Introduction

Ever since our nation first embraced the goal of mass schooling, it has faced the challenge of balancing the concern for educational quality with the desire to reach as many students as possible. Today, this dilemma is reflected in the dual aims of promoting high academic achievement while simultaneously pursuing educational equity for an increasingly diverse student population (Darling-Hammond, 1996; McLaughlin, Shepard, & O'Day, 1995). To achieve these aims, it is necessary to develop a knowledge base that situates recent advances in our understanding of educational processes within the realities of today's schools. This need is especially urgent, given the current climate of standards-based instruction, high-stakes assessment, and accountability. The literature review presented in this synthesis is a step in developing such an empirically based integration.

Knowledge about science and technology is increasingly important in today's world. Aside from the growing number of professions that require a working familiarity with scientific concepts and high-tech tools, the future of our society hangs in the balance of decisions that must be made on the basis of scientific knowledge. Documents on science education standards (American Association for the Advancement of Science [AAAS], 1989, 1993; National Research Council [NRC], 1996, 2000) represent the science education community's best efforts to define what constitutes science learning and achievement (see the summary in Lee & Paik, 2000; Raizen, 1998). According to these documents, science learning involves a two-part process: "to acquire both scientific knowledge of the world and scientific habits of mind at the same time" (AAAS, 1989, p. 190).

The development of scientific knowledge involves "knowing" science (i.e., scientific understanding), "doing" science (i.e., scientific inquiry), and "talking" science (i.e., scientific discourse). Knowing science involves making meaning of scientific concepts and vocabulary. One way that students come to know science is by doing science, that is, engaging in science inquiry by generating questions, designing and carrying out investigations, analyzing data, proposing explanations, interpreting and verifying evidence, and constructing ideas to make sense of the world. Although knowing and doing have long been acknowledged as important components of science learning, recent science reform also emphasizes "talking science," whereby "teachers structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse. A fundamental aspect of a community of learners is communication" (NRC, 1996, p. 50).

The cultivation of scientific habits of mind entails adopting scientific values and attitudes, as well as the scientific worldview. Most cultural traditions embrace some values and attitudes that are associated with science, such as wonder, curiosity, interest, diligence, persistence, openness to new ideas, imagination, and respect toward nature. Other values and attitudes are particularly characteristic of Western modern science, for example, questioning, thinking critically and independently, reasoning from empirical evidence, making arguments based on logic rather than personal or institutional authority, openly critiquing the arguments of others, and tolerating ambiguity. Furthermore, science is a way of knowing that "distinguishes itself from other ways of knowing and from other bodies of knowledge" (NRC, 1996, p. 201). The scientific worldview is defined by a tradition of seeking to understand how the world works – to describe, explain, predict, and control natural phenomena. It is distinguished from alternative worldviews: "Explanations on how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific" (NRC, 1996, p. 201).

Although the standards documents generally define science in the Western modern science tradition (AAAS, 1989, p. 136; NRC, 1996, pp. 201, 204), alternative views of science have been advocated by scholars in emerging areas of multicultural education, feminism, sociology and philosophy of science, and critical theory (Atwater & Riley, 1993; Calabrese Barton, 1998a; Eisenhart, Finkel, & Marion, 1996; Hodson, 1993; Lee, 1999a; Rodriguez, 1997; Stanley & Brickhouse, 1994, 2001). These scholars raise issues of power and the marginalization of nonmainstream groups, and challenge the very notion of science and the traditional definition of learning science (see the discussion in the section entitled "Views of Science: Is Science Independent of Culture?" in Chapter 2).

As immigrants, children of color, and children living in poverty come to represent an increasing fraction of the U.S. student population (García, 1999; National Center for Children in Poverty, 1995), science classrooms must address the educational needs of these children, who face the dual challenge of navigating the language and culture of the U.S. mainstream while also learning the academic norms, content, and processes of science disciplines. Thus, a vision of reform aiming at academic achievement for all students requires integrating disciplinary knowledge with knowledge of student diversity. Traditionally, disciplinary knowledge and student diversity have constituted separate research agendas. In the case of science education, although reform documents highlight "science for all" as the principle of equity and excellence (AAAS, 1989, 1993; NRC, 1996), they do not provide a coherent conception of equity or strategies for achieving it (Eisenhart et al., 1996; Lee, 1999a; S. Lynch, 2000; Rodriguez, 1997). On the other hand, the multicultural education literature emphasizes issues of cultural and linguistic diversity and equity, but with little consideration of the specific demands of different academic disciplines. In addition, although English language and literacy development in the context of subject area instruction is emphasized for English language learners – ELL students (Teachers of English to Speakers of Other Languages, 1997), research in this area focuses primarily on English language proficiency, with limited attention to achievement in subject areas such as science (August & Hakuta, 1997). Integration of "discipline-specific" and "diversity-oriented" approaches is necessary for achieving the goal of making science accessible for all students.

