POLICY BRIEF

All Standards, All Students? The Misalignment of NGSS with California's Science Course Graduation Policy

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ABSTRACT

This policy brief provides an overview of the vision and organization of the Next Generation Science Standards (NGSS), and reviews three high school curriculum implementation models developed for the California Science Framework. The brief aims to promote social justice in science education, and addresses the need for reforming curriculum, policy, and practices to improve the equitable preparedness of students for college and career. Recommendations for policy improvements to high school science course requirements will also be presented.

Introduction

The United States science, technology, engineering, and mathematics (STEM) workforce has grown over the past decade and is expected to increase by 17 percent through 2018 (Langdon, McKittrick, Beede, Khan, & Doms, 2011), yet we do not have sufficient numbers of STEM-prepared graduates to fill the jobs. Current education fails to prepare high school graduates with the necessary knowledge and skills in STEM (National Research Council, 2010). A potential cause for this may simply be that California high school graduation requirements in math and science are only two years. Likewise, college admission requirements (A-G approved courses) are only two years for science, but three years for math. According to the United States Department of Education (2015), we must prioritize STEM education to prepare students for the competitive global economy. But continued achievement gaps contribute to the lack of diversity in STEM. In particular, Blacks, Hispanics, and American Indians are underrepresented in science and enigneering fields (National Science Foundation, 2015). Thus, STEM education must emphasize providing equitable opportunities for all students.

Numerous curricular reforms and policies such as No Child Left Behind (NCLB) have attempted to narrow achievement gaps, but have failed (Darling-Hammond, 2007; Zhao, 2009). The NCLB policy regards high quality education as scores on standardized tests in reading and math, intending to narrow the gap by increasing students' scores. The NCLB high school reform effort also included increasing the number of required courses in math and English but further disadvantaged some students by failing to address underlying factors associated with educational performance such as poverty and the different abilities of students (Zhao, 2009). Moreover, the NCLB policy has forced many schools to emphasize basic literacy and math, limiting science education (Mervis, 2011), which mainly focuses on breadth versus conceptual depth (National Research Council, 2007). Common approaches to science instruction have also typically provided few opportunities for students to engage in authentic experiences (National Research Council, 2012).

In the wake of NCLB, there has been an overwhelming movement toward nationally recognized standards to prepare all students for college and career. The Common Core State Standards (CCSS) address kindergarten through 12th grade curriculum in English language arts/literacy and mathematics. They also include new standards for integrating literacy with History/Social Studies, Science, and Technical Subjects. Following the adoption of Common Core was a national effort to revitalize science education, so the Next Generation Science Standards (NGSS) were developed. Unlike previous content standards, many components of the CCSS and NGSS are aligned, including common practices for science, mathematics, and literacy. For example, one component of the NGSS requires students to use mathematics and computational thinking. Because science is a quantitative discipline, some of the standards are naturally consistent with math. One of the Common Core literacy standards for science asks students to obtain, synthesize, and report findings clearly and effectively in response to task and purpose. While this new method of integrating standards and practices across disciplines is designed so that connections can be made across subject areas, it will initially be more cognitively demanding for all students (NGSS Lead States, 2013).

The new standards also introduce more intensive language demands for students. For example, two of the NGSS science and engineering practices are to construct explanations and engage in argument from evidence, which requires students to participate in classroom discourse and be able to articulate their thinking via writing and dialogue. The introduction of these language demands in science will require additional support for all students, particularly English learners. While English fluency is necessary for academic success, a deep foundation in subject area knowledge is also needed (Callahan, 2005). Many English learners are assigned to courses with remedial curriculum, resulting in a very small proportion of them graduating with A-G approved courses (Callahan, 2005). So the implementation of NGSS will require additional support for students who have typically been underserved in science.

But will this new set of standards be enough to shift thinking about equitable preparedness for college and career? Furthermore, will the adoption and implementation of NGSS force a restructuring of education policies so that its vision can be met?

