Appendix D - "All Standards, All Students": Making the Next Generation Science Standards Accessible to All Students

The Next Generation Science Standards (NGSS) are being developed at a historic time when major changes in education are occurring at the national level. On one hand, student demographics across the nation are changing rapidly, as teachers have seen the steady increase of student diversity in the classrooms. Yet, achievement gaps in science and other key academic indicators among demographic subgroups have persisted. On the other hand, national initiatives are emerging for a new wave of standards through the NGSS as well as Common Core State Standards (CCSS) for English language arts and literacy and for mathematics. As these new standards are cognitively demanding, teachers must make instructional shifts to enable all students to be college and career ready.

The NGSS are building on the National Research Council's consensus reports in recent years, including *Taking Science to School* (2007) and its companion report for practitioners *Ready, Set, Science!* (2008), *Learning Science in Informal Environments* (2009), and most notably *A Framework for K-12 Science Education* (2012). These reports consistently highlight that, when provided with equitable learning opportunities, students from diverse backgrounds are capable of engaging in scientific practices and constructing meaning in both science classrooms and informal settings.

This chapter, accompanied by seven case studies of diverse student groups, addresses what classroom teachers can do to ensure that the NGSS are accessible to all students; hence the title: "*All Standards, All Students*." Successful application of science and engineering practices (e.g., constructing explanations, engaging in argument from evidence) and understanding of how crosscutting concepts (e.g., patterns, structure and function) play out across a range of disciplinary core ideas (e.g., structure and properties of matter, earth materials and systems) will demand increased cognitive expectations of all students. Making such connections has typically been expected only of "advanced," "gifted," or "honors" students. The NGSS are intended to provide a foundation for all students, including those who can and should surpass the NGSS performance expectations. At the same time, the NGSS make it clear that these increased expectations apply to those students who have traditionally struggled to demonstrate mastery even in the previous generation of less cognitively demanding standards. The goal of the chapter and the case studies is to demonstrate that the NGSS are extended to all students.

Throughout the chapter and case studies, the terms "dominant" and "non-dominant" groups are used with reference to student diversity (Gutiérrez & Rogoff, 2003). The dominant group(s) does not refer to numerical majority, but rather to social prestige and institutionalized privilege. This is particularly the case as student diversity is increasing in the nation's classrooms. Even where the dominant group(s) is the numerical minority, the privileging of their academic backgrounds persists. In contrast, non-dominant groups have traditionally been underserved by the education system. Thus, the term "non-dominant" highlights a call to action that the education system meets the learning needs of the nation's increasingly diverse student population.

The chapter highlights practicality and utility of implementation strategies that are grounded in theoretical or conceptual frameworks. It consists of three parts. First, it discusses both *learning opportunities and challenges* that the NGSS present to student groups that have traditionally been underserved in science classrooms. Second, it describes effective strategies for *implementation* of the NGSS in the classroom, school, home, and community. Finally, it provides the *context* of student diversity by addressing changing demographics, persistent science achievement gaps, and educational policies affecting non-dominant student groups.

The seven case studies (available at www.nextgenscience.org) illustrate science teaching and learning of non-dominant student groups as they engage in the NGSS. Several caveats are offered to understand the purpose of case studies. First, the case studies are not intended to prescribe science instruction, but to illustrate an example or prototype for implementation of effective classroom strategies with diverse student groups. Given the vast range of student diversity across varied educational settings, teachers and schools will implement the NGSS to meet the learning needs of specific student groups in local contexts. Second, each case study highlights one identified group (e.g., economically disadvantaged students, English language learners). In reality, however, students could belong to multiple categories of diversity (e.g., English language learners who are racial and ethnic minorities from economically disadvantaged backgrounds). Third, as there is wide variability among students within each group, "essentializing" on the basis of a group label must be avoided. For example, ELLs form a heterogeneous group with differences in ethnic background, proficiency level in home language and English, socioeconomic status, immigration history, quality of prior schooling, parents' educational level, etc.

In identifying student diversity, the case studies address the four accountability groups defined in No Child Left Behind (NCLB) Act of 2001 and the reauthorized Elementary and Secondary Education Act [ESEA], Section 1111(b)(2)(C)(v):

- economically disadvantaged students,
- students from major racial and ethnic groups,
- students with disabilities, and
- students with limited English proficiency.

Further, student diversity is extended by adding three groups:

- girls,
- students in alternative education programs, and
- gifted and talented students.

Each of the seven case studies consists of three parts that parallel the chapter. It starts with a vignette of science instruction to illustrate learning opportunities through connections to the NGSS and the CCSS for English language arts and mathematics as well as use of effective classroom strategies. The vignette emphasizes what teachers *can do* to successfully engage students in learning the NGSS. Then, it provides a brief summary of the research literature on effective classroom strategies for the student group highlighted in the case study. It ends with the context for the student group – demographics, science achievement, and educational policy. The contextual information relies heavily on government reports addressing student diversity broadly, including the ESEA Act, U.S. Census, National Center for Education Statistics (including the National Assessment of Educational Progress), and Common Core of Data. The contextual information also comes from government reports addressing specific student groups such as students in alternative education programs or gifted and talented students.

