NORTH DAKOTA SCIENCE CONTENT STANDARDS: APPENDIX C

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College and Career Readiness

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APPENDIX C – College and Career Readiness

Postsecondary education is now seen as critical to ensure the nation's long-term economic security, to respond to the transformation in both the nature and number of current and projected jobs, and to enable social mobility. Yet, alarmingly, the United States has fallen from ranking 1st among industrialized nations in both high school completion rates and the percentage of adults with a 2- or 4-year degree, to 22nd in high school graduation and 14th in the percentage of 25- to 34-year-olds with a 2- or 4-year degree (OECD, 2012a, p. 26). On the 30th anniversary of the *Nation at Risk* report, key indicators point to our nation being more at risk than ever (Kirwan, 2013):

- Sixty percent of U.S. jobs are predicted to require some form of postsecondary education by the end of the decade (Georgetown University Center on Education and the Workforce, 2013).
- The U.S. Department of Labor notes that companies have reported more than three million job openings every month since February 2011 because of an absence of applicants with the skills to fill these positions (Woellert, 2012). The National Science Foundation also reports that there are currently between two and three million unfilled positions in the STEM areas of science, technology, engineering, and mathematics.
- The shortfall in STEM employees is likely to increase. The Department of Commerce shows that in the past 10 years, STEM jobs grew at three times the rate of non-STEM jobs, a trend likely to continue and accelerate (Langdon et al., 2011).

Postsecondary education also increases an individual student's chances for a decent, well-paying job. The unemployment rate for recent high school graduates without a college degree was more than 30 percent, while for recent college graduates, it was under 6 percent (Shierholtz et al., 2012). And in terms of earnings, a holder of a bachelor's degree is likely to realize a million dollars more over a lifetime than an individual with only a high school diploma. More troubling is a grim reality underlying these statistics: a child born into a family in the lowest quartile of income has a less than 8 percent chance of earning a postsecondary degree. The Organisation for Economic Co-operation and Development (OECD) observes that children of less-educated parents in the United States have a tougher time climbing the educational ladder than in almost any other developed country (OECD, 2012a, p. 102). The American dream that one's birth circumstances do not control one's destiny is fast slipping away.

The last decade has seen an emerging consensus that effective preparation for student success in postsecondary education and careers includes a strong background in science. In particular, the best science education seems to be one based on integrating rigorous content with the practices that scientists and engineers routinely use in their work—including application of mathematics. The larger context, and perhaps the primary impetus for this consensus, is the paradigm shift in our worldview of educational priorities, a direct result of the advent of the information age and global economy. To remain economically competitive, countries are pressed to substantially increase the number of students who can put knowledge to use in the service of new frontiers—discovering new knowledge, solving challenging problems, and generating innovations (NSF, 2012). Beyond the needs of the economy, an education grounded in acquiring and applying

knowledge positions students to improve their options in a rapidly changing menu of jobs, where few students will stay in the same job throughout their working lives. In sum, today's new reality demands that science and engineering become accessible to the many, not the few. And because the needed proficiencies are acquired over time, students must experience how science and engineering are conducted in the workplace throughout their K–12 schooling (NRC, 2007).

Scientists and engineers have always integrated content and practices in their work, but that has not been the case with science instruction. As former president of the National Academy of Sciences, Bruce Alberts, stated, "rather than learning how to think scientifically, students are generally being told about science and asked to remember facts" (Alberts, 2009). Traditional instruction has emphasized lectures, note-taking, reading, and assessment that tested recall, offering little opportunity for in-depth study or research (NRC, 2007). Laboratory activities, when offered, generally consisted of cookbook or confirmatory experiences. Research indicates that most lab experiences do not integrate well with other classroom instruction and infrequently include teacher and student analysis and discussion, thereby making it difficult for students to connect learning about science content with learning the processes of science (NRC, 2005). This situation stands in stark contrast to the real work of science and engineering, where new knowledge and innovation are prized. The shift in what the world needs and values requires that K–12 science education undergo a huge transition, from a focus on knowledge itself to a focus on putting that knowledge to use—a transition that in and of itself necessitates a corresponding leap in rigor. Meeting this challenge head-on, the Next Generation Science Standards (NGSS) constructed each performance expectation by linking concepts and practices that build coherently over time throughout K–12, thereby helping to ensure that students who meet the NGSS will be prepared to succeed in science courses in both 2- and 4-year institutions.

The first step in developing the NGSS was the development of *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (*Framework*). The National Research Council (NRC) led the undertaking in partnership with the American Association for the Advancement of Science (AAAS), the National Science Teachers Association (NSTA), and Achieve, Inc. The intent of the *Framework* was to describe a coherent vision of science education by (1) viewing learning as a developmental progression; (2) focusing on a limited number of core ideas to allow for in-depth learning (both cross-disciplinary concepts with applicability across science and engineering and concepts central to each of the disciplines); and (3) emphasizing that learning about science and engineering involves integration of content knowledge and the practices needed to engage in scientific inquiry and engineering design (NRC, 2012a, pp. 10–11). The NGSS kept the vision of the *Framework* intact by focusing on a rigorous set of core concepts that are articulated for each grade band (K–2, 3–5, 6–8, 9–12) and anchored to real-world science and engineering practices. This appendix reviews the evidence for basing K–12 standards on rigorous content, science and engineering practices, mathematics, and the benefits of integrating content with practices.