International studies, such as the Third International Mathematics and Science Study (TIMSS), reveal alarmingly poor performance of U.S. students on standardized science assessments (National Center for Education Statistics, 1996; Schmidt, McKnight, & Raizen, 1997). Additionally, the rank of U.S. students declines even further as they move up into the higher grades. Studies based on U.S. national samples, such as the National Assessment of Educational Progress (NAEP), indicate that the average scores for students of every age level and race/ethnicity have increased only slightly since the 1970s (Campbell, Hombo, & Mazzeo, 2000; O'Sullivan, Lauko, Grigg, Qian, Zhang, 2003; Rodriguez, 1998a). Furthermore, achievement gaps among students of diverse racial/ethnic and socioeconomic backgrounds have persisted in science achievement, as well as in science course enrollments leading to careers in science and engineering fields (Chipman & Thomas, 1987; National Science Foundation [NSF], 2002; Oakes, 1990).

Given overall poor science performance and the persistent gaps in science outcomes between mainstream and nonmainstream students in the United States, there is a pressing need to address students' cultural, linguistic, and socioeconomic circumstances in relation to science outcomes. Traditionally, while the science and science education communities advocate for greater participation of nonmainstream individuals in science-related fields, they expect these individuals to assimilate to the established institutional culture. There has been little recognition of the cultural and linguistic resources that nonmainstream individuals and groups bring to the science classroom, and little thought has been given to how to articulate these resources with the values and practices of science in order to enhance science outcomes in school and beyond.

Although classroom practices, local institutional conditions, and broader policy contexts affect all students, they are more likely to negatively impact nonmainstream students. All too often, teachers' knowledge of science and/or student diversity is insufficient to guide students from all backgrounds toward meaningful science learning. Furthermore, beginning teachers or those with inadequate teacher preparation tend to be assigned to inner-city schools where nonmainstream students are concentrated. Additionally, resources are scarcer and teacher attrition is higher in inner-city schools. Limited resources often force a trade-off between providing modified instruction that takes student diversity into account and reinforcing general standards to raise the quality of instruction for mainstream students (often to the detriment of other student groups). The trend toward standardization of curricula and assessment may also work against educational equity (McNeil, 2000), although there are efforts to promote both goals simultaneously (Delpit, 2003).

If we start from the assumption that high academic achievement is potentially attainable by most children, then achievement gaps among racial/ethnic, linguistic, or socioeconomic status (SES) groups can be interpreted as a product of (a) the learning opportunities available to different groups of students and (b) the degree to which circumstances permit them to take advantage of those opportunities. This poses questions for researchers and educators: What constitutes equitable learning opportunities, how do they vary for different student populations, and how can they be provided in a context of limited resources and conflicting educational priorities?

The literature reviewed in this book presents promising results about effective science education for nonmainstream students. These students come to school with already constructed knowledge, including their home language and cultural values. *Equitable learning opportunities* occur when school science values and respects the experiences these students bring from their home and community environments, articulates their cultural and linguistic knowledge with science disciplines, and offers educational resources and funding to support their learning at a level comparable to that available for mainstream students. Provided with equitable learning opportunities, these students are capable of demonstrating science achievement, interest, and agency, becoming bicultural and bilingual border crossers between their own cultural and speech communities and the science learning community.

This book analyzes and synthesizes current research on how cultural, linguistic, and socioeconomic factors in school and at home promote or hinder science achievement among nonmainstream K–12 students who have traditionally been underserved by the education system. Specifically, it examines how science achievement and other outcomes (broadly defined) are related to various factors involving science curriculum (including computer technology), instructional practices, assessment, teacher education, school organization, educational policies, and home and community connections to school science. The book emphasizes science education initiatives, interventions, or programs that have been successful with nonmainstream students. Based on the research synthesis, it proposes a research agenda to strengthen those areas in which the need for a knowledge base is most urgent, as well as those which show promise in establishing a robust knowledge base.

