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Next Generation Science Standards: All Standards, All Students

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Abstract The Next Generation Science Standards (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 underserved in science classrooms. The NGSS have addressed issues of diversity and equity from their inception, and the NGSS Diversity and Equity Team completed four major charges: (1) bias reviews of the NGSS, (2) Appendix D on diversity and equity, (3) inclusion of the topic of diversity and equity across Appendices, and (4) seven case studies of diverse student groups. This article starts with an overview of the NGSS Diversity and Equity charges, followed by a description of each of the four charges. This body of work addresses what science educators can and should do to ensure that the NGSS are accessible to all students, hence the title: "*All Standards, All Students*." In the coming years, the nation's student diversity will continue to grow rapidly while states adopt and implement the NGSS. Therefore, science teaching for non-dominant student groups equates to science teaching for all students.

Keywords Diversity · Equity · Science education reform · Policy

The Next Generation Science Standards (NGSS) are released at a pivotal time in the nation's history for revolutionizing science education. The NGSS offer a vision of science learning and teaching by seamlessly blending science and engineering

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practices, crosscutting concepts, and disciplinary core ideas to form a portrait of comprehensive science knowledge. The drive toward academically rigorous learning approaches to ensure that all students are college and career ready by the end of high school is transforming science teaching and learning.

In addition, the NGSS make connections to the Common Core State Standards (CCSS) for English language arts/literacy and mathematics. At the same time, the NGSS are released as the nation's student demographics are changing rapidly, while science achievement gaps among demographic groups of students persist. School-aged students from racial or ethnic minority backgrounds are projected to become the numeric majority collectively within the next decade (US Census Bureau, 2012). Almost half of the nation's student population is eligible for free or reduced-price lunch program, and the number of students living in homes in poverty or attending high-poverty schools continues to increase (National Center for Education Statistics, 2013). English language learners make up the fastest-growing student population in the nation (National Center for Education Statistics, 2012).

As the NGSS are academically rigorous, teachers should make instructional shifts that enable all students to be college and career ready. In addition, as science and engineering practices are language intensive, teachers should recognize and meet increased language demands while capitalizing on language-learning opportunities for all students, especially English language learners, students with limited literacy, students with disabilities involving language processing, and students who are speakers of social or regional varieties of English that are generally referred to as "non-Standard English" (Lee, Quinn, & Valdés, 2013). Furthermore, the education system broadly must provide resources and supports to successfully implement the NGSS both inside and outside of science classrooms by connecting with homes, communities, and informal settings.

Diversity and equity issues were addressed from the inception of the NGSS writing. The NGSS Diversity and Equity Team takes the stance that the standards must be made accessible to all students, especially those who have traditionally been underserved in science classrooms, hence the title: "*All Standards, All Students*." Through the two-year process of the development of the NGSS, the NGSS Diversity and Equity Team completed four major charges: (1) bias reviews of the NGSS, (2) Appendix D on diversity and equity, (3) inclusion of the topic of diversity and equity across Appendices, and (4) seven case studies of diverse student groups.

The purpose of this article is to describe the scope of work by the NGSS Diversity and Equity Team as an integral part of the NGSS. As an "information piece," the article serves as a historical record of how diversity and equity issues are addressed in the NGSS and how the work could serve as an example for reform initiatives of comparable nature, scale, and impact. The article starts with an overview of the team's work, to be followed by a description of each of the four charges.

Overview of the NGSS Diversity and Equity Charges

The National Research Council (NRC)'s consensus reports *America's Lab Report* (2005), *Taking Science to School* (2007), *Ready, Set, Science!* (2008), *Learning*

Science in Informal Environments (2009), and most notably *A Framework for K-12 Science Education* (2012) challenged thinking about science education. These reports highlight that students, regardless of background, are capable of making sense of scientific phenomena. What is critical is that all students be provided equitable opportunities to engage with scientific practices and construct meaning in science classrooms.

The NGSS increase academic rigor and demand that all students apply science and engineering practices (e.g., develop and use models, construct explanations, argue from evidence) and crosscutting concepts (e.g., cause and effect, patterns) across a range of disciplinary core ideas (e.g., structure and properties of matter). While integral to advanced science programs, developing such a comprehensive understanding of science has been missing in science programs at schools with limited resources. The NGSS provide this rich foundation for all students.

