Effective STEM Education Strategies for Diverse and Underserved Learners

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The poor performance of U.S. students on international and national science assessments has received much public attention in recent years. At the same time, increasing numbers of non-mainstream students in U.S. classrooms have caused concerns among school personnel and the broader public. Furthermore, persistent achievement gaps between “non-mainstream” students (i.e., students of color, from low-income families, and learning English as a new language) and “mainstream” students (i.e., White, from middle- or high-income families, and native speakers of standard English) have led to concerns among policy makers as well. In this article, the terms “mainstream” and “non-mainstream” are used with reference to students’ racial, ethnic, cultural, linguistic, and social class backgrounds. By “mainstream” we do not refer to numerical majority, but rather to social prestige and institutionalized privilege.

When we start from the evidence that high academic achievement in science is attainable by most children, we recognize that gaps in science outcomes among racial, ethnic, cultural, linguistic, or socioeconomic status (SES) groups are a product of different learning opportunities available to students. This leads to questions such as: What is the relationship between student outcomes and factors influencing those outcomes? what constitutes equitable learning opportunities?

In recent years, science learning and teaching with non-mainstream students has been studied using a wide range of theoretical perspectives. These perspectives have included: (a) a cognitively based perspective, (b) a cross-cultural perspective, and (c) a sociopolitical perspective. Although all of these perspectives share the belief that connecting students’ cultural and linguistic experiences to the practices of science is central to effective teaching and learning, specific approaches to achieving this goal differ. Despite their theoretical variety, the results in the emerging literature indicate that when provided with equitable science learning opportunities, non-mainstream students demonstrate high science achievement and develop successful science learner identities while maintaining cultural identities.

This article starts with defining the notion of equitable learning opportunities. Then, each of the four theoretical perspectives is described using examples from representative research programs, the unique ways that each perspective addresses the challenge of providing equitable learning opportunities for non-mainstream students in science classrooms, and students' learning outcomes. The article concludes with implications for instructional strategies that teachers can use to make their classrooms equitable science learning environments and promote science outcomes.

Equitable Learning Opportunities

Science outcomes need to be conceived broadly including standardized test scores, course-taking patterns, school retention or dropout, learning with understanding, identity as science learners, cultural and linguistic identity, and agency. Science outcomes are influenced by instructional practices, curriculum materials including computer technology, assessment, teacher education, school organization, state and district policies, and home and community connections to school science.

For non-mainstream students, *equitable learning opportunities* occur when school science: (a) values and respects the experiences that all students bring from their homes and communities, (b) articulates this cultural and linguistic knowledge with disciplinary knowledge, and (c) offers sufficient educational resources to support science learning (Lee & Buxton, 2010). When provided with equitable learning opportunities, students from non-mainstream backgrounds are capable of attaining science outcomes comparable to their mainstream peers.

The notion of equitable learning opportunities starts with an understanding that all students come to school with previously constructed knowledge grounded in their home language and cultural values. While connecting new knowledge to prior knowledge is a fundamental part of learning for all students, the linguistic and cultural resources that mainstream students bring to school are more likely to be closely in line with typical classroom practices. Non-mainstream students often find themselves disadvantaged by a school culture that seems to overlook the linguistic and cultural resources that are valued in their home and community. Nevertheless, they bring funds of knowledge (González, Moll, & Amanti, 2005; Moll, 1992) from their home and community environments that can serve as intellectual resources in science classrooms (Warren et al., 2001). At the same time, some aspects of students' linguistic and cultural traditions may, in fact, be inconsistent with a scientific orientation toward knowledge construction and problem solving. Such inconsistencies may create difficulties for students learning science as well as for their teachers (Aikenhead & Jegede, 1999; Snively & Corsiglia, 2001). Thus, effective science instruction considers students' prior knowledge, experiences, and beliefs and explicitly articulates their relationships with the norms of school science in order to make science accessible and relevant for all students (Lee & Fradd, 1998; Warren et al., 2001).

