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Science Curriculum and Student Diversity:
Culture, Language, and Socioeconomic Status

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Abstract

We address issues of science curriculum for nonmainstream students—students of color, students learning English as a new language, and students from low-income families—who are often concentrated in urban schools. First, we discuss challenges in designing and implementing science curriculum materials for nonmainstream students. While some of these challenges impact nonmainstream students more broadly, other challenges are more closely related to specific student groups. Second, we review the literature and provide examples of curriculum development and research programs for targeted student groups. Finally, we offer a research agenda to guide future research and development efforts. We highlight how alternative, sometimes competing, theoretical views on curriculum development in the literature can be brought together. We also consider curriculum development in the context of high-stakes testing and accountability policy across school subjects.

Science Curriculum and Student Diversity:
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While appropriate curriculum materials are essential to effective instruction, high quality materials that meet current science education standards are difficult to find, and are even less likely to be available in urban schools where nonmainstream students—students of color, students learning English as a new language, and students from low-income families—are concentrated. Despite this paucity of quality materials, especially for nonmainstream students, such materials have not been in high demand compared to curriculum materials for the core subjects of reading, writing, and mathematics. Given the impending educational context of high-stakes testing and accountability in science, however, the need for such robust science curriculum materials has never been greater. The fact that nonmainstream students are less likely to have access to high quality materials presents a barrier to learning opportunities.

In this article, we address issues of science curriculum for nonmainstream students who are often concentrated in urban schools. Although we limit our discussion to curriculum materials as products that can be used for wide dissemination, we acknowledge that multicultural and urban science educators emphasize the role and value of emergent curriculum as part of instruction in particular local contexts. First, we discuss challenges in designing and implementing science curriculum materials for nonmainstream students. Second, we review the literature and provide a few examples of curriculum development and research programs for targeted student groups. Finally, we offer a research agenda to guide future research and development efforts. We highlight

how alternative, sometimes competing, theoretical views can be brought together within the context of high-stakes testing and accountability policy.

Challenges

The socio-cultural forces at work in science education with nonmainstream students cannot be fully understood without reference to the socio-historical forces that have long disadvantaged nonmainstream students by failing to provide them with equitable distribution of physical, human, and material resources (including curriculum) needed to excel at learning science. While some of the challenges in designing and implementing science curriculum for nonmainstream students impact them more broadly, other challenges are more closely related to specific student groups.

Accountability Policies Influencing Culture, Language, and Socioeconomic Status

After almost a decade of accountability in reading, writing, and mathematics, many states are now moving to incorporate science in accountability measures. This trend coincides with the planned federal policy on science accountability within the *No Child Left Behind [NCLB]* Act (Public Law No. 107-110, 115 Stat. 1425, 2002), scheduled to take effect in 2007. These policy changes at the federal and state levels may bring about dramatic modifications in many aspects of science education. Given that the *NCLB* Act is inadequately funded, however, it does not provide schools with the resources necessary to meet the accountability standards it imposes. The consequences of such changes will likely be greater for students at under-funded urban schools (McNeil, 2000) and ELL students (Abedi, 2004) than for their mainstream counterparts.

Standards-based instruction and accountability policies reinforce the mainstream view that linguistic and cultural minorities are expected to assimilate to the dominant

language and culture (Lee & Luykx, 2005). State science standards and benchmarks usually make no mention of students' home language and culture and, thus, there is no expectation to infuse home language and culture into accountability measures. These policies give rise to ideological and conceptual challenges, since there are few incentives for curriculum developers (or teachers) to incorporate students' home language and culture in the climate of a one-size-fits-all approach. Such policy demands are felt more strongly in urban schools where the threat of accountability-related sanctions is more serious (Spillane, Diamond, Walker, Halverson, & Jita, 2001).

Education reform and specifically the *NCLB* Act require that all students achieve high academic standards. Assessments of science achievement necessitate consideration of fairness to different student groups. How can valid and equitable assessments be ensured for all students? With ELL students, assessments should distinguish among academic achievement, English proficiency, and general literacy (Solano-Flores & Trumbull, 2003). Although large-scale assessments may include various accommodation strategies, they are rarely administered in languages other than English (Abedi, 2004). Even when assessments are administered in a student's home language, ensuring the comparability of assessment instruments between two languages is complicated. Such assessment policies can drive curriculum in directions that lead to inequitable outcomes.