Several factors contribute to the persistence of achievement gaps, including tracking, institutional racism, and a deficit belief model of student ability (Anyon, 1997; Jencks & Phillips, 1998; Kozol, 1991; Oakes, 1986). These structures influence the lack of opportunity for many students to experience connecting interdisciplinary concepts or apply science in meaningful ways. This type of engagement has typically been reserved for students who are assigned or tracked into in honors or gifted courses (NGSS Lead States, 2013). The NGSS acknowledge continued achievement gaps in science for students with diverse backgrounds, including English learners, as well as inequitable opportunities for some students to learn (NGSS Lead States, 2013; National Research Council, 2012). In particular, recent achievement data from the National Assessment of Educational Progress illustrates discrepancies between average scale scores in science of White (163), Black (129), and Hispanic (137) students (National Center for Education Statistics, 2012).

Transforming education to prepare all students for college and career is needed. A fundamental part of the NGSS design is to make the standards accessible to all students. "All Standards, All Students." One goal of the NGSS is that all students, not just those pursuing college or careers in STEM, gain sufficient knowledge of science and engineering to become critical consumers of information that is essential for a life well-lived in the twenty-first century. But will this new set of standards be enough to shift thinking about equitable preparedness for college and career? Furthermore, will the adoption and implementation of NGSS force a restructuring of education policies so that its vision can be met?

Policy Options

The NGSS promise to provide equitable opportunities to deepen students' conceptual knowledge and application of science and engineering in preparing them for college and career. Unlike the old state standards, the new ones are written as performance expectations, integrating three dimensions that are interwoven across Kindergarten through twelfth grade: (1) science and engineering practices, (2) disciplinary core ideas, and (3) crosscutting concepts. The NGSS also cover four domains (the physical sciences; the life sciences; the Earth and space sciences; and engineering, technology, and applications of science), where engineering, technology, and application of science standards are embedded into the other three domains.

The NGSS are currently being used to develop a California Science Framework, which was permitted by Senate Bill 300 (Hancock), and passed in 2013. Written as performance expectations, NGSS do not specify curriculum, nor is the framework itself a curriculum manual. Rather, the framework is designed to provide guidance for curriculum development and implementation of the standards. The NGSS are organized differently than prior standards

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across K-12. For grades K-5, they are organized by individual grade level. However, the standards are banded for middle school (grades 6-8) and high school (9-12). This is due to the varying policies across states in curriculum decision-making. In California, Education Code (EC 51225.3) allows Local Education Agencies such as school districts and county offices of education to make curriculum decisions for grades 6-12, and choose how to organize the standards. Because Local Education Agencies will select which model to implement, various curriculum plans will exist. Thus, the standards must be bundled in meaningful ways to develop courses. The Science Curriculum Framework and Evaluation Criteria Committee (CFCC) approved a Framework document that includes the following three curriculum implementation options for high school.

Policy Option 1 - Four Course Model

This model promotes a four-year course sequence to address all of the performance expectations, which appears to promote the "All Standards, All Students" curriculum vision of NGSS, and the advancement of STEM education. This option is based on the National Research Council's (2012) Science Domain Model, and divides the high school performance expectations into separate courses that cover these domains: life science (Biology), Earth and space science (Earth science), and physical science. The performance expectations for physical science are sub-divided further into two separate courses: Chemistry and Physics. A potential advantage of this model is that teachers of these domain specific courses can provide specialized instruction in one content area. Studies on teacher effectiveness have suggested that the higher pedagogical content knowledge teachers have in their subject area, the more effective they are (Loucks-Horsley, Hewson, Love, & Stiles, 1998; Nilsson, 2014; Shulman, 1986).

In this model, however, fulfilling the vision of NGSS would mean that every student would need to take all four of these proposed courses. But some students do not take four years of high school science. Only two years are required to graduate, and not all of them meet UC and CSU college entrance requirements (A-G approved). So which science courses are A-G approved and which students are taking them? Table 1 outlines the number of courses that are A-G approved in each science domain.