Cognitively Based Perspective

Science Learning

Scientific reasoning and argumentation have emerged as key factors in promoting science learning from a cognitively based perspective. This perspective focuses on mental processes such as reasoning, problem solving, inquiry, and argumentation.

To better understand how scientific reasoning can be developed with culturally and linguistically diverse students, the Chèche Konnen team conducted case studies of low-income students from African American, Haitian, and Latino backgrounds in both bilingual and monolingual classrooms. The research addressed questions such as: What do children do as they engage in experimental tasks? What resources – linguistic, conceptual, material, and imaginative – do non-mainstream students draw on as they develop and evaluate experimental tasks? How does children's scientific reasoning correspond to the nature of experimentation as practiced by scientists? The results of these case studies indicated that non-mainstream students were capable of conducting scientific inquiry and using scientific reasoning through open science inquiry or "doing science" (Rosebery, Warren, & Conant, 1992).

The research also considers students' everyday experiences and ways of knowing and talking. When views of both scientific practices and children's sense-making are broadened and treated flexibly, conclusions can be drawn about the degree of convergence between the two. Rosebery, Warren, and colleagues examined relationships between scientific practices and the everyday sense-making of children from diverse cultures and languages (Ballenger, 1997; Hudicourt-Barnes, 2003; Warren et al., 2001). The results highlight that non-mainstream students' ways of knowing and talking are often similar to those of scientific communities in some important ways, such as practicing the use of deep questions, vigorous argumentation, and innovative uses of everyday words to construct new meaning. For example, argumentative discussion is a major feature in social interactions among Haitian adults known as *bay odyans* or "to give talk," which could be loosely translated as "chatting" and may include storytelling or telling jokes and riddles in public settings (Hudicourt-Barnes, 2003). This discourse practice can be a resource for students as they practice argumentation in science. While Haitian students are typically quiet and respectful in the classroom, when in a culturally familiar environment, these same students participate in animated arguments about scientific phenomena in a way that is both integral to Haitian culture and consistent with scientific practices (Ballenger, 1997; Warren et al., 2001).

As illustrated by *bay odyans*, the key to opening up this robust student talk is in valuing community discourse patterns as a resource. Teachers who are not familiar with the community discourse patterns of their students can benefit from observing and listening to the ways of talking and interacting among their students and families. Teachers can then attempt to identify community discourse patterns and adapt their instruction to better align with those patterns, while helping their students to learn mainstream discourse patterns.

Science Teaching

From the cognitively based perspective, a major problem faced by non-mainstream students is that teachers often fail to recognize the intellectual resources that the students bring from their home and community environments into science classrooms. The Chèche Konnen project has a long history of promoting scientific inquiry among language minority and low-SES students. This group's earlier work emphasized how students learned to engage in scientific inquiry and to appropriate scientific argumentation in a collaborative learning community (Rosebery et al., 1992). A central premise of this work has been that school science should be connected to science as it is practiced in professional communities. Although scientific practice in school cannot exactly mirror the practice of research scientists, teachers provide students with opportunities to engage in the practice of science. Based on a simplified model of what scientists do in the real world, students learn to use language, to think, and to act as members of a science learning community.

As is the case in research science, this type of science instruction should not be predetermined; rather, inquiry grows out of students' own beliefs, observations, and questions.

The investigation of one question often leads to additional questions and a new round of inquiry. When science teaching is organized around students' own questions and inquiries, much of the science curriculum emerges from the questions that students pose, the experiments they design, the arguments they engage in, and the theories they construct. The teachers' role is to facilitate students' investigations of their own questions, while offering guidance and resources as needed. Even though this approach to science instruction has sometimes been used for academically advanced students, the Chèche Konnen project has demonstrated that it is also feasible for non-mainstream students with limited formal science experience (Warren et al., 2001).