Epistemology and Culture

The core of epistemological debate involves universal vs. multicultural views of science (Buxton, 2001; Loving, 1997; Snively & Corsiglia, 2001; Stanley & Brickhouse, 1994). "Science" has traditionally been equated with Western science over the last 500 years (American Association for the Advancement of Science [AAAS], 1989, p. 136,

1993; National Research Council, 1996). This definition conceives of science in universal terms—“Science assumes that the universe is, as its name implies, a vast single system in which the basic rules are everywhere the same. Knowledge gained from studying one part of the universe is applicable to other parts” (AAAS, 1989, pp. 3-4). Universalism considers that Western modern science, while originating in a specific cultural tradition, is a universally valid endeavor with a set of tenets that transcends cultural boundaries.

Multicultural science educators and feminist philosophers of science criticize the traditional assumption that science is universal and “culture-free” and claim that such a standpoint fails to consider other cultures’ views of the natural world (Atwater, 1996; Eisenhart, Finkel, & Marion, 1996; Harding, 1993; Rodriguez, 1997). The multicultural science literature conceives of science as a socially and culturally constructed discipline, questions the dominance of Western modern science, and advocates for inclusion of non-Western, indigenous, or other racial/ethnic traditions of knowing the natural world. In addition, this literature calls into question the assumption that “Western” science is a uniquely Western construct (Teresi, 2003).

Although the multicultural science literature values both Western modern science and alternative views of the natural world, the relative emphasis placed on each differs along a spectrum of epistemologies. Approaches grounded in theories of cultural congruence aim to integrate the beliefs and worldviews of non-Western peoples, while recognizing the explanatory and predictive power of Western modern science and ways of knowing (Aikenhead & Jegede, 1999; Loving, 1997). Approaches grounded in theories of practice propose explanations of how individuals from diverse backgrounds learn to function both within and against structural and cultural norms of science and may

gradually change these norms in ways that make them more accepting of diverse perspectives (Buxton, 2001; Carlone, 2004; Eisenhart & Finkel, 1998; Rahm, Miller, Hartley, & Moore, 2003). Approaches grounded in postmodern and critical epistemologies argue that the nature and practice of science, as traditionally defined by middle-class White males, should be transformed to include multiple voices and ways of knowing characteristic of female and non-Western participants (Calabrese Barton, 1998; Haraway, 1991; Rodriguez, 1997).

Despite such variations, the multicultural science literature is consistent in the concern that universalism grounded in Western modern science may lead to a model of assimilation that discounts and devalues cultural diversity, as it expects students to identify with science as universal knowledge and to leave their cultural beliefs behind in order to succeed in the dominant society. This literature argues for the importance of using culturally relevant curriculum materials that recognize diverse cultural perspectives and contributions (National Science Foundation, 1998; Ninnes, 2000). This approach presents various challenges. First, there is an inadequate knowledge base of how the norms and practices of different cultural groups relate to specific science topics. The knowledge base for science-related examples, analogies, beliefs, and practices from a range of cultures is also limited. Where such a knowledge base does exist, instructional materials may be developed for specific cultural groups (e.g., Aikenhead, 1997; Matthews & Smith, 1994). However, in educational settings that bring together students from multiple cultural backgrounds, it is difficult to incorporate knowledge from all these groups into instructional materials without making the materials too cumbersome, expensive, or otherwise impractical. Additionally, there are concerns about fueling

stereotypes, biases, or overgeneralizations about particular student groups on the basis of limited information. Furthermore, developing instructional materials that incorporate local linguistic and cultural knowledge may run counter to the desire for standardized materials in large-scale implementation.