The NGSS Diversity and Equity Team was formed as an integral part of the NGSS writing. From the inception of the NGSS, several members were specifically selected to provide input on issues of student diversity and equity. Under the leadership of Okhee Lee, team members provided their expertise on poverty (Jennifer Gutierrez), race and ethnicity (Netosh Jones), special education (Betsy O'Day), English language learners (Emily Miller), alternative education (Bernadine Okoro), and gifted and talented students (Rita Januszyk). All were in school settings from various grade levels; geographic regions; and urban, suburban, and rural areas. The members served as writers of the NGSS and members of the NGSS Diversity and Equity Team.

The goal of the NGSS Diversity and Equity Team's work is to realize the vision set out in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012) and to support implementation of the NGSS with demographic student groups that reflect the student diversity found in the nation's classrooms. The NGSS present educators with the task of enabling all students to meet rigorous and comprehensive standards. However, teachers are unaccustomed to approaching science instruction with student learning outcomes in this manner. Furthermore, the research literature on classroom strategies typically focuses on each demographic group in isolation from other groups. For example, studies on English language learners, students with disabilities, poverty tend to exist separately.

The guiding principle for the *NGSS All Standards, All Students* is that certain conditions must be met to make the academic rigor of the NGSS accessible to all students. First, biases and stereotypes against specific demographic groups or individuals should be avoided, while representation and inclusiveness of diversity should be ensured. Second, science instruction should capitalize on "funds of knowledge" students bring from their homes and communities that can serve as resources for their science learning (González, Moll, & Amanti, 2005). Finally, the education system should offer sufficient resources (e.g., materials, human capital, and social capital) to support science learning for diverse student groups.

The NGSS Diversity and Equity Team refers to student diversity in terms of "dominant" and "non-dominant" groups (Gutiérrez & Rogoff, 2003). Dominant group(s) does not represent a numeric majority, but rather social prestige and

institutionalized privilege. Even in educational settings where the dominant group(s) is the numerical minority, the high status 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 growing student diversity.

Collectively, the NGSS Diversity and Equity Team's charges make important contributions. First, the charges highlight *diversity and equity issues in relation to the NGSS specifically* as the NGSS present both learning opportunities and challenges for all students to attain rigorous standards. Second, they address *classroom practice*—the case studies have been written by the Diversity and Equity Team members who work with diverse student groups. Teacher-as-expert voices offer invaluable insight into implementation of the NGSS, adding authenticity to the claim of practicality and utility for science instruction. Third, they identify key findings in *research literature on student diversity and equity* for seven demographic groups of students in science education. This is noteworthy because they address diverse student groups collectively, whereas research for each student group tends to exist independently from the others. Fourth, they provide the context for each student group in terms of *demographics, science achievement, and educational policy.* Finally, they are intended to inform *educational policies* as they highlight emerging national initiatives through the NGSS as well as the CCSS for English language arts/literacy and mathematics.

Bias Reviews of the NGSS

The Diversity and Equity Team was charged with conducting bias reviews of the standards to ensure that the NGSS avoid stereotypes, avoid unnecessarily difficult language, and represent inclusiveness of diversity. Based on the *ETS Guidelines for Fairness Review of Assessments* (2009) and our review of the CCSS, we offered overall recommendations for the NGSS writers at large. As team members were also involved in writing the standards, we remained vigilant to issues of bias and inclusiveness during the writing and revision of the NGSS.

The NGSS Diversity and Equity Team formally conducted two rounds of bias reviews of the standards: first for the January 2013 draft for public release and second for the April 2013 final version for public release. As we reviewed all of the standards, we developed systematic and comprehensive procedures in our document, "Diversity and Equity Guidelines for Review of the NGSS." We considered performance expectations, clarification statements, and assessment boundaries as they corresponded to practices, core ideas, and crosscutting concepts in the foundation boxes. For each recommendation, we provided example(s), suggested change(s), and offered rationale for our recommendation. The bias reviews focused on three areas: (1) representation of diversity and equity, (2) consistency of language, and (3) clarity of language.