Less than half of Earth science courses offered are A-G approved, implying that the course content is not as important as the others. Alternatively, 91% of the Physics courses are A-G approved, even though there are fewer number of courses offered. One reason for this may be that Physics has traditionally been a course assigned to students who are in honors or have already passed the

Table 1
High School Science Course Offerings

	Total # of Courses	A-G Approved	Percent A-G Approved
Earth Science	6,782	3,179	47%
Biology	17,398	13,712	79%
Chemistry	9,083	8,479	93%
Physics	3,508	3,201	91%

Note. California Department of Education DataQuest: 2012-2013 Academic Year.

other courses. So which students are taking the A-G approved courses? Only 39% of high school graduates in California met college entrance requirements in 2013, and numbers varied based on students' ethnicities (see Table 2). Hispanic and African American student populations were among the lowest percentages of students that met college admission requirements, highlighting institutional course assignment policies to track particular students into or out of A-G approved courses.

This four course model appears to be like most existing high school curriculum, but its adoption would require substantial changes to education policies. First, if this model were adopted, there may not initially be enough certified teachers to teach Earth science and Physics, simply because fewer of the courses exist, so the current demand for teachers in those areas is low. Second, for equitable opportunity to learn, all students would need to take all four courses. This means that science course requirements for graduation also need to increase. Otherwise, the Earth science course will continue to be viewed as unimportant for college admission, and a wide gap between the numbers of courses offered in each discipline will persist. Finally, Table 2 illustrates the varying levels of preparedness for college admission based on ethnicity, so changes in institutional practices for assigning students into (or out of) A-G courses is also needed.

Policy Option 2 - Three Course Model with ESS Integrated

This model promotes a three-year course sequence to address the performance expectations, and removes Earth and space science (ESS) as a stand-alone course. It is based on the National Research Council's (2012) Modified Science Domain Model, where science domains are assigned to commonly taught high school courses (Biology, Chemistry, and Physics). These only address the life science and physical science domains, so Earth and space science performance expectations are distributed across all three courses as they are conceptually related. One advantage is that it is more likely for students to take three years of A-G science approved courses than four, as described above. Likewise, the courses easily align with currently approved courses for college admission, promoting preparedness for college and career in STEM. Another advantage is that Earth and space science can be used to contextualize content in the other disciplines, such as addressing earthquakes when studying waves in Physics,

Table 2
Number of Graduates Meeting UC/CSU Entrance Requirements (A-G)

Ethnicity	Percent
American Indian or Alaska Native, Not Hispanic	26%
Asian, Not Hispanic	68%
Pacific Islander, Not Hispanic	35%
Filipino, Not Hispanic	54%
African American, Not Hispanic	29%
White, Not Hispanic	47%
Two or More Races	47%
Hispanic or Latino	29%
None Reported	30%
Total	39%

Note. California Department of Education DataQuest: 2012-2013 Academic Year.

versus studying waves void of interdisciplinary context.

However, a potential limitation of this model is that single subject credentials in Biology, Chemistry, and Physics allow teachers to teach Earth science, but those with an Earth science credential (Geoscience) are not authorized to teach Biology, Chemistry, or Physics without additional authorizations on their credential. With the Earth science credential, teachers are certified to teach introductory general science courses and even 7-12 grade Integrated Science courses, but this model is different. It takes existing courses and integrates Earth and space science performance expectations across the other three core courses. Thus, this model could lack coherent curriculum and be implemented in such a way that the "core" part of the courses (Biology, Chemistry, and Physics) is taught as usual, with some time set aside to cover the Earth and space science standards. It could also displace some Earth science teachers who do not have added authorizations on their credential. Contrary to the four course model, this model could potentially limit teaching effectiveness in terms of teachers' pedagogical content knowledge because teachers may not have expertise in their single subject area plus Earth and space science, which are both required for this model.

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Adoption of this model would also require change to education policy. To ensure equitable opportunity to learn, all students would need to take all three courses, which contradicts current high school graduation requirements. Furthermore, because Physics currently isn't offered as frequently as Biology and Chemistry, additional Physics teachers would need to be hired and more courses offered. Moreover, if the science graduation requirements remain two years, which two courses would students take? Based on Table 1, most students would probably take Biology and Chemistry (with some integrated Earth and space science), but could be assigned or tracked out of the Physics course. This could perpetuate existing achievement gaps if Physics continues to be viewed as a course reserved for some students but not others, limiting opportunities for all students to access all the standards.