Bilingual and ESOL Education Policy and Home Language

Language programs for ELL students have been a topic of debate among politicians and the public as well as educators (Wiley & Wright, 2004). Policies mandating different types of bilingual/ESOL education largely determine how subject areas are taught to ELL students. In states that support bilingual education, science instruction can build on students' prior knowledge in science and the home language while students develop English proficiency (Kelly & Breton, 2001; Rosebery, Warren, & Conant, 1992). Currently, more states are shifting from bilingual education to "English only" policies that disregard development of students' home language and fail to consider students' proficiencies in the home language as relevant to academic achievement (Gutiérrez et al., 2002). In these states, science instruction for most ELL students is conducted in English; thus students must learn new academic content in a language that they are still in the beginning stages of acquiring. In addition, some students may be removed from their classrooms during science instruction to receive instruction for English language development, and thus may receive little or no science instruction until they are assessed as English proficient. Furthermore, they may be deemed English proficient well before they have mastered the academic register of English. All of these policies tend to restrict the science learning opportunities available to ELL students.

Teachers who are willing to make use of students' home language and culture in science instruction face additional challenges. Curriculum materials and other science trade books in languages other than English are limited. Many of the curricular resources in languages other than English are translations of English language materials that lag behind the current generation of English language curriculum and thus may not be fully aligned with the demands of accountability policy. Additionally, the more innovative curriculum materials, such as those developed in the science education research community, are less likely to be translated into languages other than English than some of the mass produced curricular materials.

Research on science curriculum with ELL students highlights the role of hands-on, inquiry-based science in enabling these students to develop scientific understanding and acquire English proficiency simultaneously (Amaral, Garrison, & Klentschy, 2002; Lee, Deaktor, Hart, Cuevas, & Enders, 2005). First, hands-on activities are less dependent on formal mastery of the language of instruction, thus reducing the linguistic burden on ELL students. Second, hands-on activities through collaborative inquiry foster language acquisition in the context of authentic communication about science knowledge and practice. Third, inquiry-based science promotes student communication of their understanding in a variety of formats, including written, oral, gestural, and graphic. Fourth, by engaging in the multiple components of science inquiry, ELL students develop their grammar and vocabulary as well as their familiarity with scientific genres of speaking and writing. Finally, language functions (e.g., describing, hypothesizing, explaining, predicting, reflecting) can develop simultaneously with science inquiry and process skills (e.g., observing, describing, explaining, predicting, estimating,

representing, inferring) (Casteel & Isom, 1994). In reality, however, ELL students rarely experience hands-on, inquiry science due to a host of reasons.

Urban Schools and Socioeconomic Status

The research has generally focused on (a) low SES rather than middle or high SES and (b) urban rather than rural or suburban settings. In the first case, the rationale is that “mainstream” studies of science learning have taken place with student populations of middle or high SES and thus the impact of poverty on science education should be more closely examined. In the second case, the rationale is that high concentrations of students in poverty reside in urban settings. While rural poverty impacts science education in unique ways, there is a paucity of literature on the subject (see Brown, & Swanson, 2003 for an overall discussion of the challenges of rural poverty).

As teachers increase their knowledge of science content and instructional strategies, they also need support in the form of science curricular resources to implement these new practices. Many elementary classrooms lack appropriate science instructional materials and supplies, a state of affairs often exacerbated by a more generalized lack of resources and funding in urban schools serving large numbers of students from low SES backgrounds (Knapp & Plecki, 2001; Spillane et al., 2001).

Another related pair of challenges to innovative science education in urban contexts are the high rates of both teacher and student mobility (moving about within the system) and attrition (leaving the system). Mobility is a limiting factor because even the best curriculum can only be as effective as its implementation. Innovative curriculum materials require extensive professional development. If teachers move from grade to grade or school to school, they are less likely to be able to take advantage of systematic

professional development that could help them make better use of existing science curriculum materials. The same can be said of teacher attrition. As teachers continually leave urban districts or leave the profession altogether, they are often replaced by inexperienced teachers who must be trained anew. Student mobility and attrition can be seen in much the same way, as this can negatively influence innovative curriculum. In the current context of high stakes testing, some projects are designing curricula that move students through several years of articulated topics. Students coming and going both within and beyond a given school or district means that these students miss large chunks of the curriculum.