The case studies were written by the members of the NGSS Diversity and Equity Team with expertise on specific student groups. In working on their case studies, many of the members piloted the NGSS in their own science instruction. The case studies represent science disciplines across grade levels:

- economically disadvantaged students – 9th grade chemistry
- students from major racial and ethnic groups – 8th grade life science
- students with disabilities – 6th grade space science
- students with limited English proficiency – 2nd grade earth science
- girls – 3rd grade engineering
- students in alternative education programs – 10th and 11th grade chemistry
- gifted and talented students – 4th grade life science

Collectively, the chapter and the seven case studies make contributions in several ways. First, they focus on *issues of student diversity and equity in relation to the NGSS specifically* as the NGSS present both learning opportunities and challenges to all students, particularly non-dominant student groups. Second, they are intended for *educational policies* as they highlight emerging national initiatives through the NGSS as well as the CCSS for English language arts and mathematics. Third, they are intended for *classroom practice* as the case studies were written by members of the NGSS Diversity and Equity Team who are themselves teachers working with diverse student groups. Fourth, they highlight key findings in *research literature on student diversity and equity* for seven demographic groups of students in science education. This is noteworthy because research for each student group tends to exist independently from the others. Finally, for each student group, they provide the context in terms of *demographics, science achievement, and educational policy.*

NGSS: Learning Opportunities and Demands for Non-Dominant Student Groups

The NGSS offer a clear vision of rigorous science standards by blending scientific and engineering practices with disciplinary core ideas and crosscutting concepts across K-12. In addition, the NGSS make connections to the CCSS for English language arts and literacy and for mathematics. For the student groups that have traditionally been underserved in science education, the NGSS offer both learning opportunities and challenges. Instead of making a long list of opportunities and challenges, major considerations are discussed below. Then, learning opportunities and challenges are illustrated in the seven case studies for economically disadvantaged students, racial or ethnic minority students, students with disabilities, English language learners, girls, students in alternative education programs, and gifted and talented students.

NGSS Connections to CCSS for English Language Arts and Mathematics

The NGSS make connections across school curricula. For example, students understand the crosscutting concept of patterns not only across science disciplines but also across other subject areas of language arts, mathematics, social studies, etc. Likewise, the crosscutting concept of cause and effect can be used to explain phenomena in Earth science as well as to examine character or plot development in literature. Thus, students develop mastery of crosscutting concepts through repeated and contrastive experiences across school curricula.

The requirements and norms for classroom discourse are shared across all the science disciplines, and indeed across all the subject areas. The convergence of disciplinary practices across the CCSS for English language arts and literacy, the CCSS for mathematics, and the NGSS are highlighted in Figure 1 (on page 21). For example, students are expected to engage in argumentation from evidence; construct explanations; obtain, synthesize, evaluate, and communicate information; and build a knowledge base through content rich texts across the three subject areas. Such convergence is particularly beneficial for students from non-dominant groups who are pressed for instructional time to develop literacy and numeracy at the cost of other subjects, including science.

Integration of subject areas strengthens science learning for all students, particularly for students who have traditionally been underserved. In the current climate of accountability policies, which are dominated by reading and mathematics, science tends to be de-emphasized. This is due to the perceived urgency of developing basic literacy and numeracy for students in low-performing schools including, but not limited to, English language learners and students with limited literacy development. Thus, allocation and utilization of instructional time across subject areas will benefit these students. Furthermore, the convergence of core ideas, practices, and crosscutting concepts across subject areas offers multiple entry points to build and deepen understanding for these students.

Initiatives are emerging to identify language demands and opportunities as English language learners engage in the NGSS as well as the CCSS for English language arts and literacy and for mathematics. For example, the Understanding Language Initiative <http://ell.stanford.edu> is aimed at heightening educator awareness of the critical role that language plays in the CCSS and the NGSS. Its long-term goal is to help educators understand that the new standards cannot be achieved without providing specific attention to the language demands inherent to each subject area. This initiative seeks to improve academic outcomes for English language learners by drawing attention to critical aspects of instructional practices and by advocating for necessary policy supports at the state and local levels.

Inclusion of Engineering

Inclusion of engineering along with science in the NGSS has major implications for non-dominant student groups. First, from an epistemological perspective, the NGSS reinterpret a traditional view of epistemology and history of science. For example, *Science for All Americans* stated:

> The recommendations in this chapter focus on the development of science, mathematics, and technology in Western culture, but not on how that development drew from earlier Egyptian, Chinese, Greek, and Arabic cultures. The sciences accounted for in this book are largely part of a tradition of thought that happened to develop in Europe during the last 500 years – a tradition to which most people from all cultures contribute today. (American Association for the Advancement of Science [AAAS], 1989, p. 136)

At that time, although the goal of "Science for all Americans" was visionary, the definition of science in terms of Western science while ignoring historical contributions from other cultures presented a limited or distorted view of science. The NGSS, by emphasizing engineering, recognize contributions of other cultures historically. This (re)defines the epistemology of science or what counts as science, which, in turn, defines or determines school science curriculum.

Second, from a pedagogical perspective, engineering has potential to be inclusive of students who have traditionally been marginalized in the science classroom and do not see science as being relevant to their lives or future. By solving problems through engineering in local contexts (e.g., gardening, improving air quality, cleaning water pollution in the community), students gain knowledge of science content, view science as relevant to their lives and future, and engage in science in socially relevant and transformative ways (Rodriguez & Berryman, 2002).

Finally, from a global perspective, engineering offers opportunities for "innovation" and "creativity" at the K-12 level. Engineering is a field that is critical to innovation, and exposure to engineering activities (e.g., robotics and invention competitions) can spark interest in the study of STEM or future careers (National Science Foundation [NSF], 2010). Although exposure to engineering at the pre-collegiate level is currently rare (Katehi, Pearson, & Feder, 2009), the NGSS make exposure to engineering at the pre-collegiate level no longer a rarity, but a necessity. This opportunity is particularly important for students who traditionally have not recognized science as relevant to their lives or future or students who come from multiple languages and cultures in this global community.

Focus on Practices

The ways we describe student engagement in science have evolved over time. Terms such as "hands-on" and "minds-on" have traditionally been used to describe when students engage in science. Then, *National Science Education Standards* (National Research Council [NRC], 1996, 2000) highlighted "scientific inquiry" as the core of science teaching and learning through which students "develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23). In the NGSS, "inquiry-based science" is refined and deepened by the explicit definition of the set of eight scientific and engineering practices, which have major implications for non-dominant student groups (for details, see Lee, Quinn, & Valdés, 2013; Quinn, Lee, & Valdés, 2012).