In analyzing and synthesizing current research, the book considers primarily peer-reviewed journal articles that provide clear statements of research questions, clear descriptions of research methods, convincing links between the evidence presented and the research questions, and valid conclusions based on the results (Shavelson & Towne, 2002). The rigor of the research methods employed is critically important in assessing the evidentiary warrants for the claims being made in each study and, more importantly, in assessing the robustness of a knowledge base in each area of research. The book provides descriptions of research methods along with results in each study, as well as discussion about methodological orientations and key findings in each area of research. The methodological and other criteria for the inclusion of research studies in the synthesis are described in detail in the Appendix.

There are four sections to the book, each with multiple chapters. In the first section, a range of conceptual and policy issues is addressed. The discussion starts with science achievement (i.e., measured outcomes) and student diversity as two key constructs in this synthesis. Based on this discussion, desired science outcomes for nonmainstream students are defined. Then, conceptual and policy issues guiding the synthesis are discussed, including the epistemological debate over definitions of science and school science, theoretical perspectives guiding research studies, and the policy context of high-stakes assessment and accountability in science education.

The second section starts with student characteristics and science learning linked to gaps in science outcomes among different student populations. Student learning occurs in the context of classroom practices – what materials are used, what content is taught, how the content is taught, and how students' mastery of the content is assessed. This section is organized into the following chapters: (a) student characteristics and science learning, (b) science curriculum (including computer technology), (c) science instruction, and (d) science assessment. Within each category, studies addressing bilingual or ELL students are discussed separately.

The third section addresses school- and home-based factors supporting or hindering science education in relation to gaps in science outcomes among different student populations. Classroom practices occur in the broader context of teacher education programs and educational policies. Although educational policies and practices influence all students, the impact is more consequential with nonmainstream students who are less likely to live in homes that provide the sort of academic supports that the school takes for granted. Thus, establishing connections between home/community and school science is critically important for nonmainstream students. This section consists of the following chapters: (a) science teacher education, (b) school organization and educational policy, and (c) home and community connections to school science. Within each category, studies addressing bilingual or ELL students are discussed separately.

Finally, we draw conclusions regarding two areas: (a) key features of the literature with regard to theoretical perspectives and methodological orientations, and (b) key findings about school- and home-based factors related to science outcomes of nonmainstream students. We offer recommendations for a research agenda to improve science outcomes and narrow achievement gaps among diverse student groups.

SECTION I

CONCEPTUAL GROUNDING AND POLICY CONTEXT

Knowledge of science and technology is an important part of being an educated citizen in the 21st century. As nonmainstream students come to constitute a large fraction of the nation's overall student population, achievement gaps in science among students of diverse cultural, linguistic, and socioeconomic backgrounds are of great concern. While achievement gaps in school science are generally comparable to those in other subject areas, science has not received as much attention from educators and researchers as have core subjects, such as reading, writing, and mathematics. Unlike literacy and numeracy, science is not perceived as a "basic skill"; this trend is reinforced by the fact that current policies of high-stakes assessment and accountability focus mainly on reading, writing, and mathematics. Furthermore, science is often ignored in inner-city schools (where nonmainstream students tend to be concentrated), due to limited funding and resources and the urgency of developing basic literacy and numeracy (National Center for Education Statistics, 1997).

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Student Diversity and Science Outcomes

A focus on student diversity presumes that educational decisions, from statewide policies to individual classroom practices, may affect different student populations differently. Therefore, while the various aspects of student diversity are reflected in differing science outcomes, the ways in which policies and schools define, delimit, and manage student diversity may affect outcomes at least as much as does "diversity" itself. Regardless of the origin or nature of students' marginalization, academic success depends to a significant degree on assimilation to mainstream cultural and linguistic norms, for example, particular ways of structuring narratives, displaying competence, or interacting with adults, not to mention the phonological and grammatical conventions of standard English (Delpit, 1995; Heath, 1983). Traditional science instruction generally assumes that students have access to certain educational resources at home (such as computers, or adults with the time and academic skills to help with homework), and it requires students living in poverty to adopt learning habits that necessitate a certain level of socioeconomic stability (such as a quiet place to study, and freedom from child care or work-related responsibilities). While some students may overcome these barriers to academic success through exceptional talent, effort, or family support, the existence of such individuals does not negate the inequity of their educational circumstances or the need for social solutions to what are social, not individual, problems. Such issues must be taken into account in interpreting gaps in science outcomes among diverse student groups and in devising instructional programs to close the gaps.