Curriculum Development and Research Programs

One way to promote science learning and careers for nonmainstream students is to use science curriculum materials and teacher resource manuals to portray scientists from diverse backgrounds, diverse traditions of constructing and transmitting knowledge about the natural world, and information about diverse languages and cultures. Research indicates that the portrayal of minorities in science-related career roles in textbooks is limited (Powell & Garcia, 1985), problems remain unresolved even in materials designed to emphasize indigenous knowledges (Ninnes, 2000), and cultural diversity is not adequately represented in teacher resource manuals (Eide & Heikkinen, 1998). Considering the importance of role models from one's own race/ethnicity in choosing a science career, the limited representation of diversity in most science curriculum materials in the U.S. raises concerns. To ameliorate this problem, science educators have addressed curricula for culturally and linguistically diverse students and low SES students in urban schools.

Culturally Relevant Science Curriculum

Faced with the dearth of science curriculum materials designed to be culturally relevant to nonmainstream students, a small number of science education researchers have developed materials incorporating experiences, examples, analogies, and values from specific cultural groups.

In response to the low science achievement of Native American students, as measured by standardized tests, Matthews and Smith (1994) examined culturally relevant materials (see the article for details about these materials) with Native American students in grades 4 through 8 at Bureau of Indian Affairs schools. Using a pretest-posttest control group design, the study tested the effect of the intervention on two student outcome variables: science achievement and attitudes toward Native Americans and school science. Teachers in the intervention group used culturally relevant materials to teach science (i.e., profiles of Native Americans who use science in their daily lives), whereas teachers in the control group taught science using the same curriculum materials as the intervention group but without the Native American references. Statistical results indicated that students in the intervention group showed higher achievement scores and displayed more positive attitudes toward both Native Americans and science than did students in the control group.

Aikenhead (1997, 2001) offered a conceptual framework for designing culturally relevant curriculum materials, based on the notion of “cultural border crossing” between students’ everyday worlds and the culture of science. Based on this framework, Aikenhead described the development of grade 6 – 11 curriculum units that integrate Western science with “Aboriginal sciences” of First Nations groups in northern

Saskatchewan, Canada. The units identified two important cultural contexts: that of students' Aboriginal communities and that of Western science and technology. Each lesson plan explicitly identified a Western scientific value (e.g., control over nature) and/or an Aboriginal value (e.g., harmony with nature). Based on a bicultural and bilingual model, the units encouraged students to traverse cultural borders between the realm of Western science and their own cultural identity. Informal assessment of classroom practices indicated that students participated in these units in ways that were culturally meaningful to them (but no specific information about assessment results was provided).

Science Curriculum for ELL Students

The literature on science curriculum materials for ELL students focuses on (a) evaluation of existing curriculum materials and (b) development of materials using a traditional text format or computer programs.

Lynch, Kuipers, Pyke, and Szesze (2005) examined the effect of a highly rated science curriculum unit on diverse student groups. The curriculum unit was not designed for the purpose of cultural or linguistic relevance to specific groups; instead, it was designed for wide implementation. The unit was used with 8th grade students in five middle schools selected for student diversity, whereas a variety of district approved curriculum materials were used with students in the comparison group. Disaggregated achievement data indicated that subgroups of students in the treatment group outscored their comparison group peers in all cases, except for students currently enrolled in ESOL.

Hampton and Rodriguez (2001) implemented a hands-on, inquiry science curriculum (i.e., the Full Option Science Series, FOSS) with Spanish-speaking

elementary students who were developing English fluency along with their first language skills. Using this curriculum, university interns taught science to students in kindergarten through 5th grade at three elementary schools near the U.S.-Mexican border. They taught six one-hour lessons over the course of six weeks, with half of the instruction in Spanish and half in English. On the 5th grade written assessment containing three inquiry items and three open-ended response items on the Food and Nutrition unit, correct performance ranged from about 33% to 51% across the six items. There was relatively little difference between 55% of the students who chose to respond in Spanish and 45% of the students who chose to respond in English. Furthermore, there were strong positive feelings among university interns, classroom teachers, and elementary students about the value of this inquiry approach for increasing the children's understanding of science concepts in both languages.