Over the years, the Chèche Konnen team has studied the informal, everyday knowledge that students of diverse backgrounds bring to the learning process and how teachers can build on that knowledge by connecting it to the practice of science (Ballenger, 1997; Warren et al., 2001). The results indicate that students apply their cultural knowledge and practices in the context of scientific reasoning and argumentation. For example, when a 6th grade Haitian student asserted that "The bathrooms in Haiti have mold, the bathrooms here don't get moldy," a classmate challenged this claim and an animated discussion ensued in which students offered arguments and counter-arguments and had to defend their positions (Ballenger, 1997).

The work has also evolved to consider the role of students' home language in scientific sense-making (Ballenger, 1997; Warren et al., 2001). Promoting the use of a student's mother tongue such as Haitian Creole or Spanish adds a valuable resource to science learning. Students' more nuanced understanding of their home language allows them to express more precise meaning when doing science. Additionally, reflecting on the differences in how ideas are expressed in the home language and in English helps students understand the concept of linguistic register and language functions in different contexts. For example, Ballenger (1997) described how a 5th grade Haitian boy, who was learning English as a new language and considered a special education student, used both Haitian Creole and English to understand metamorphosis as a particular kind of change in biology. Speaking in Haitian Creole and using Haitian Creole syntax, the student differentiated the meanings of two terms “grow” (referring to continuous change) and “develop” (referring to reliably patterned transformation from one discrete stage to the next). Then, the student switched into English and used the terms “grow” and “develop” to further enhance his understanding of these two aspects of change.

Equitable Science Learning Opportunities

The cognitively based perspective highlights the continuity between non-mainstream students’ explorations of the natural world and the way science is practiced in scientific communities. Like scientists, non-mainstream students can and do use diverse linguistic and cultural resources in their sense-making practices. Although their scientific reasoning and argumentation skills can be enhanced through instructional practices modeled after the way scientists work, a number of structural features, such as school funding and academic tracking, result in non-mainstream students typically receiving less access to high-quality, inquiry-driven science instruction than their mainstream peers. From the cognitive science perspective, equitable science learning opportunities involve examining the dynamic intersections between students’ everyday knowledge and experiences and scientific practices. When teachers identify and incorporate students’ cultural and linguistic experiences as intellectual resources for science learning, they provide opportunities for students to learn to use language, to think, and to act as members of a science learning community. Such guidance helps non-mainstream students view themselves as successful science learners and members of a science learning community.

Cross-Cultural Perspective

Science Learning

The growing awareness of the importance of multicultural perspectives on content area instruction has led to some research that examines science learning from a cross-cultural perspective. This perspective addresses cultural patterns of communicating, interacting, and especially ways of knowing. This literature has several features that distinguish it from the cognitively based perspective, most notably, the idea that students from some cultural communities come to school with knowledge and experiences that may be discontinuous with Western modern science (i.e., a tradition of thought that has developed in Europe during the last 500 years and that is often falsely perceived to be the beginning of scientific thought) both as it is practiced in the science community and as it is taught in school science. Studies from this perspective have examined worldviews and culturally specific communication and interaction patterns in the context of science instruction (see the review by Snively & Corsiglia, 2001).

Learning experiences in the community may be more or less culturally congruent with practices in the science classroom. According to Lipka (1998), Yup'ik children in Alaska learn science-related skills (e.g., fishing, building fish racks, and using stars to navigate) from observing experienced adults and then actively participating as apprentice-helpers in home and community settings. Children and adults engage in joint activities for long periods of time, during which observation and guided practice, rather than verbal interaction, are central to the learning process. This orientation toward learning may prove problematic within a traditional Western school system that organizes learning around short and frequent classroom activities and expects students to learn by listening to teachers, following directions, and responding quickly to questions verbally or in writing. Additionally, values that are instilled in children in indigenous cultures, such as managing natural resources and living in harmony with the environment, have sound scientific rationales that could serve as a bridge for teaching and learning science. In contrast, traditional Western scientific approaches to the natural world, such as an analytical and depersonalized approach to knowledge, can be alienating for indigenous youth.