Engagement in any of the scientific and engineering practices involves both scientific sense-making and language use (see Figure 1). Students engage in these practices for the scientific sense-making process as they transition from their naïve conceptions of the world to more scientifically-based conceptions. Engagement in these practices is also language intensive and requires students to participate in classroom science discourse. Students must read, write, and visually represent as they develop models and construct explanations. They speak and listen as they present their ideas or engage in reasoned argumentation with others to refine their ideas and reach shared conclusions.

These scientific and engineering practices offer rich opportunities and demands for language learning while they support science learning for all students, especially English language learners, students with language processing difficulties, students with limited literacy development, and students who are speakers of social or regional varieties of English that are generally referred to as "non-Standard English." When supported appropriately, these students are capable of learning science through their emerging language and comprehending and carrying out sophisticated language functions (e.g., arguing from evidence, constructing explanations, developing models) using less-than-perfect English. By engaging in such practices, moreover, they simultaneously build on their understanding of science and their language proficiency (i.e., capacity to do more with language).

Crosscutting Concepts

Crosscutting concepts are overarching scientific themes that emerge across all scientific disciplines. These themes provide the context for new disciplinary core ideas and enable students to “develop a cumulative, coherent, and usable understanding of science and engineering” (NRC, 2011, p. 4-1). Thus, crosscutting concepts bridge the engineering, physical, life, and Earth/space sciences, and offer increased rigor across science disciplines over K-12. Although *Science for All Americans* (AAAS, 1989) identified “common themes” and *National Science Education Standards* (NRC 1996) identified “unifying concepts and processes,” the NGSS bring crosscutting concepts to the forefront as one of three dimensions of science learning.

Crosscutting concepts offers frameworks to conceptualize disciplinary core ideas. In this way, students think of science learning not as memorization of isolated or disconnected facts, but as integrated and interrelated concepts. This is a fundamental understanding of science that is often implied as background knowledge for students in “gifted,” “honors,” or “advanced” programs. Through the NGSS, explicit teaching of crosscutting concepts enables less privileged students, most from non-dominant groups, to make connections among big ideas that cut across science disciplines. This could result in leveling the playing field for students who otherwise might not have exposure to such opportunities.

Implementation of Effective Strategies

To make the NGSS accessible to all students, implementation of effective strategies capitalizes on learning opportunities while being aware of demands that the NGSS present to non-dominant student groups, as described in the previous section. Unfortunately, existing research literature does not address students’ performance expectations as envisioned in the NGSS based on the mastery of scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. Furthermore, the existing research literature addresses non-dominant student groups separately. For example, research on race or ethnicity, research on English language learners, research on students with disabilities, and research on gender comprise distinct research traditions (for effective strategies for non-dominant groups in science classrooms, see Special Issue in *Theory Into Practice*, 2013; for discussion of classroom strategies and policy issues, see Lee & Buxton, 2010).

There seem to be common themes that unite these distinct research areas. In describing “equitable learning opportunities” for non-dominant student groups, Lee and Buxton (2010) highlight the following themes: (1) value and respect the experiences that all students bring from their backgrounds (e.g., homes or communities), (2) articulate students’ background knowledge (e.g., cultural or linguistic knowledge) with disciplinary knowledge, and (3) offer sufficient school resources to support student learning.

First, to value and respect the experiences that all students bring from their backgrounds, it is important to make diversity visible. In the process of making diversity visible, there are both connections and disconnections between home/community and classroom/school. Effective teachers understand how disconnections may vary among different student groups, as well as how to capitalize on connections. These teachers bridge diverse students' background knowledge and experiences to scientific knowledge and practices.

Second, to articulate students' background knowledge with disciplinary knowledge of science, it is important to capitalize on "funds of knowledge" (González, Moll, & Amanti, 2005). Funds of knowledge are culturally-based understandings and abilities that develop over time in family and neighborhood contexts, and the social and intellectual resources contained in families and communities can serve as resources for academic learning. Effective teachers ask questions that elicit students' funds of knowledge related to science topics. They also use cultural artifacts and community resources in ways that are academically meaningful and culturally relevant.

Finally, school resources constitute essential elements of a school's organizational context for teaching and learning. School resources to support student learning involve material resources, human resources (or capital), and social resources (or capital). School resources are likely to have a greater impact on the learning opportunities of non-dominant students who have traditionally been underserved in science education. In schools and classrooms where non-dominant students reside, resources are often scarce, forcing allocations of the limited resources for some areas (e.g., reading and mathematics) and not others (e.g., science and other non-tested subject areas).

Below, each of these themes is described as it relates to classroom strategies, home and community connections, and school resources – all of which can enable non-dominant student groups to engage in the NGSS.

Effective Classroom Strategies

Key features of effective classroom strategies from the research literature on each of non-dominant groups are summarized below. In recognition of the fact that each area of research literature has been developing as an independent body of knowledge, the description of strategies is provided for each group. Yet, it is noted that while some strategies are unique to a particular group (e.g., home language use with English language learners, accommodations or modifications for students with disabilities), other strategies apply to all students broadly (e.g., multiple modes of representation). More detailed descriptions are provided in each of the seven case studies, including the four accountability groups defined in ESEA and three additional groups. While effective science instruction of the NGSS will be based on the existing research literature, the NGSS will also stimulate new directions for research to actualize its vision for all students.

Economically disadvantaged students. Strategies to support economically disadvantaged students include: (1) connecting science education to students' sense of "place" as physical, historical, and sociocultural dimensions, (2) applying students' funds of knowledge and cultural practices, (3) using project-based science learning as a form of connected science, and (4) providing school resources and funding for science instruction.