As part of their ongoing research, Lee and colleagues developed curriculum materials in order to implement a professional development intervention with elementary teachers. Over the years, the research team developed a series of science booklets for students, teachers' guides including transparencies, and class sets of supplies including trade books for 3rd, 4th, and 5th grade students. These materials emphasize three domains: (a) science inquiry, progressing along a continuum from teacher-explicit instruction to student-initiated inquiry, (b) integration of English language and literacy in science instruction, and (c) incorporation of students' home language and culture in science instruction. The results indicate the positive impact of the intervention on students' science and literacy achievement and on narrowing of achievement gaps among demographic subgroups (Fradd, Lee, Sutman, & Saxton, 2002; Lee et al., 2005).

In their current research, “Promoting Science among English Language Learners within a High-Stakes Testing Policy Context,” Lee and colleagues have extended their efforts to develop comprehensive curriculum materials for ELL students from grades 3, 4, and 5 in urban schools. The research tests two conventional wisdoms: (1) Can ELL students learn academic subjects, such as science, while also developing English proficiency? and (2) Can ELL students, who learn to think and reason scientifically, also perform well on high-stakes assessments? The results of first-year implementation with 3rd grade students indicate positive achievement outcomes in support of both conventional wisdoms (Buxton, Mahotiere, Lee, & Secada, 2006; Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2006).

Buxton (1999) described the use of interactive, computer-based curriculum materials in a bilingual classroom. Student-generated computer models were used as a medium for elementary students to develop meaningful explanations of science content while also developing English proficiency. The study was set in a two-way bilingual classroom of roughly half native-English speakers and half native-Spanish speakers. Qualitative results indicated that even for primary grade students with limited prior exposure to computers, the use of student-generated computer models in conjunction with the construction of physical models and other hands-on activities provided meaningful opportunities for students to think, act, and engage in scientific discourse.

Science Curriculum for Students in Low SES Settings

The literature on the development and use of science curriculum materials for students in low SES settings involves (a) traditional text materials designed to be relevant to urban environments and (b) computer-based materials implemented in urban school

districts. Computer-based materials, accompanied by interactive web-based technology, are intended for large-scale implementation, although local adaptations are necessary for effective use.

Calabrese Barton and colleagues (Calabrese Barton, Koch, Contento, & Hagiwara, 2005) developed the “LiFE” (Linking Food and the Environment) curriculum focusing on biology education through inquiry-based investigations of food and the food system. The curriculum consisted of five modules: (1) production of food on the farm, (2) food processing and transportation, (3) impacts of food on personal health, (4) food waste and pollution, and (5) the food choices individuals make. Implemented in high poverty urban schools in New York City, the curriculum explicitly connected scientific and nutritional content with topics that students, parents, and community members find to be important. Student interview results indicated that middle school children from low SES backgrounds had an awareness of the complexity of the food system but that this knowledge came largely from experiences in the home and with television rather than from schooling. The researchers concluded that academic curriculum should begin with the incipient knowledge that students bring to the classroom from home and community and advance toward formal science knowledge.

The “Learning Technologies in Urban Schools” [LeTUS] project is aimed at developing curriculum materials that would be usable in urban settings and scalable across entire school districts. The research team has conceptualized project-based curriculum (grounded in a social constructivist perspective) that contextualizes science learning in meaningful and real-world problems, engages students in science inquiry, and uses computer technology to support science inquiry. Over the years, the team has

developed a series of curriculum units for middle school students and examined the impact of these units accompanied by learning technologies on science achievement in two large, predominantly African-American urban school districts. In addition to the inquiry-based and technology-infused curriculum units, the project offered professional development opportunities for teachers. The statistical results showed significant achievement gains in both understanding of science concepts and inquiry process skills (Marx et al., 2004; Rivet & Krajcik, 2004). Furthermore, the impact continued to grow while scaling-up occurred.