The culture of Western science is unique in ways that are viewed as foreign to many students, both mainstream and non-mainstream. Additionally, the challenges of science learning seem to be greater for students whose cultural practices are sometimes discontinuous with the ways of knowing that are characteristic of both Western science and school science. The ability to shift competently between different cultural contexts, belief systems, and communication styles is critically important to non-mainstream students' academic success. Giroux (1992), among others, has used the notion of border crossing to describe this process. To succeed in school, non-mainstream students must learn to negotiate the boundaries that separate their own cultural environments from the culture of Western science and school science (Aikenhead, 2001; Aikenhead & Jegede, 1999; Jegede & Aikenhead, 1999; Loving, 1997).

Science Teaching

In one set of examples of cultural congruence and cultural border crossing in science teaching, Parsons (2008) focused on African American students and examined their science achievement in relation to the notion of Black cultural ethos, a set of cultural practices based on West African tradition that are commonly found in African American communities. While acknowledging within-group variations, Parsons and others have argued that Black cultural ethos broadly consists of nine dimensions including spirituality, affect, harmony, orality, social perspective of time, expressive individualism, verve, communalism, and rhythmic-movement expressiveness. In related studies, Parsons (2000) and Parsons, Foster, Travis, and Simpson

(2007) illustrated culturally congruent instruction using science lessons and role playing with African American students. They highlighted how Black cultural ethos was incongruent with the communication patterns typically valued and reinforced in school science. Using role-play, teachers considered how congruence could be fostered in their classrooms between student practices grounded in Black cultural ethos and school science practices.

Lee and colleagues extended ideas about cultural congruence and culturally relevant pedagogy through a framework called instructional congruence that connects science disciplines with students' languages and cultures (Lee, 2002; Lee & Fradd, 1998). Instructional congruence highlights the importance of relating students' linguistic and cultural experiences with the specific demands of particular academic disciplines such as science. Thus, instructional congruence emphasizes the work that teachers should do through their instruction to bring students and science together, especially when there are potentially discontinuous elements. For example, validity of knowledge claims in scientific communities is based on coordinating theory and evidence, whereas the validity of knowledge claims in some cultures is based on authority figures including parents, teachers, or textbooks. Teachers can help students learn that different ways of validating knowledge claims may be appropriate in different cultural contexts.

Lee and colleagues also proposed the model of a teacher-explicit to student-exploratory continuum for teaching inquiry-based science (Fradd & Lee, 1999; Lee, 2002). In the multicultural education literature, school knowledge is often represented as the "culture of power" of the dominant society (Au, 1998; Banks, 1993; Delpit, 1988). The rules of classroom discourse, which are essential for students to access this culture of power, are largely implicit and assumed, making it difficult for students who have not learned the rules at home to figure out these rules on their own. Teachers need to provide explicit instruction about rules and norms for classroom behavior and academic achievement, rather than assuming that students know and understand these rules. Without this explicit instruction, non-mainstream students lack the opportunities both to learn the rules and to take advantage of the learning opportunities that knowledge of the rules offers. In science classrooms, teachers make the rules of scientific practices explicit for non-mainstream students. Then, teachers move progressively from teacher-explicit to student-exploratory inquiry experiences. Students are encouraged to take the initiative for different portions of the inquiry process and gradually build toward the full inquiry process. Along the way, teachers maintain a balance between teacher guidance and student initiative, ensuring that all students are successful at each point on the continuum.