Policy Option 3 - Three-Year Model: Every Science, Every Year.

This is an integrated model, combining performance expectations from Earth and space science, life science, and physical science into each of the courses. This model is designed to address all performance expectations in three years, but was written with the realization that many students will only take the minimum two years of science required for high school graduation. Thus, the sequence of courses is designed to follow a developmental progression such that the first two years address the foundational concepts from all domains, reserving the third year for introducing more complex concepts that build upon years one and two.

One benefit of this model is that it is integrative, supporting inter-disciplinary teaching and learning, which could improve students' ability to apply their knowledge of the content in more relevant ways. In California a similar model for grades 6-8, the Integrated Learning Progression model, was recommended by the State Superintendent of Public Instruction, and adopted in 2013 by the State Board of Education as the preferred model. For high school, this model would ensure that students are exposed to all domains because they are integrated within each course, whereas the other options may discourage students from taking courses such as Earth Science or Physics. This model also appears to fulfill the "All Standards, All Students" vision of NGSS, but only if all students take all three courses.

While this model's integrative structure may provide opportunities for students to engage in all science domains, it is designed in response to California's science course graduation policy. Thus, one limitation of this model is that students can be assigned or tracked out of the third year of science. Since the NGSS are not designed to fit into two courses, those not taking the third course will be disadvantaged, and will not have opportunities to engage in the culminating third of the curriculum. Again, education policy on science course graduation needs to be revised to require three years of science if we want all students to have equitable opportunities to learn. Otherwise, students will graduate with only basic foundational understanding in science and engineering, and may not have learned or practiced the advanced skills needed to apply that knowledge to relevant societal problems, which is what NGSS are designed to support.

This model also introduces a discrepancy between which courses are approved for UC versus CSU entry. For CSU, two years of integrated science fulfills the A-G requirement. However, for UC, "the final two years of an approved three-year integrated science program that provides rigorous coverage of at least two of the three foundational subjects may be used to fulfill this requirement" (UC Admissions, 2015). So students who take two years of science at schools whose Local Education Agencies have selected this curriculum model would be eligible for CSU, but not UC. While this integrated model and sequence has the potential to prepare students for college and career, it limits opportunities for students to meet A-G requirements for UC admission. This has major implications for college admission requirements to UCs and must be considered by Local Education Agencies as decisions are made about which model to adopt.

Conclusion and Policy Recommendations

The newly adopted Common Core and Next Generation Science Standards (NGSS) promise a paradigm shift in K-12 education: to serve diverse populations, engage students in critical thinking, and to prepare them for college and career. However, NGSS are not aligned to current California high school graduation policies. Only two years of science are required, potentially discouraging many students from college or careers in STEM. The California Science Framework proposes three different models for course organization. But the science course graduation policy limits each of them in terms of allowing students to be assigned or tracked out of third or fourth year courses. Furthermore, achievement gaps will persist in science education unless additional support is provided for underserved students and transformations to institutional policies for course assignment are made. If NGSS are truly designed for all students, then alignment must be made between curriculum, policy, and practice.

Two major recommendations for policy improvement are: (1) increasing the science course graduation requirements from two to three years and (2) transforming course assignment policies so that all students have equitable opportunities to learn.

Current state mandated high school graduation policy is merely two years. If the NGSS are intended to improve current science education, and are designed to span across K-12, that cannot possibly be done effectively if only two years of science are required for high school graduation. Rather, "students are better prepared for postsecondary work when the practices are used over three years of science in high school" (NGSS Lead States, 2013, p. 13). Preparing students to meet the increasing demand for STEM jobs will mean aligning school policies to meet the vision of the new standards. Under current policy, the vision of "All Standards, All Students" won't be realized because inequitable opportunities to learn science will continue to exist if some students take the minimum two courses but others take three or four.

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Because NGSS span across K-12, embracing the vision of NGSS in preparing students for college and career means transforming science education across all grade levels. Current high school students have little experience with NGSS in K-8, so increasing science course requirements could be challenging for them. More time needs to be devoted to science instruction across all grade levels so that students entering high school are prepared to engage in this new method of science instruction. If science course requirements increase to three years, perhaps a phase-in approach can be applied. During the early implementation of NGSS over the next couple of years, all high school students could be allowed to graduate with two years of science. Curriculum must be adopted and teachers must learn how to effectively implement it. After this transition phase is completed, the science graduation policy could increase such that all incoming freshmen would be required to take three years of science to graduate.