Students from major racial and ethnic groups. Effective strategies for students from major racial and ethnic groups fall into the following categories: (1) culturally relevant pedagogy, (2) community involvement and social activism, (3) multiple representation and multimodal experiences, and (4) school support systems including role models and mentors of similar racial or ethnic backgrounds.

Students with disabilities. Students with disabilities have their Individualized Education Plans (IEP), specific to the individuals, that mandate the accommodations and modifications that teachers must provide to support student learning in the regular education classroom. By definition, accommodations allow students to overcome or work around their disabilities with the same performance expectations of their peers, whereas modifications generally change the curriculum or performance expectations for a specific student. Two approaches for providing accommodations and modifications are widely used by general education teachers in their classrooms: (1) differentiated instruction and (2) Universal Design for Learning.

Students with limited English proficiency. The research literature indicates five areas where teachers can support both science and language learning for English language learners: (1) literacy strategies for all students, (2) language support strategies with ELLs, (3) discourse strategies with ELLs, (4) home language support, and (5) home culture connections.

Girls. The research literature points to three main areas where schools can positively impact girls' achievement, confidence and affinity with science and engineering: (1) instructional strategies to increase girls' science achievement and their intentions to continue studies in science, (2) curricula to improve girls' achievement and confidence in science by promoting images of successful females in science, and (3) classrooms' and schools' organizational structure in ways that benefit girls in science (e.g., after school clubs, summer camps, and mentoring programs).

Students in alternative education programs. The research literature focuses on school-wide approaches to promote increased attendance and high school graduation. Specific factors, taken collectively, correspond with alienation from school prior to dropping-out. Public alternative schools employ strategies to counteract these factors and increase student engagement: (1) structured after-school opportunities, (2) family outreach, (3) life skills training, (4) safe learning environment, and (5) individualized academic support.

Gifted and talented students. Gifted and talented students may have such characteristics as intense interests, rapid learning, motivation and commitment, curiosity, and questioning skills. Teachers can employ effective differentiation strategies to promote science learning of gifted and talented students in four domains: (1) fast pacing, (2) level of challenge (including differentiation of content), (3) opportunities for self-direction, and (4) strategic grouping.

Home and Community Connections to School Science

While it has long been recognized that building home-school connections is important for the academic success of non-dominant student groups, in practice, this is rarely done in an effective manner. There are tensions as parents and families want their children to maintain the cultural and linguistic practices of their heritage while also wanting their children to participate fully in the dominant school culture. A challenge facing schools is the perceived disconnect between school science practices and home and community practices of non-dominant student groups. Traditionally, research on home-school connections looked at how the family and home environments of non-dominant student groups measured up to the expectations and practices of the dominant group. The results were interpreted in terms of deficits in students' family and home environments, as compared to their dominant counterparts. In contrast, more recent research has identified resources and strengths in the family and home environments of non-dominant student groups (Calabrese Barton et al., 2004). Students bring to the science classroom funds of knowledge from their homes and communities that can serve as resources for academic learning, and teachers should understand and find ways to activate this prior knowledge (González, Moll, & Amanti, 2005). Science learning builds on tasks and activities that occur in the social contexts of day-to-day living, whether or not the school chooses to recognize this.

Through the NGSS, students can engage in scientific and engineering practices, crosscutting concepts, and disciplinary core ideas by connecting school science to their out-of-school experiences in home and community contexts. Several approaches build connections between home/community and school science: (1) increase parent involvement in their children's science classroom by encouraging parents' roles as partners in science learning, (2) engage students in defining problems and designing solutions of community projects in their neighborhoods (typically engineering), and (3) focus on science learning in informal environments.

Parent involvement in school science. Concerted efforts should be made to support and encourage parent involvement in promoting positive engagement and achievement of non-dominant student groups in science classrooms. Siblings and peers can serve as role models on academic achievement. Parents without academic background in science can still be partners in their children's science education by setting high expectations for academic success and higher education. Teachers can form partnerships with parents, facilitating dialogue to solicit their help with homework and their attendance at science-related events in the school.

To promote parents' involvement in school science, schools can play a part to address parents' needs from the school and remove roadblocks to participation. Schools may need to individually invite underserved families on science related field trips, making certain that particular concerns are met (e.g., child care, translation, transportation) so that the parents are able to attend. Teachers can create homework assignments that invite joint participation of the child and parent to complete a task together (e.g., observe the phases of the moon, record water use in the house). A non-evaluative survey related to science content can generate classroom discussions that bridge home and school. Homework assignments can encourage dialogue, increase interest among both parents and students, and solicit home language support for science learning.

Parents from non-dominant backgrounds feel comfortable with the school when they perceive the school as reflecting their values, and such parents, in turn, are most likely to partner with the school. For example, a science camp focused on African American achievement had high parental participation because its goals highlighted issues related to African American identity and culture (Simpson & Parsons, 2008). Teachers can also increase parent involvement by relating after-school and summer school themes around values that are important to the families and communities.

Student engagement with school science in community contexts. Strategies that involve the community underscore the importance of connecting the school science curriculum to the students' lives and the community in which they live. It is through these connections that students who have traditionally been alienated from science recognize science as relevant to their lives and future, deepen their understanding of science concepts, develop agency in science, and consider careers in science.

Science learning in community contexts may take different approaches. First, both disciplinary and informal education experts underscore the connection between science and the neighborhood that the students reside in. Effective approaches can include engaging in outdoor exploration (e.g., bird surveys, weather journals) and analyzing local natural resources (e.g., land forms in the neighborhood, soil composition).

Second, the community context for science education capitalizes on the community resources and funds of knowledge to make science more culturally, linguistically, and socially relevant for diverse student groups (González, Moll, & Amanti, 2005). For example, a teacher could tap into the community as a resource by recruiting a community member(s) to assist an upper elementary class, as students investigate the pollution along a river near the school. By bringing the neighborhood and community into the science classroom, students learn that science is not only applicable to events in the classroom, but it also extends to what they experience in their homes and what they observe in their communities.