As the work by Lee and colleagues has been scaled up over the years, the models of instructional congruence and the teacher-explicit to student-exploratory continuum have served as a conceptual and practical guide for ongoing curriculum design, teacher professional development, classroom practices, and student assessments. Their latest project used a quasi-experimental design involving six treatment and six comparison schools that had high proportions of English language learners and students from low SES backgrounds and traditionally performed poorly according to the state's accountability plan. After participating in the intervention aimed at promoting science learning and English language development, students from grades 3 through 5 in the treatment group demonstrated significant achievement gains on the project-developed science tests, and students at ESOL levels 1 to 4 made gains comparable to those of students who had exited from ESOL or never been in ESOL (Lee, Penfield, Maerten-Rivera, & Ahn, under review). When the fifth grade students in the treatment group were compared to those in the comparison group, students in the treatment schools demonstrated significantly higher scores on the state science tests, and this effect did not vary as a function of English proficiency. In addition, the project examined third grade students' writing achievement that included "form" (i.e., conventions, organization, and style/voice) and "content" (i.e., specific knowledge and understanding of science) in expository writing on a science topic (Lee, Mahotiere, Salinas, Penfield, & Maerten-Rivera, 2009). Students displayed a statistically significant increase, and students at ESOL levels 1 to 4 made gains comparable to those of students who had exited from ESOL or never been in ESOL.

Equitable Science Learning Opportunities

The cross-cultural perspective argues that since non-mainstream students are not from the "culture of power" (e.g., Western modern science), they carry with them cultural beliefs and practices that are sometimes discontinuous with the ways science is practiced in the science community and taught in school science classes. Teachers should teach their non-mainstream students the "rules of the game" that govern school science (e.g., empirically tested explanations being valued over descriptions using personal experiences), make the norms of school science explicit, and help the students learn how to cross cultural borders between home and school. Equitable science learning opportunities allow non-mainstream students to successfully participate in Western science, while also validating and building upon the knowledge, beliefs, and practices that are characteristic of their communities of origin (Aikenhead, 2001; Aikenhead & Jegede, 1999; Snively & Corsiglia, 2001). For example, students can learn to argue and justify their knowledge claims based on empirical testing of evidence in school science, while still respecting decisions based on cultural authority and traditions at home. When such learning opportunities are provided, students gain access to the high status knowledge of Western science, without feeling that they must choose between school success and the beliefs and practices of their own cultural group. Science teaching and learning that recognizes and values diverse views of the natural world and diverse ways of knowing can simultaneously promote academic achievement and strengthen students' cultural and linguistic identities.

Sociopolitical Perspective

Science Learning

As an outgrowth of critical studies of schooling, some research has examined science learning as a sociopolitical process (Calabrese Barton, 1998; Siler, 2001). The sociopolitical perspective places prominence on issues of power, prestige, and privilege. This literature has key features that distinguish it from research informed by the cognitively based and cross-cultural perspectives. First, sociopolitical research questions the relevance of science to students who have traditionally been underserved or even oppressed by the education system. It argues that science education, and schooling generally, is not useful to non-mainstream students when driven by externally imposed standards, rather than by the intellectual resources and experiences of the learners. Only when taking the latter approach can teaching and learning attempt to invert the power structure of schooling and its negative effects on students from marginalized groups. Unlike the traditional learning paradigm where science (or any subject matter) is at the center, as a target to be reached by students at the margins, the sociopolitical perspective places students' experiences as central and asks how science can be made relevant to those experiences. Second, research from the sociopolitical perspective foregrounds issues of poverty, as well as cultural and linguistic diversity, and focuses on the unequal distribution of social and educational resources along the lines of class, race, and ethnicity. Researchers generally ground their analyses in the political, cultural, and socioeconomic history of the study participants.

Recognizing the persistent achievement gap between mainstream White and inner-city African-American students, Seiler (2001) described a science lunch group that she organized with eight African-American male students in an inner-city high school. The students and the researcher met once each week to eat lunch, talk about their lives, and discuss and carry out science-related activities. In this informal setting within the school, science activities started from students' own interests, prior knowledge, and lived experiences. The results indicate how the science lunch group forged a learning community based on respect and caring that afforded these African-American teens the opportunity to participate in science in new ways. Seiler argues that the imposition of external standards on inner-city schools does little to ameliorate achievement gaps because it fails to address the significance of students' social and cultural lives. Instead, science educators should learn from students about how science education can change to meet the students' aims and interests.