We cannot raise the number of science course graduation requirements without considering the consequences. One potential unintended consequence for this type of policy change is an increase in high school dropout rates (Plunk, Tate, Bierut, & Grucza, 2014). While there are various reasons students drop out, the review of 25 years of research on high school dropout illustrates that no single factor has been identified as a predictor of high school dropout, nor is school policy alone responsible for higher levels of dropout rates (Rumberger and Lim, 2008). Rather, a combination of factors associated with both individual student characteristics (i.e. educational performance, attitudes, behaviors, background) and institutional characteristics (i.e. family structure, composition of student body, school policies) predict high school student dropout (Rumberger and Lim, 2008). But putting additional demands on students to graduate, without providing the necessary support, could contribute to increased dropout rates. We cannot continue demanding more of students and teachers with little or no support, especially since structural inequities in schools contribute to achievement gaps, which could be exacerbated with an increase in science course requirements.

If science course requirements increase, historically underserved populations will need additional support just to catch up. First language or bilingual science courses should be offered to support English learners, especially with the increased language demands of NGSS. Likewise, achievement data on the discrepancies between ethnic groups for meeting A-G requirements demands transformation of school policies such as course assignment. Why are there higher percentages of Blacks, Hispanics, and American Indians graduating without meeting college entrance requirements? Which science courses are they taking and how are students being assigned to them?

One potential underlying factor responsible for this type of structural inequity is tracking (Anyon, 1997; Callahan, 2005; Kozol, 1991; Oakes, 1986). New standards and an increase in science course requirement alone will not be sufficient for transforming science education because tracking limits some students' opportunities to learn. A paradigm shift in institutional and cultural beliefs about which students have the opportunity to learn which content is needed. All students must be given equitable opportunities to participate in high quality science education to prepare for college and career. Thus, science course assignment policies should allow students to access the same curriculum, and schools' academic advising policies should reflect inclusive practices such that students cannot be tracked out of higher level (A-G college approved) courses based on their language or ethnicity status.

In addition to the implementation of new science standards, pedagogical transformation within all science classrooms is required. Even if the prescribed NGSS curriculum is improved, the enacted curriculum can be vastly different because teachers' beliefs about science often differ from how curriculum is implemented in the classroom (Tobin & McRobbie, 1997). Thus, the pedagogy and implementation of standards will need to focus not just on the science content, but the cultural relevance to students and society. Teachers must transform their ideas about schooling, and practice culturally relevant pedagogy (Ladson-Billings, 1995) and critical pedagogy (Freire, 1970). We cannot continue using one-dimensional methods that emphasize basic knowledge of facts and expect students to be prepared for solving challenging problems or advancing knowledge to support the global economy. Instead, teachers and students must discover how to apply three-dimensional methods of teaching and learning that integrate science and engineering practices, disciplinary core ideas, and concepts that cut across all domains in the application of science. This transformation will take time and collaborative efforts of students, teachers, administrators, academic advisors, parents, and policymakers must align to provide equitable structures for accessing curriculum.

First language or bilingual science courses should be offered to support English learners, especially with the increased language demands of NGSS.

Future investigations on the effectiveness of NGSS implementation should be conducted to study how well the standards are equitably preparing students for college and career. Specifically worth examining is the extent to which the current two-year graduation policy will sufficiently prepare students for college and careers in STEM. Also worth consideration is how teacher credential programs and policies will change because of NGSS implementation. Finally, data needs to be collected on the different curriculum options that Local Education Agencies select to implement, the number of science courses students take, and what students take which courses. This would be useful in determining if or how the implementation of NGSS provides curricular access to students. These types of studies can yield critical information for improving science education. Under current policy, there is a misalignment in the application of NGSS. A truly effective transformation in science education will require realignment between educational policies, teaching practices, and NGSS's promise of "All Standards, All Students."

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