Student Diversity

Student diversity in general, as well as particular categories of students, can be defined in different ways (Gutiérrez & Rogoff, 2003). This book focuses on student diversity in terms of race/ethnicity, culture, home language, and SES. This focus places particular emphasis on immigrant or U.S.-born racial/ethnic minority students, whose educational success depends largely on acquiring the standard language and shared culture of "mainstream" U.S. society. Most of these students are characterized as non-White, and a disproportionate number come from low-income families (August & Hakuta, 1997; García, 1999; National Center for Children in Poverty, 1995).

While categories such as these are necessary for analytic reasons, they are heuristic tools rather than natural groupings or fixed human characteristics. Researchers aiming to shed light upon the social patterning of educational access and achievement, as well as readers of educational research, should keep in mind that the social reality in which educational processes occur is inevitably more complex than such categorical divisions imply. For this reason, the following caveat by Lemke (2001) is pertinent, though infrequently observed:

> I should not be using terms such as *class, gender, sexuality*, and especially *race*, or even in many contexts *culture* and *language*, without problematizing them. None of these notions has objective definitions; all of them represent potentially misleading and harmful oversimplications of the complexity of human similarities and differences. All of them owe their origins and historical prominence to explicitly political rather than scientific agendas. Every research study which frames itself in these terms should also be an inquiry into the limitations of applicability of the concepts themselves, refining and replacing them according to the salient features of the data at hand. Every researcher who uses them should have investigated their histories and be familiar with the relevant critiques of their validity. This is not often enough the case in the science education literature. (p. 303)

Each of the dimensions of identity named here – race/ethnicity, culture, language, and social class – is itself a complex, shifting, social, and political field. At the same time, the interplay among them is also complex. On the one hand, it is difficult methodologically to separate out the influences of different variables, which may cut across populations in ways that are not easily untangled. For example, a given immigrant population may contain individuals of varied racial/ethnic backgrounds, racial/ethnic groups are internally stratified by class, and certain cultural values and practices may be shared across different socioeconomic strata within a racial/ethnic group while others may not (e.g., Lee, 1999b). On the other hand, these variables are not entirely independent of one another, conceptually speaking; language is an important element of race/ethnicity, culture is partly determined by social class, and so on. Racial/ethnic identities as well as language proficiencies are less discrete than is implied by commonly used demographic categories; they may vary within a single household or across the life-span of a single individual. Furthermore, although shared language, culture, and ancestry are generally important components of racial/ethnic identity, the relative importance of each component varies widely from one racial/ethnic group to another and from one social context to another.

Social theorists have proposed concepts such as "languaculture" (Agar, 1996), "class cultures" (Bourdieu, 1984), "social class dialects" (Labov, 1966), and even "Ebonics" (Ogbu, 1999) to capture the inevitable intertwining of race/ethnicity, culture, language, and social class – not to mention the complex ways in which gender interacts with all of these areas.[1] Especially with regard to native speakers of nonstandard dialects of English (e.g., African Americans, working-class Whites, and some Hispanic and Native American populations), the influences of race/ethnicity, culture, language, and social class on students' educational performance are more often conflated than systematically analyzed. Failure to disaggregate student outcomes according to these variables has limited the knowledge base with regard to the educational progress of nonmainstream students. On the other hand, the habit of treating these variables as discrete and independent, both conceptually and methodologically, and the failure of most educational research to adequately theorize the connections among them, has further limited research.

Varying usages of terminology to refer to human social groups often reflect different theoretical stances or disciplinary traditions. This is particularly notable with regard to racial/ethnic categories. Most social scientists today agree that human "races" are cultural categories rather than biological ones (American Anthropological Association, 1998). This is evident from the fact that racial groupings are defined differently from one society to another. Nevertheless, governmental bureaucracies, including educational systems, continue to treat them as discrete, self-evident designations, with the result that children may be categorized differently from their parents, or children of different nationalities may be lumped together in the same statistical category on the basis of their skin color.

The lack of consensus around demographic designations for different categories of students reflects the rapidly changing makeup of the population, the changing political connotations of different terms, and the specific aspects of identity that researchers and/or subjects may wish to emphasize. Although this sometimes causes difficulty with regard to comparability of studies, the lack of a standard terminology to describe the overlapping dimensions of student diversity is a valid reflection of the fluid, multiply determined, and historically situated nature of identity, and the ways in which such designations are used to stake out particular claims about the location and nature of social boundaries. While much of the science

[1] The science education literature on gender as it intersects with race/ethnicity, culture, language, and social class is limited and is not discussed in this report (see Baker & Leary, 1995; Brickhouse & Potter, 2002; Brickhouse, Lowery, & Schultz, 2000; Catsambis, 1995; Davis, 2002; Jegede & Okebukola, 1992; Rennie, 1998).