Calabrese Barton and colleagues (Calabrese Barton, 1998; Fusco, 2001) carried out research with children living in poverty, specifically urban homeless children living in shelters who were most at risk of receiving an inequitable education or no formal education at all. Calabrese Barton (1998) allowed the students to take the lead in planning activities, documenting their explorations, and making meaning of their findings (e.g., youth exploring their personal theories about pollution in the community, the shelter's policies around food, or involvement in community gardening projects). The role of the researcher, as teacher, was to validate the students' experiences as the starting point for their explorations in order to help them locate questions in their experiences and find ways to critically investigate those questions. Throughout the teaching and learning process, students' identities remained one central focus and democratic principles of empowerment remained another.

Pushing the idea of imposed definitions of science further, Fusco (2001) raised the issue of why youth find informal, out-of-school science experiences (i.e., non-school, non-curriculum-based interactions with science in environments such as science centers, museums, zoos, parks, and nature centers) more engaging and relevant to their lives than school science. Fusco worked with teenagers from homeless families in an after-school project that involved urban planning and community gardening. In this community-based science project, science became relevant or "real" to the students because: (a) it was created from their own concerns, interests, and experiences related to science, (b) it was an ongoing process of researching and then enacting ideas, and (c) it was situated within the broader community. A key conclusion is that schools must reconsider how science learning can become more closely connected to students' interests, experiences, and communities if it is to be relevant to the students' lives.

Overall, studies of science learning from a sociopolitical perspective reject the notion that external standards can make science learning more equitable for students who have been marginalized from science and science education. These standards are imposed on students by those who typically have little understanding of the lived experiences of these students. There is little or no space in national science standards for place-based science learning or science in support of social justice (Calabrese Barton, 1998; Siler, 2001). Instead, sociopolitical research points to the need for the students to make sense of science based on their lived experiences in social, cultural, and political conditions. The results indicate that a sociopolitical approach to science learning can lead marginalized students to gain knowledge and understanding of science content, to see science as relevant to their lives, and to engage in science in socially relevant and transformative ways.

Science Teaching

The sociopolitical perspective considers that typical science instruction, even when it is "reform-oriented," reinforces the power structures that privilege mainstream over non-mainstream students. From this perspective, the substandard performance of non-mainstream students is not due to an inability to perform well, but rather, it is due to an active resistance to science instruction and to a school system that is seen as irrelevant and non-engaging.

Even when teachers attempt to push non-mainstream students to engage in rigorous inquiry-oriented science, challenges may hinder success. Seiler, Tobin, and Sokolic (2001) explored teaching science through design and technology as a way to support science learning for inner-city high school students. Results indicated that while some students participated in ways that allowed them to develop design and technological competence, other students resisted by participating sporadically and refusing to cooperate with teachers. Whereas teachers enacted the curriculum as if learning science was the goal for students, students used the class opportunistically to earn and maintain the respect of their peers. The researchers concluded that science teachers must learn to take into account the historical, social, and cultural environments in which their students live and attend school and to develop science-related goals that emerge from the knowledge of their students.

Rodriguez and Berryman (2002) worked with high school students in predominantly Latino and impoverished school settings in a U.S.- Mexican border city. The instructional approach was guided by a “sociotransformative constructivism” that merged multicultural education with social constructivism. Using a curriculum unit on investigating water quality in their community, the students engaged in authentic activities as they explored how this topic was socially relevant and connected to their everyday lives. The quantitative results indicate that the instructional approach enhanced not only students’ enthusiasm for the science curriculum but also their knowledge and understanding of science content. In addition, qualitative results indicate that students took on empowered positions by testing water in their homes and investigating ways to improve water standards in their communities. They quickly understood the precariousness of water availability in their desert region and informed their families of ways to conserve water at home. Having come to see science as relevant to their lives, students saw scientific investigations as worthwhile for themselves and for students in other schools in the region. Rodriguez and Berryman conclude that the instructional approach has the potential to open empowering spaces where students can engage with science curricula in socially relevant and transformative ways.