Finally, "place-based" science education is consistent with culturally relevant pedagogy (Ladson-Billings, 1995). Through social activism, students develop critical consciousness of social inequities, especially as such inequities exist in their communities. When youth find science education to be empowering and transformative, they are likely to embrace and further investigate what they are learning, instead of being resistant to learning science. Thus, school science should be reconceptualized to give a more central role to students' lived experiences and identities.

Science learning in informal environments. Informal environments for science learning (e.g., museums, nature centers, zoos, etc.) have the potential to broaden participation in science and engineering for youth from non-dominant communities. Informal environments may also include non-institutional opportunities that are not traditionally recognized by school systems (e.g., community gardens, woodlots, campgrounds). However, informal institutions face challenges in reaching and serving non-dominant groups, as reflected in low attendance patterns. Although research on how to structure science learning opportunities to better serve non-dominant groups in informal environments is sparse, it highlights two promising insights and practices (NRC, 2009).

First, informal environments for science learning should be developed and implemented with the interests and concerns of particular cultural groups and communities in mind. Project goals should be mutually determined by educators and the communities and cultural groups being served. It is also important to develop strategies that help learners identify with science in personally meaningful ways. Having community-based contacts that are familiar and safe can be critical in engaging families in science explorations and conversations and even, at a more basic level, in helping non-dominant groups see museums as worthwhile destinations for their families.

Second, environments should be developed in ways that expressly draw upon participants' cultural practices, including everyday language, linguistic practices, and cultural experiences. In designed environments, such as museums, bilingual or multilingual labels provide access to the specific content and facilitate conversations and sense-making among participants. Developing peer networks may be particularly important to foster sustained participation of non-dominant groups. Designed spaces that serve families should consider visits by extended families. Members of diverse cultural groups can play a critical role in the development and implementation of programs, serving as designers, advisers, front-line educators, and evaluators of such efforts.

School Resources for Science Instruction

School resources to support student learning generally fall into three categories (Gamoran et al., 2003; Penuel, Krause, & Frank, 2009). First, material resources include time available for teaching, professional development, and collaboration among teachers. Material resources also include curricular materials, equipment, supplies, and expenditures for school personnel and other purposes related to teaching and learning. Second, human capital includes individual knowledge, skills, and expertise that might become a part of the stock of resources available in an organization. In schools, human capital involves teachers' knowledge, including content knowledge, pedagogical knowledge, and pedagogical content knowledge, as well as principal leadership. Finally, social capital concerns the relationships among individuals in a group or organization, including such norms as trust, collaboration, common values, shared responsibility, a sense of obligation, and collective decision making.

School resources are likely to have a greater impact on the learning opportunities of non-dominant student groups. This is because the dominant student group is more likely to have the benefits of other supports for their learning, such as better equipped schools, more material resources at home, and highly educated parents. In contrast, the academic success of non-dominant students depends more heavily on the quality of their school environment; yet, it is these students who are less likely to have access to high quality learning environments. Thus, inequitable resources are a central concern. The NGSS present both opportunities and challenges to reconceptualize the allocation and utilization of school resources.

Material resources. Science receives less instructional time (a form of material resources) than language arts and mathematics, which are both considered to be basic skills. Particularly, science instruction in low-performing schools is often limited and tightly regulated due to the urgency of developing basic literacy and numeracy. In addition, under the demands of accountability policies, schools devote extended time and attention to the heavily tested subjects of language arts and mathematics, leaving limited time for science.

The NGSS capitalize on the synergy with the CCSS for English language arts and literacy and for mathematics. The standards across the three subject areas share common shifts to focus on core concepts and practices that build coherently across K-12. Scientific and engineering practices in the NGSS (e.g., argumentation from evidence) share commonalities with those of the CCSS for English language arts and for mathematics (see Figure 1). Furthermore, the CCSS for literacy require strong content knowledge, informational texts, and text complexity across subject areas, including science. In a similar manner, the NGSS make connections to the CCSS. Such synergy will help effective use of instructional time among English language arts, mathematics, and science.

Human capital. While all students deserve access to highly qualified teachers, schools serving non-dominant student groups require the most effective teachers to enable students to overcome achievement gaps (Marx & Harris, 2006). The NGSS require science teachers who possess knowledge of disciplinary core ideas, scientific and engineering practices, and crosscutting concepts. For non-dominant student groups, teachers should also be able to connect science to students' home and community experiences as the students engage in the NGSS. Such expectations present both opportunities and challenges to teacher preparation and professional development for urban or low-performing schools where non-dominant student groups tend to be concentrated.

NGSS is built on continuity of learning progressions across grade levels. This presents both opportunities and challenges to students who are highly mobile or transient. On one hand, the nationwide purview of the NGSS may help these students by providing them with consistent standards among states, districts, and schools. On the other hand, this assumption may impede the ability of new immigrant students to catch up as they are unable to draw from a base of years of shared experiences. Likewise, students who miss school because of homelessness or other reasons for mobility may struggle to fill gaps in understanding.

Social capital. The conditions of urban or low-performing schools are not conducive to building social resources in the form of trust, collaboration, and high expectations collectively. Urban settings present challenges, including overcrowding, management issues, and emotional concerns related to conditions of poverty in students' homes.

The NGSS reinforce the need for collaboration among teachers of different specializations and subject areas beyond the traditional forms of collaboration. Science teachers need to work with special education teachers and teachers of English language learners in order to foster a deeper understanding of science. In addition, science, math, and English language arts teachers need to work together in order to address both the opportunities and demands for meaningful connections among these subject areas. Furthermore, collaboration needs to involve the entire school personnel, including teachers, administrators, counselors, etc. Utilization and development of social capital among school personnel is key to effective implementation of the NGSS with all students, particularly students from non-dominant groups.