First, we checked for how diversity and equity issues were expressed in the standards. While no instances of negative or positive bias or stereotype were evident in the drafts of the NGSS, we advocated for representation of diversity. We

recommended the use of inclusive language (e.g., *scientists and engineers from diverse backgrounds*), relevance of science to students' lives (e.g., *real-world problems, local contexts*), and low-cost science supplies in consideration of districts or schools with limited resources. The rationale for representation of diversity is that science instruction that is inclusive of and sensitive to diverse cultures increases access to all students.

Second, we looked for consistency of language among performance expectations, clarification statements, and assessment boundaries across science disciplines and across grade levels/bands. For example, "*draw on* evidence" could be confusing to English language learners who may interpret it as providing evidence in drawing. Based on our suggestion, it was changed to "*use* evidence." Similar confusion could occur with an expression such as "*look for* patterns," which was changed to "examples of patterns." Terms could have multiple meanings, thus causing confusion. For example, "relative qualitative length" appeared in a draft version of the NGSS. We pointed out that "relative" is unnecessary because "qualitative" indicates that measurement is not required; this term was omitted. The term "gross appearance" could be confusing because "gross" has multiple meanings such as vulgar and large. The term was changed to "macroscopic appearance." We also looked for consistency of terms to indicate learning progressions, for example, claims, *valid* claims, *reliable* claims, or *valid and reliable* claims. The rationale for consistency of language is that it enhances common and clear understanding of scientific terms, concepts, and practices (e.g., use evidence, find patterns, test cause and effect). Consistent language also promotes specific purposes for terms or statements across grade levels/bands (e.g., progressions from claims to valid and reliable claims).

Finally, we reviewed for clarity of language. We recommended removing unnecessarily difficult language and, instead, using the most accessible level of language or simplified sentence structure. We highlighted unclear pronouns (e.g., it, that, they) and, instead, suggested specific referents. Similarly, we avoided ambiguous, unnecessary, or redundant words and phrases, as well as confusing terms (e.g., some, many, between, among, and/or). The rationale for clarity of language is that it improves comprehension of meaning, which, in turn, enhances understanding of the intention of the standard. Clarity of language is particularly important to provide a common understanding of the standards for students who require linguistic support, including English language learners, students with limited literacy, and students with disabilities involving language processing. In addition, clarity of language increases access for community and family members, as well as educators from non-science backgrounds.

Appendix D on All Standards, All Students: Making the NGSS Accessible to All Students

Appendix D and the seven case studies work in tandem as they address seven demographic student groups (more details are provided in the case studies; visit http://www.nextgenscience.org/appendix-d-case-studies). As Appendix D serves as

an extended executive summary of the seven case studies, it offers a theoretical and conceptual grounding for diversity and equity issues that are specific to the NGSS. It meets three objectives that are explicated in its three sections.

First, Appendix D summarizes the opportunities and challenges that the NGSS offer to underserved student groups. The focus of the NGSS on science and engineering practices and crosscutting concepts offers multiple entry points for students who traditionally have not recognized science as relevant to their lives or future or have not been exposed to such opportunities. Furthermore, the NGSS connections to the CCSS for English language arts/literacy and mathematics are important for diverse student groups in the current climate of accountability policies that are dominated by reading and mathematics. The integration of these subject areas is particularly important for students from non-dominant groups who may be allotted fewer instructional hours in science due to these accountability practices.

Second, Appendix D discusses effective strategies that teachers can employ in order to enable all students to meet the NGSS in science classrooms. Existing research literature does not address students' performance expectations as envisioned in the NGSS. Furthermore, existing literature addresses non-dominant student groups separately. Despite these limitations, common themes seem to unite these distinct research areas: (1) value and respect the experiences that all students bring from their backgrounds (e.g., homes, communities, or informal settings); (2) articulate students' background knowledge (e.g., cultural or linguistic knowledge) with disciplinary knowledge; and (3) offer sufficient school resources (e.g., materials, human capital, and social capital) to support student learning (Lee & Buxton, 2010). In addition to common effective strategies across diverse student groups, Appendix D also presents effective classroom strategies for specific student groups.

