and learning in today's diverse schools. We can maintain our project's methodological rigor and, at the same time, adjust our research tools to fit the organic and fluid contexts of culturally diverse classrooms.

One more methodological issue we should consider is the concept of *catalytic validity* (Lather 1991). This construct—which also draws from Paulo Freire's (1970) notion of *conscientization*—essentially states that one of the goals of the research enterprise is to instigate participants to take transformative action. In this way, the role of the researcher is not that of the traditional, Western, positivist, detached, and objective gatherer of data, but one who is actively working with research participants to become more active (and aware) agents of their own professional knowledge and growth (Rodriguez 2008). This approach requires then that we again reconceptualize the ways in which we conduct research to meet the demands of twenty-first-century classrooms. In doing so, we could work with "the Other" toward sustainable and positive change that will continue long after our finite research projects have come to an end.

How Do We Impact Research Funding, Evaluation, and Policy?

This policy-related question is probably the hardest to impact due to the perceived low status science educators have in the eyes of funding agencies. This is better explained with an example. Using federal funding from the Improving Teacher Quality (Title II) Grants Programs, the California Department of Education has a program designed to support mathematics and science partnerships projects (CaMSP). These partnerships are to be established between institutions of higher education and high-need schools. One million dollars is allocated to support projects that "provide professional development for teachers using scientifically based and researched teaching methods to improve the mathematics or science achievement and academic performance of students participating in these projects" (CaMSP 2011, p. 3). This is definitely an excellent mission; but according to this program, the best qualified to help teachers become "qualified teachers leading the way" are not experienced science or mathematics education scholars. In fact, not even a seasoned science or mathematics education scholar can be the principal investigator (PI) of any of these projects! According to the CaMSP's guidelines, "The PI must be a mathematics, science, or engineering faculty member from a partnership IHE (Institution of Higher Education) and the Co-PI must be from the Lead LEA (Local Education Agency or school)" (2011, p. 12). This means that a science or engineering faculty member, fresh out of graduate school, whose last experience working with teachers could very well have been when they were students themselves, can become PI of these programs; whereas, a seasoned science education or math education scholar with years of experience in teacher professional development is not even permitted to become a Co-PI. Furthermore, according to the CaMSP (2011) guidelines, the primary purpose of the partnerships is

> to increase the body of research on professional development models that: 1. Impact teachers' content knowledge, pedagogical content knowledge, and instructional strategies; 2. Improve student achievement in the content areas of mathematics and science, and 3. Result in change to the institutions involved in the project, including change to the IHEs and professional development providers (p. 4).

What kind of training in curriculum development, learning theory, cross-cultural education, educational research, bilingual education, and pedagogical content knowledge do subject area scientists and engineers receive that would automatically make them qualified to be the PI of teacher professional development projects in culturally diverse classrooms as those commonly found in California? Who writes these policies? How can this policy in the CaMSP be allowed to exist for many years unchallenged by leaders of the science and mathematics education communities? What other states have similar policies?

Those of us who have served on review panels for Federal agencies (such as the National Science Foundation or the US Department of Education) know that this low status perception of science and mathematics educators is not unique to the California Department of Education. In fact, I recently finished a manuscript entitled, *Puppet PI's, Shadow PI's and Other Acts of Deception: Exposing Another Reason for the Slow Progress in Improving Science Teaching Practice and Student Learning*, in which I describe other abuses and contradictions in existing funding policies. For example, the biased support funding agencies provide to "grant mill" projects. That is, projects produced by a specially hired group of people, usually associated with colleges of science or engineering, to compete for science and/or math education grants with little or no participation from science and/or math education scholars.

I realize that most may find it difficult to criticize existing funding agencies and their policies for fear of the impact this may have on their future applications for support. However, how are these agencies to become aware of the current inequities and contradictions in their policies if we do not point them out? This is where the leadership of major research organizations, such as AERA and NARST, could play a powerful role in bringing about change. We should require those we elect to represent the interests of the educational research communities to call for meetings with top government officials, agency directors, and private foundation directors to discuss the revision of current policies and the refocusing of funding priorities.

It is obvious that we cannot afford business as usual in the ways educational research is funded, evaluated, and implemented. The current census indicates that almost 37% of the population of the USA is composed of ethnic minorities, and 46.5% of all individuals below 18 years are minorities (U.S. Census 2010). At the same time, Latinos/as—the fastest growing ethnic group in the country—continue to experience the highest school dropout rate and widest academic achievement gap. The economic implications of this trend to the country have been widely discussed, but most importantly, we should be cognizant that the moral and social consequences of this trend will most likely leave deeper wounds among scores of youth who will ask why we—as privileged intellectuals—did not act more promptly and decisively.

We can begin to address the issues brought up here and by the authors of this volume by seeking to indeed move the equity agenda forward at multiple levels, decisively and focused on transformative action.

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ERRATUM

Epilogue: Moving the Equity Agenda Forward Requires Transformative Action

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