Context

To engage all students in learning the NGSS, it is important to understand the context that influences science learning by diverse student groups. This section briefly describes student demographics, science achievement, and educational policies affecting non-dominant student groups. More details are presented in each of the seven case studies in terms of economically disadvantaged students, racial or ethnic minority students, students with disabilities, English language learners, girls, students in alternative education programs, and gifted and talented students.

Student Demographics

The student population in the U.S. is increasingly more diverse:

- **Economically disadvantaged students.** The American Community Survey report from the U.S. Census Bureau summarized the poverty data (U.S. Census Bureau, 2012). Overall 21.6% of children in the U.S. live in poverty, the highest poverty rate since the poverty survey began in 2001. The poverty rate was the highest for Black at 38.2% and Hispanic at 32.3%, compared to White at 17.0% and Asian at 13.0%. According to the *Common Core of Data* report, 48% of students were eligible for free or reduced price lunch in 2010-11. A greater number of students live in poverty in the cities compared to suburban areas, towns, and rural areas.

- **Students from major racial or ethnic minority groups.** The student population in the U.S. is increasingly more diverse racially and ethnically. According to the 2010 U.S. Census, 36% of the U.S. population is composed of racial minorities, including 16% Hispanics, 13% Blacks, 5% Asians, and 1% American Indian or Native Alaskans (U.S. Census Bureau, 2012). Among the school age population under 19 years old in 2010, 45% were minorities. It is projected that the year 2022 will be the turning point when minorities will become the majority in terms of percentage of the school-age population.

- **Students with disabilities.** The number of children and youth ages 3-21 receiving special education services under the Individuals with Disabilities Education Act (IDEA) rose from 4.1 million to 6.7 million between 1980 and 2005, or from 10% to 14% of the student enrollment (National Center for Education Statistics [NCES], 2011). That number decreased to 6.5 million or 13% of student enrollment by 2009.

- **Students with limited English proficiency.** Over 1 in 5 students (21%) speak a language other than English at home, and limited English Proficient (LEP) students (the federal term) have more than doubled from 5% in 1993 to 11% in 2007. The 11% of LEP students does not count those who were classified as LEP when younger but who are now considered proficient in English or during a monitoring period.

- **Students in alternative education programs.** Reporting the demographics of students in alternative education is difficult due to wide inconsistencies in definitions across the nation. A significant proportion of students who attend public alternative schools specifically targeting dropout prevention are economically disadvantaged students, racial and ethnic minorities, and English language learners (NCES, 2012).

- **Gifted and talented students.** Reporting the demographics of gifted and talented students is difficult due to wide inconsistencies in definitions, assessments to identify these students, and funding for programs across the nation. The National Association for Gifted Children (NAGC, 2012) defines giftedness as “those who demonstrate outstanding levels of aptitude or competence in one or more domains” and estimates that this definition describes approximately three million or roughly 6% of all students, K-12.

Several caveats are made with regard to student diversity. First, each demographic subgroup is not a homogenous or monolithic group, and there is a great deal of variability among members of the group. For example, categories of disabilities include specific learning disabilities, speech and language impairments, other health impairments, intellectual disability, emotional disturbance, developmental delay, autism, multiple disabilities, hearing impairment, visual impairment, orthopedic impairment, deaf-blindness, and traumatic brain injury. These categories could be classified as cognitive, emotional, and physical disabilities. Such variability among members of a group cautions that essentializing should be avoided.

Second, there is a significant overlap among non-dominant student groups. For example, most English language learners are racial or ethnic minorities. In addition, 60% of economically disadvantaged students, including large proportions of racial or ethnic minorities and English language learners, live cities (NCES, 2012). As a result, these students face multiple challenges in achieving academic success.

Finally, specific student groups are either overrepresented or underrepresented in education programs. For example, females are underrepresented in engineering and physics (NSF, 2012). Racial or ethnic minority students, economically disadvantaged students, and English language learners are underrepresented in gifted and talented programs, whereas they are overrepresented in special education programs (Harry & Klingner, 2006).

Science Achievement

While the student population in the U.S. is becoming more diverse, science achievement gaps persist by demographic subgroups. The results of international and national science assessments indicate the need for a two-pronged approach to enhancing student science outcomes. Achievement gaps must be closed among demographic subgroups of students, while improved science outcomes should be promoted for all students. In the report, *"Preparing the Next Generation of STEM Innovators* (NSF, 2010), the National Science Board states, "In America, it should be possible, even essential, to elevate the achievement of low-performing at-risk groups while simultaneously lifting the ceiling of achievement for our future innovators" (p. 16).

U.S. students have not ranked favorably on international comparisons of science achievement as measured by Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA). Although TIMSS science results for U.S. 4th and 8th graders showed positive trends since its first administration in 1995 through the latest administration in 2007, PISA results for 15 year olds did not corroborate trends indicated by TIMSS. When it comes to applying science in meaningful ways (e.g., using scientific evidence, identifying scientific issues, and explaining phenomena scientifically) as measured by PISA, U.S. students performed in the bottom half of the international comparison and did not show significant improvements since its first administration in 2000 through its latest administration in 2009.

At the national level, National Assessment of Educational Progress (NAEP) provides data for U.S. students' science performance over time. Focusing only on more recent NAEP science assessments in 1996, 2000, 2005, 2009, and 2011, achievement gaps persist among demographic subgroups of students across grades 4, 8, and 12. Results are reported by family income level (based on eligibility for the National School Lunch Program), race or ethnicity, students with disabilities, English language learners, gender, and type of school (public or private). It is noted that these subgroups represent the accountability groups defined in ESEA.