Buxton (2010) used a model of social problem solving through science that was carried out with middle school students during a summer nature camp. The project engaged students in inquiry activities based on local environmental challenges with implications for human health and well-being. Students were supported in creating public service announcements on an environmental health topic of their choosing which they then shared with peers, family members, and staff and scientists from the nature center. This critical, place-based instructional approach proved to be engaging for young adolescents because it positioned them centrally as actors with the power to make a difference in their local community, while positioning science as a tool to be used in support of their goals. At the same time, students' science content knowledge increased over the course of participation in the two-week project.

Equitable Science Learning Opportunities

The sociopolitical perspective reverses the question from focusing on how to bring students' worldviews more in line with the views of Western science to focusing on how science itself can be reconceptualized to better relate to and learn from the worldviews of people from marginalized groups. This perspective highlights a deep mistrust of schooling, science instruction, and science teachers among non-mainstream students who have traditionally been at best ignored and at worst oppressed by schooling in general and science education in particular. For example, when teachers view English language learners, students of color, or students living in poverty as problems needing to be fixed, then schooling becomes oppressive for the students and their families. When access to advanced science courses, which is a gateway to higher education and scholarships, is denied to non-mainstream students, then science education is oppressive. These inequities do not go unnoticed by the students and their families.

Thus, mistrust presents a serious barrier to science teaching and learning with non-mainstream students until it is dealt with explicitly in the classroom. From the sociopolitical perspective, science teaching should focus on building trusting relationships with students who have been marginalized in science classrooms. Equitable science learning opportunities occur when new relationships are forged and students come to see their teachers as allies in a struggle against oppression rather than as part of an oppressive system. When teachers provide safe environments for students to take part in rigorous learning of science, they can help their students see science as personally meaningful and relevant to their current and future lives.

Discussion

The literature on science learning and teaching and student diversity indicates that the science learning of non-mainstream students is influenced by a variety of factors associated with their racial, ethnic, cultural, linguistic, and social class backgrounds. These factors include students' scientific reasoning and argumentation styles, cultural beliefs and practices, and sociopolitical features of schools and communities. These factors influence the process of identity formation that all students go through. Since the relationships between and among these factors are multifaceted and complex, it is difficult to tease out the influence of each factor, either independently or interactively.

It is widely accepted that connecting students' cultural and linguistic experiences to the practices of science is central to effective teaching and learning. However, specific approaches to achieving this goal differ from one theoretical perspective to another when it comes to student learning. Research grounded in different theoretical traditions has produced results that are consistent in some regards and inconsistent in others. This is due, in part, to differences in the focus or emphasis of the research, which, in turn, reflects differences in the conceptual, ideological, and political commitments among researchers, both individually and collectively.

Despite variations in the conceptions of science learning and teaching for non-mainstream students, the literature converges on two common findings. First, while science learning is demanding for all students, non-mainstream students often face additional challenges. Students from all racial, ethnic, cultural, linguistic, and socioeconomic backgrounds come to school with a wide range of prior knowledge, including their home language and cultural values, ideas about science, and ideas about schooling, that have been acquired in their home and community environments. However, even the experiences and prior knowledge that the students bring to school that could serve as intellectual resources for learning science are generally marginalized from school science. This is just one of many ways in which the education system often fails to provide equitable science learning opportunities for non-mainstream students.