Finally, Appendix D describes the context of student diversity in terms of changing demographics, persistent science achievement gaps, and educational policies affecting non-dominant student groups. The contextual information relies heavily on government reports, including the ESEA Act (e.g., Title I, Title 3), US Census, National Center for Education Statistics (including the National Assessment of Educational Progress), Common Core of Data, and other government reports addressing specific student groups (more details are provided in the case studies). While presenting the overall context for each student group, Appendix D adds caveats with regard to complexities of demographics, science achievement gaps, and educational policies within each group and across groups.

Diversity and Equity Topic in Appendices

In addition to Appendix D, issues of diversity and equity are addressed across the NGSS Appendices, reinforcing the vision that the NGSS should be accessible to all students. Key points of diversity and equity issues, as they are addressed in each of the appendices, are summarized next (full text is found in each appendix).

Appendix F: Science and Engineering Practices

Engagement in practices is language intensive and requires students to participate in classroom science discourse. Science and engineering practices are language intensive, thereby affording all students a discourse-rich science classroom. This learning environment offers both opportunities and demands for science learning and language learning simultaneously for all students, especially English language learners, students with language processing disabilities, 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."

Appendix G: Crosscutting Concepts

Crosscutting concepts are for all students. Students with low science achievement take basic level classes that primarily teach memorization of facts and other lower-order thinking skills. It is essential that all students engage in making connections among science disciplines described by crosscutting concepts. This engagement promises to lead to deeper understanding of science for students who have traditionally not had such access.

Appendix H: Understanding the Scientific Enterprise: The Nature of Science

Science is a human endeavor. The learning progressions across grade bands emphasize that individuals and teams of men and women from diverse cultures and nations have contributed to science and engineering. They also highlight that scientists' backgrounds, theoretical commitments, and fields of endeavor influence the nature of their findings.

Appendix I: Engineering Design

Engineering design in relation to student diversity. The NGSS engineering disciplinary core ideas and practices are extended to students whose experiences have led them to believe that science is irrelevant to their lives. By defining local problems and seeking design solutions (e.g., air or water quality in the community), students may be inspired to consider engineering as a career choice. Furthermore, engineering is a field that is critical to undertaking the world's challenges, and exposure to engineering activities (e.g., robotics and invention competitions) can spark interest in engineering majors in college or engineering careers for females and students from multiple languages and cultures in this global community.

Appendix J: Science, Technology, Society, and the Environment

Home and community connections to school science for student diversity. Students bring funds of knowledge from their home and community environments that can

serve as intellectual resources for academic learning (González et al., 2005). Effective approaches include parents and community members as partners in science learning, engineering projects in local contexts, and science learning in informal settings.

Seven Case Studies

To ensure that the NGSS are accessible to all students, the case studies demonstrate how teachers provide access to the NGSS through blending of the three dimensions, connecting to the CCSS for English language arts/literacy and mathematics, and employing effective classroom strategies (Miller & Januszyk, 2013). As the case studies illustrate implementation of the NGSS in diverse classrooms, they provide practical and tangible routes toward effective science instruction with diverse student groups.

In identifying student diversity, the case studies address the four accountability groups defined in the No Child Left Behind (NCLB) Act of 2001 and the reauthorized Elementary and Secondary Education Act [ESEA], Section 1111(b)(2)(C)(v): (1) economically disadvantaged students, (2) students from major racial and ethnic groups, (3) students with disabilities, and (4) students with limited English proficiency (the federal term). Then, student diversity is extended by adding three groups: (5) girls, (6) students in alternative education programs, and (7) gifted and talented students.

The case studies have been written by the NGSS Diversity and Equity Team members who are classroom teachers and have expertise in specific demographic groups across science disciplines and grade levels. In developing their case studies, some members piloted the NGSS in their own classrooms. The title of each case study reflects a particular demographic group of students engaging in the three dimensions of the NGSS (see Table 1).

Each of the seven case studies consists of four parts that parallel the organization of Appendix D, described earlier. First, it starts with a vignette of science instruction to illustrate learning opportunities for the specific student group highlighted. The vignettes are extensive in duration, ranging from 2 weeks of science instruction to an entire school year. They span K-12 grade levels and encompass all science disciplines and engineering. They emphasize how teachers *can* enable diverse student groups to meet the NGSS. Second, each case study provides a brief summary of research literature on the effective classroom strategies for the student group. Third, it describes the context for the student group in terms of demographics, science achievement, and educational policy. Finally, it ends with an NGSS-style foundation box for a user-friendly summary of the NGSS and CCSS for English language arts/literacy and mathematics found in the vignette.