The framework for NAEP science involves science content in three areas (physical science, life science, and Earth and space sciences) and four science practices (identifying science principles, using science principles, using scientific inquiry, and using technological design). Two developments are noteworthy in relation to the NGSS. First, the 2009 NAEP science assessment included interactive computer and hands-on tasks to measure how well students were able to reason through complex problems and apply science to real-life situations. This approach could pave a way for assessment of scientific and engineering practices in the

NGSS. Second, the first-ever NAEP Technology and Engineering Literacy Assessment (TELA) is currently under development. The initial assessment, planned for 2014, will be a probe—a smaller-scale, focused assessment on a timely topic that explores a particular question or issue. This approach could be used for assessment of engineering in the NGSS.

A clear understanding of science achievement gaps should take into account certain methodological limitations in how these gaps are measured and reported. Science achievement is typically measured by standardized tests administered to national and international student samples. A strength of these measures is that they provide access to large data sets that allow for the use of powerful statistical analyses. However, these measures also present limitations.

First, standardized tests provide only a general picture of how demographic variables relate to science achievement. For example, "Hispanic" is likely to be treated as a single category of race or ethnicity, masking potentially important differences in performance among Mexican-Americans, Puerto Ricans, and Cuban-Americans. Similarly, the group of students with disabilities (SD) is generic, referring to students who usually have Individualized Education Programs (IEP) and could include both learning disabled (LD) or emotionally disturbed (ED). Thus, achievement data are generally lumped together for very different disabilities. Such overgeneralization hinders more nuanced understanding of achievement gaps, thereby limiting the potential effectiveness of educational interventions aimed at reducing these gaps.

Second, standardized tests have the potential to reinforce stereotypes, both positive and negative, of certain demographic groups (Rodriguez, 1998). For example, the "model minority" stereotype of Asian American students as strong performers in mathematics and science may well be supported by generalized test data for the racial category of Asian American. However, such a result masks great disparities within this group, such as Southeast Asian refugees with limited literacy development in their homes or communities. These students are less likely to have their needs met in equitable ways if teachers presume that they "naturally" learn science and mathematics with little trouble. In contrast, high-achieving Hispanic or African American students may be disadvantaged by teachers or counselors who underestimate them and set low expectations of their academic success.

Finally, standardized tests do not analyze or report interactions between demographic variables. For example, as racial/ethnic minority students are disproportionately represented in free or reduced price lunch programs, science achievement gaps between race/ethnicity and socioeconomic status are confounded. In a similar manner, science achievement gaps between race/ethnicity and gender are confounded.

Educational Policies

The passing of the NCLB Act of 2001 (the reauthorized Elementary and Secondary Education Act [ESEA]) ushered in a new era of high-stakes testing and accountability policies. Districts and schools are accountable for making an adequate level of achievement gain each year, referred to as annual yearly progress (AYP). The theory behind ESEA (NCLB) assumes that states, districts, and schools will allocate resources to best facilitate the attainment of AYP. Decisions concerning resources and practices are determined largely by test scores on state assessments.

Although ESEA is most often associated with accountability systems, there is a second property of ESEA that has also been a focus of attention. ESEA mandates that each state report AYP disaggregated for demographic subgroups of students. Mandating this disaggregated reporting of AYP results in potentially desirable outcomes: (a) each of the groups is publicly monitored to examine achievement and progress; (b) resources are allocated differentially to these groups to enhance the likelihood that they meet AYP; and (c) if AYP is not met for these groups in schools receiving Title I funding, students are provided with additional academic assistance through Supplemental Educational Services (e.g., tutoring) and the right to transfer to another public school. Schools, districts, and states cannot hide historically underperforming demographic groups, since ESEA forces the state to publicly monitor these groups and to be accountable for their performance. On the undesirable side, however, all of the added attention to high-stakes testing does not necessarily result in improved teaching. In fact, the increased emphasis on testing could detract from academically rigorous learning opportunities that are often lacking with students from certain demographic subgroups. Similarly, calling more public attention to the failures of schools to adequately meet the needs of these students does little to ensure that they will receive instruction that is more engaging, more intellectually challenging, or more culturally or socially relevant.

Although ESEA mandates reporting of AYP for reading and mathematics, the same is not true for science. With respect to science, ESEA only requires that by the 2007-2008 school year each state would have science assessments to be administered and reported for formative purposes at least once during grades 3-5, grades 6-9, and grades 10-12. However, it is up to each state to decide whether to include high-stakes science testing in state accountability systems or AYP reporting. Although science accountability policies affect all students, the impact is far greater for student groups that have traditionally been underserved in the education system.

Separate from federal and state policies that apply to all students, specific policies apply to specific student groups. According to the ESEA Act:

- Title I is the largest federally funded educational program intended for "improving the academic achievement of the disadvantaged" in order to meet "the educational needs of low-achieving children in our Nation's highest-poverty schools, limited English proficient children, migratory children, children with disabilities, Indian children, neglected or delinquent children, and young children in need of reading assistance."

- Title I, Part H, states that the Dropout Prevention Act aims "to provide for school dropout prevention and reentry and to raise academic achievement levels by providing grants that (1) challenge all children to attain their highest academic potential; and (2) ensure that all students have substantial and ongoing opportunities to attain their highest academic potential through school-wide programs proven effective in school dropout prevention and reentry."

- Title III addresses "language instruction for limited English proficient and immigrant students."

- Title VII is designed for "Indian, Native Hawaiian, and Alaska Native education."

- Title IX prevents gender-based discrimination within federally funded educational programs. Title IX states, "No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving federal financial assistance" (Public Law No. 92-318, 86 Stat. 235).

- Title IX, Part A, SEC. 9101 (22), provides a federal definition and federal research funding for gifted and talented students: "The term gifted and talented, when used with respect to students, children, or youth, means students, children, or youth who give evidence of high achievement capability in areas such as intellectual, creative, artistic, or leadership capacity, or in specific academic fields, and who need services or activities not ordinarily provided by the school in order to fully develop those capabilities."