The “Kids as Global Scientists” Weather program by Songer involves a technology-based middle school science curriculum along with teacher professional development. Songer, H.-S. Lee, and McDonald (2003) examined scaling-up of this curriculum with two groups of teachers: (a) 40 “maverick” teachers distributed throughout the nation, who sought out the program, worked in schools with a relatively rich fund of resources and supports, and did not receive systematic professional development and (b) 17 teachers from a large, high-poverty urban school district, who received targeted professional development to address obstacles common among their respective schools. The teachers’ self-reports indicated differences in classroom practices. Almost half of the “maverick” teachers favored having students work in small, self-paced groups with relative autonomy, whereas most urban teachers usually had the whole class doing the same activity in unison and tended toward a more teacher-directed pedagogy. The researchers interpreted these differences in terms of class size, students’ prior experience with science inquiry, and institutional resources and support structures. Rather than calling for student-initiated science inquiry as a pedagogical ideal (as science

standards documents tend to do), they claim that different versions of science inquiry or instruction should be adapted for different types of classrooms.

Discussion

Research on science curricula for nonmainstream students remains limited. In efforts to develop culturally relevant science curricula, Aikenhead (1997, 2001) and Matthews and Smith (1994) present detailed descriptions about how they articulated science content and process with the cultural beliefs and practices of specific groups. Given that these studies either did not provide information about science assessment (Aikenhead, 1997, 2001) or suffered limitations in carrying out an experimental research design (Matthews & Smith, 1994), it is difficult to conclude whether the curriculum materials employed indeed had a positive impact in terms of higher achievement in science, more positive attitudes toward science, or enhanced cultural identity among nonmainstream students

To ameliorate the lack of science curriculum materials for ELL students efforts are being made to develop and/or test these materials. Hampton and Rodriguez (2001) tested the impact of a commercially available FOSS science curriculum that fosters hands-on, inquiry science. Lee and colleagues developed and tested materials that integrate science inquiry, English language and literacy, and students' home language and culture (Fradd et al., 2002; Lee et al., 2005), and their efforts have evolved into comprehensive curriculum development for ELL students at grades 3, 4, and 5 within the context of high-stakes testing and accountability policy. Buxton (1999) designed and tested computer-based curriculum materials for ELL students. Through these interventions, ELL students learned to engage in scientific discourse (Buxton, 1999),

made positive achievement gains in both science knowledge and inquiry (Fradd et al., 2002), narrowed achievement gaps (Lee et al., 2005), and performed comparably when they chose to respond either in English or in their home language (Hampton & Rodriguez, 2001). Although the results are promising, caution is warranted in drawing conclusions based on this limited literature.

The “LeTUS” project and the “Kids as Global Scientists” Weather project highlight challenges in large-scale implementation of technology-based science curricula in urban settings. Since the LeTUS project was designed to involve all the middle schools in a school district, it was not feasible to conduct an experimental study (Marx et al., 2004). Also, high rates of both teacher and student mobility and attrition present formidable challenges to carrying out research. Such issues and concerns become more complicated when a technology-based science curriculum is implemented across the nation (Songer, H.-S. Lee, McDonald, 2003). While the program is striving toward its goal of large-scale implementation, this entails risks to the researchers’ control of the research design, systematic data collection, and the capacity to handle large data sets. Given these limitations, results from these two technology-based projects should be interpreted with caution. However, the rigor and evidentiary warrants should be evaluated in the context of the constraints inherent in large-scale research.

While science curriculum for student diversity often focuses on developing materials for specific student groups, standardized science curriculum is intended for large-scale implementation across a wide range of student groups or educational settings. The goal of localization using culturally relevant curriculum and the goal of large-scale implementation using standardized curriculum each present unique sets of challenges.

The demand for localized knowledge in culturally relevant curriculum reduces its applicability to student groups other than those originally intended, whereas large-scale implementation of standardized curriculum requires adaptations and modifications to account for local educational settings.