Second, when non-mainstream students are provided with equitable science learning opportunities in formal or informal learning environments, they demonstrate high academic achievement and successful science learner identity. When learning environments are created that present science content and practices in relation to non-mainstream students' cultural and linguistic practices, they capitalize on their prior knowledge as intellectual resources and embrace science learning. When non-mainstream students are provided with socially safe learning environments, they explore and construct both cultural and science learner identities. When science is presented as a way of talking, thinking, and acting in the world and when these practices are explicitly taught, non-mainstream students embrace the role of bicultural and bilingual border-crossers between their own cultural and speech communities and the science learning community.

To promote effective science teaching in the midst of expanding student diversity, science educators should build on the experiences that non-mainstream students bring from their homes and communities. Policies and practices at every level of the education system should be aligned to provide equitable science learning opportunities for all students. When provided with such opportunities, non-mainstream students demonstrate high science achievement and develop successful science learner identities while maintaining their cultural and linguistic identities.

Recommendations for Classroom Practice

Each of the theoretical perspectives discussed in this article places value on making connections between students' cultural and linguistic experiences and the practices of science as a key to fostering equitable teaching and learning. Different theoretical perspectives have led to a range of instructional approaches about how teachers can best meet the learning needs of non-mainstream students in the science classroom. Teachers should make choices that can offer equitable learning opportunities for their students in daily classroom practices.

From the cognitive science perspective, teachers need to identify points of contact where scientific practices are continuous with students' everyday knowledge and build on such continuities to promote student learning (Warren et al., 2001). For example, teachers can listen to student discourse that takes place during inquiry-based activities and highlight for the students the ways in which their inquiry and discourse practices are similar to how research scientists pursue new knowledge.

From the cross-cultural perspective, teachers need to make the norms and practices of science explicit for students, especially when such norms and practices are discontinuous with the norms and practices of students' cultures. For example, teachers can use the instructional congruence framework (Lee & Fradd, 1998) to scaffold students' gradual progress from a teacher-directed inquiry approach, where the teacher makes the "rules" of good inquiry practice explicit for students, to a student-centered inquiry approach, where students take the lead in developing and exploring their own testable questions (Lee, 2002).

From the sociopolitical perspective, teachers need to build trusting and caring relationships with their non-mainstream students, and engage together in a critical analysis of the purposes of schooling and of science before the teachers engage the students in learning science. For example, teachers can facilitate class discussions of ways that science has been used to enhance and justify inequitable distributions of power and social class, and then work along with students on community projects that use science in more equitable ways (Rodriguez & Berryman, 2002).

Reflecting on each of these perspectives, we can conclude that research on science learning and student diversity is multifaceted and evolving. Although each perspective highlights features that are unique and in some cases conflicting with other perspectives in a theoretical/conceptual sense, in practice, there may be complementary ways in which teachers can make use of the insights gained from multiple perspectives. Science teachers may recognize that scientific practices are continuous with everyday knowledge of diverse student groups in some contexts (i.e., the cognitive science perspective). At other times teachers may become aware of discontinuities or cultural conflicts between some of their students' worldviews and scientific views (i.e., the cross-cultural perspective). At still other times, teachers may recognize deeply-rooted mistrust and resistance to either science or schooling more generally that some students bring to the classroom; resistance that seems to go beyond the question of match or mismatch between students' cultural and linguistic experiences and the practices of science (i.e., the sociopolitical perspective). As teachers learn to "read" their students' actions for signs of learning, they will become better able to provide equitable learning opportunities for all students, particularly those who have traditionally been marginalized in science classrooms.

The most important point to recognize is that a one-size-fits-all instructional approach will surely fail to meet the learning needs of the students in any classroom. Building on what the research literature tells us about science learning and student diversity, science educators can make better professional judgments to help our students become successful learners in science classrooms. The evidence from the literature that gaps in science learning outcomes can be moderated when teachers take action to create equitable learning opportunities offers hope that the goal of science for all can be achieved.

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