- The Individuals with Disabilities Education Act (IDEA) is a law ensuring services to children with disabilities.

Conclusions and Implications

The NGSS offer a vision of science teaching and learning that presents both learning opportunities and demands for all students, particularly student groups that have traditionally been underrepresented in the science classroom. Furthermore, the NGSS are connected to the CCSS for English language arts and mathematics. Changes in the new standards occur as student demographics in the nation become increasingly diverse while science achievement gaps persist among demographic subgroups.

The academic rigor and expectations of the NGSS are less familiar to many science teachers than conventional or traditional teaching practices and require shifts for science teaching, which are consistent with shifts for teaching the CCSS for English language arts and mathematics (see Figure 1). Science teachers need to acquire effective strategies to include all students regardless of racial, ethnic, cultural, linguistic, socioeconomic, and gender backgrounds. While effective classroom strategies that enable students to engage in the NGSS will draw from the existing research literature, the NGSS will also stimulate new research agenda. For example, future research may identify ways to make connections between school science and home/community for non-dominant student groups as they engage in the NGSS. Future research may also explore how to utilize and allocate school resources to support student learning in terms of material resources, human capital, and social capital in relation to the NGSS.

Effective implementation of the NGSS for all students, including non-dominant student groups, will require shifts in the education support system. Key components of the support system include teacher preparation and professional development, principal support and leadership, public-private-community partnerships, formal and informal classroom experiences that require considerable coordination among community stakeholders, technological capabilities, network infrastructure, cyber-learning opportunities, access to digital resources, online learning communities, and virtual laboratories. As the NGSS implementation takes root over time, these components of the education system will also evolve and change accordingly.

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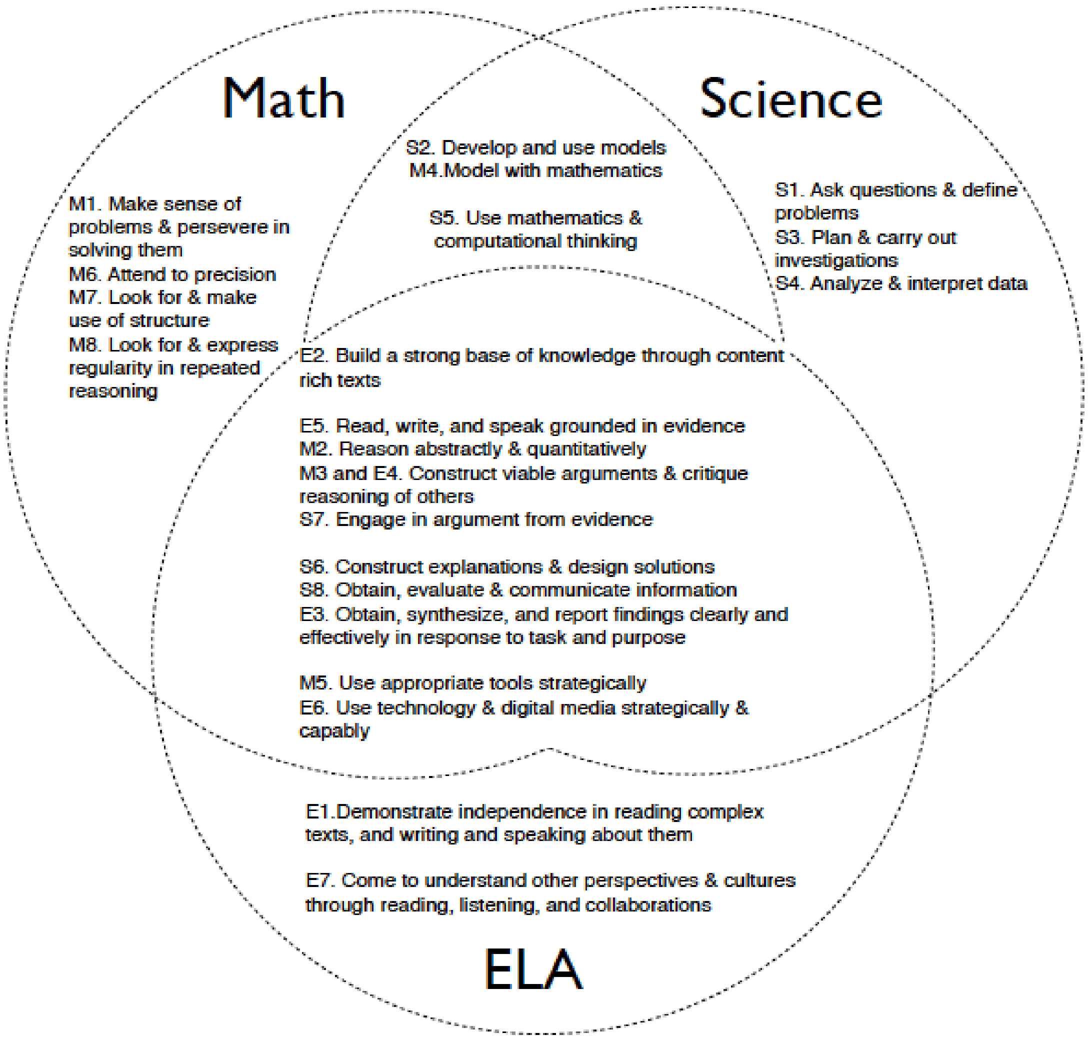

Figure 1. *Relationships and convergences found in the Common Core State Standards for Mathematics (practices), Common Core State Standards for English Language Arts and Literacy (student portraits), and the NRC Framework (science & engineering practices)*

Note: The letter and number set preceding each phrase denotes the discipline and number designated by the content standards. The NRC *Framework* is being used to guide the development of the Next Generation Science Standards.

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