Research Agenda

The development and implementation of high quality science curriculum has a key role to play in promoting science education for nonmainstream students. In this article we have discussed a multitude of challenges in designing and implementing science curriculum materials for nonmainstream students in urban schools. While trying to be realistic about these challenges, we also described examples of curriculum development efforts that had varying degrees of success in supporting science learning with students from nonmainstream cultures, ELL students, and students in low SES settings. We especially wished to highlight how alternative, sometimes competing, theoretical views can be brought together, and how curriculum development must take into account the current political context such as English-only policy and high-stakes testing and accountability policy. Below, extending the emerging literature, we offer a research agenda to guide future curriculum development and research efforts.

Efforts to develop curriculum materials for culturally and linguistically diverse student groups present particular challenges. There is a deep concern over the fact that science curriculum materials tend to exclude the cultural and linguistic experiences of nonmainstream students. Despite such concern, curriculum development efforts for nonmainstream students are few and far between. Even when culturally relevant materials are developed and prove effective, their effectiveness may be limited to the particular

cultural or linguistic group for which they are targeted. Conversely, while materials developed for wide use may be implemented across a range of educational settings, local adaptations are essential for such materials to be used effectively. This, in turn, requires curricular expertise on the part of teachers, a skill in which they are unlikely to have received substantive professional training. Further research could examine the tension and trade-offs between science curriculum for all students and the curriculum targeted for specific groups.

While efforts are being made to establish design principles guiding the development of “standard” high quality science curriculum materials for all students (Kesidou & Roseman, 2002; “LeTUS” project, “Kids as Global Scientists” Weather project), efforts are also being made to establish guidelines for curriculum development targeted for specific groups, such as culturally relevant curriculum for various groups of Native American students in North America (Aikenhead, 1997, 2001; Matthews & Smith, 1994; Stephens, 2000) or curriculum integrating science and English literacy for ELL students (Fradd et al., 2002; Lee et al., 2006). Up to this point, these efforts have been emerging independent of one another. Further research may examine how these multiple sets of guidelines are compatible and applicable to all students and where divergent approaches are needed for specific groups.

An expanded knowledge base around students’ science-related experiences could offer a stronger foundation for science curriculum. Students of all backgrounds should be provided with academically challenging curriculum materials that allow them to explore scientific phenomena and construct scientific meanings based on their own cultural and linguistic experiences. At the same time, some students may need more explicit guidance

in articulating their cultural and linguistic experiences with scientific knowledge and practices. Curriculum designers (and teachers) need to be aware of students' differing needs when deciding how much explicit instruction to provide and to what degree students can assume responsibility for their own learning (Fradd & Lee, 1999; Lee, 2002; Songer et al., 2003). The proper balance of teacher-centered and student-centered activities may depend on the degrees of continuity or discontinuity between science disciplines and students' backgrounds, the extent of students' experience with science disciplines, and the level of cognitive difficulty of science tasks. Further research could examine what is involved in explicit instruction, when and how to provide it, and how to determine appropriate scaffolding for specific tasks and students.

Still another area of research, which currently dominates the landscape of science education in general but has largely been ignored with nonmainstream students, involves the use of computer technology in science curriculum and instruction (Buxton, 1999). Additionally, an emerging body of research on science curriculum that employs interactive web-based technology shows promising outcomes for culturally and linguistically diverse students in urban schools (e.g., "LeTUS" project and "Kids as Global Scientists" Weather project). Further research in this vein may provide detailed descriptions of how various types of student diversity intersect with the introduction of computer technology into science classrooms, as well as examining the impact of large-scale implementation of computer technology on science outcomes across a range of educational settings.

As science is included in high-stakes testing and accountability policy in increasing numbers of states and as part of NCLB starting in 2007, a critical question is

how to make science curriculum relevant and meaningful for diverse student groups while also preparing them to perform well on high-stakes science assessments. For any curriculum to make an impact on these assessments, it should cover a broad range of science topics in a comprehensive manner and over an extended period of time. This approach requires new thinking about the role of curriculum materials, teacher professional development, classroom practices, and achievement outcomes with culturally and linguistically diverse students in urban settings. Concurrently, it requires new thinking about research methods to examine the design of the curriculum, fidelity of implementation, and the impact on teachers and students. Such large-scale efforts within policy contexts could lead to promising avenues for future research and enhanced curriculum to better serve all students.

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