Several caveats should be kept in mind in understanding the intent of the case studies. First, each vignette focuses on a limited number of performance expectations. In addition, student understanding progresses over time, and some topics or ideas require extended revisiting. Second, the case studies are not intended to be prescriptive of science instruction, but to illustrate an example or prototype for implementation of the NGSS. Teachers are expected to tailor their instruction to

Table 1 Seven case studies

Demographic group	Discipline	Grade level	Title of case study
Economically disadvantaged students	Physical science	9	Developing conceptual models to explain chemical processes
Students from racial and ethnic groups	Life science	8	Constructing explanations to compare the cycle of matter and the flow of energy through local ecosystems
Students with disabilities	Space science	6	Using models of space systems to describe patterns
English language learners	Earth science	2	Developing and using models to represent Earth's surface systems
Girls	Engineering	3	Defining problems with multiple solutions within an ecosystem
Students in alternative education	Physical science	10 and 11	Constructing explanations about energy in chemical processes
Gifted and talented students	Life science	4	Constructing arguments about the interaction of structure and function in plants and animals

respond to the learning needs of specific student groups in local contexts. Third, each case study highlights one identified group (e.g., English language learners). In reality, however, students could belong to multiple categories of diversity (e.g., English language learners with disabilities). The seven vignettes collectively demonstrate the NGSS implementation for diverse student groups. Finally, because students within each group vary widely, educators are cautioned against essentializing on the basis of a group label.

Conclusions and Implications

The NGSS present both learning opportunities and challenges for all students. As the educational system has failed to narrow achievement gaps in science, the Diversity and Equity Team was charged with offering guidance to make the NGSS accessible to those student groups that have traditionally been underserved in science classrooms. Thus, increased academic rigor of the NGSS is expected of the increasingly diverse student population in the nation, even though achievement gaps persist among demographic groups. Furthermore, the NGSS are also connected to the CCSS for English language arts/literacy and mathematics, thus forging the synergy and shared responsibilities of teachers across subject areas for all students in meeting academically rigorous standards and becoming college and career ready.

The performance expectations of the NGSS require shifts in science teaching for many science teachers who are more familiar with conventional teaching practices. Science teachers need extensive professional development to achieve this level of science learning for their students. While classroom strategies that enable all

students to engage in the NGSS draw from the existing research literature, the NGSS will also stimulate a call for a new research agenda. For example, future research may examine language-learning opportunities and demands for all students, especially English language learners, as they engage in language-intensive practices (e.g., constructing explanations, arguing from evidence) (Lee, Quinn, & Valdés, 2013). Future research may identify ways to make connections between school science and home/community for non-dominant student groups as they strive to meet the NGSS. Future research may also explore how urban and rural schools, which often face the challenge of limited resources (materials, human capital, and social capital), can maximize their limited resources in enabling all students to meet the academic rigor of the NGSS.

The education system as a whole will be required to make shifts to address the opportunities and challenges extended by the NGSS to non-dominant student groups. Key components of the education system include teacher preparation and professional development, school leadership, and parent and community involvement. Enhancements to technological capabilities, network infrastructure, cyber-learning opportunities, access to digital resources, utilization of online learning communities, and virtual laboratories require coordination among public–private-community partnerships. As the NGSS implementation takes root over time, these components inside and outside of schools will also evolve and change accordingly.

While the NGSS are a policy initiative, they have gone through the consensus building process through multiple steps until the final release in April 2013: (1) they are grounded in the *Framework* document (NRC, 2010); (2) the 41 writing team members consisted of classroom teachers, state and district supervisors, faculty from higher education institutions, and representatives from the private sector; (3) 26 Lead State Partners provided guidance and direction in the development of the NGSS; (4) hundreds of experts offered confidential reviews; and (5) two rounds of public feedback in May 2012 and January 2013 added to the evolving standards. Throughout this extensive and comprehensive process, issues of diversity and equity were addressed to make the NGSS accessible to all students. As the nation's student diversity continues to grow rapidly while the NGSS are expected to be implemented across states, *science teaching for non-dominant student groups equates to science teaching for all students.*

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