IMPORTANCE OF RIGOROUS CONTENT FOR COLLEGE AND CAREER READINESS IN SCIENCE

The first challenge facing the developers of the *Framework* was to identify the core conceptual knowledge that all students need to know and that also provides a foundation for those who will become the scientists, engineers, technologists, and technicians of the future (NRC, 2012a). Not all content is equally worth learning. Some science concepts deserve the lion's share of instruction because they have explanatory or predictive power or provide a framework that facilitates learning and applying new knowledge. To that end, the NRC convened members of the scientific community and engaged them in a rigorous, 2-year iterative process of formulating and refining the document based on multiple, critical reviews involving key organizations, distinguished scientists, mathematicians, engineers, and science educators, as well as the public. The resulting *Framework* sets forth not only the core ideas in the major science disciplines (life, physical, and earth and space sciences), but also the crosscutting concepts that have applicability to most fields in science and engineering. In keeping with the idea that learning is a developmental progression, the natural and cognitive scientists who developed the *Framework* further articulated what students should know by the end of each grade band. Significantly, the *Framework* also embraces the core concepts and essential practices of engineering, and in doing so, opens a window of interest and career opportunities not previously available to most K–12 students.

Once the *Framework* was completed, the NGSS writing team used the content to construct the NGSS performance expectations. Throughout the 2-year development process, the disciplinary core ideas (DCIs), and the related learning progressions from the *Framework*, along with their incorporation into the student performance expectations, were reviewed multiple times by a large group of expert reviewers (including major science, engineering, and mathematics associations), by the state teams in each of the 26 lead states as well as some additional states, and by the general public. In addition, Achieve convened postsecondary faculty and business representatives on two separate occasions to evaluate the content of the standards as being both necessary and sufficient for college and career readiness for all students. The comprehensive nature and thoroughness of the review process should ensure that the NGSS express the content expectations that will allow all students to be successful in advanced science courses and postsecondary careers.

Both the *Framework* and the NGSS reflect current thinking about the need for greater depth and rigor in K–12 science schooling. College Board, for example, has had a rich history in defining college and career readiness. "In order for a student to be college-ready in science, he or she must… have knowledge of the overarching ideas in the science disciplines (i.e., earth and space science, life science, physical science, and engineering) and how the practices of science are situated within this content…" (College Board, 2010, p. 3). The content represented in the *Framework* is also in line with the content identified in the College Board *Standards for College Success* (2009), which defines the rigorous knowledge and skills students need to develop and master in order to be ready for college and 21st-century careers. These were developed to … help students successfully transition into Advanced Placement (AP) and college-level courses. College Board standards, like the *Framework*, are based on (1) overarching unifying concepts

that are important across the science disciplines but also often apply to other fields such as mathematics and technology, and (2) like the *Framework*, are based on the core ideas of each science discipline (College Board, 2009). For students pursuing postsecondary coursework in science, core content clearly plays a key role. By virtue of being based on the content from the *Framework*, the NGSS provide a strong foundation for students to be successful in advanced science coursework.

ACT takes a similar, though not identical, stance as College Board with respect to core content. The ACT assessment assumes "that students are in the process of taking the core science course of study (three years or more of science in high school) that will prepare them for college-level work, and have completed a course in Biology and a course in Physical Science and/or Earth Science by the time they take the ACT" (ACT, 2011, p. 20). Based on their available data, ACT builds the case that students are better prepared for postsecondary work when the practices are used over 3 years of science in high school. ACT concludes: "Postsecondary expectations clearly state the process and inquiry skill in science are critical as well as rigorous understanding of fundamental (not advanced) science topics" (ACT, 2011, p. 9). However, while both ACT and College Board argue for winnowing content, ACT goes further, making the case that studying advanced content is not a quality predictor of postsecondary success. ACT goes on to state, "Therefore, for example, including a great deal of advanced science topics among the Next Generation standards would conflict with available empirical evidence" (ACT, 2011, p. 9). Postsecondary faculty report that a firm grasp of core concepts is more important than a weak grasp of advanced topics. Thus, a few components originally included in the *Framework* and early drafts of the NGSS were eliminated over time, based on the reviews of faculty in 2- and 4-year institutions in NGSS lead states, as well as on the ACT research.

ACT is not alone in arguing for a more limited coverage of content. Recent research examining the relationship between the performance of college students in introductory science courses and the amount of content covered in their high school courses concluded that "students who reported covering at least one major topic in depth, for a month or longer, in high school were found to earn higher grades in college science than did students who reported no coverage in depth. Students reporting breadth in their high school course, covering all major topics, did not appear to have any advantage in Chemistry or Physics and a significant disadvantage in Biology" (Schwartz et al., 2009, p. 1). Additional research supports limiting coverage, but offers little in the way of advising standards or policy developers *what* content should be eliminated. In fact, little empirical evidence exists on the content alignment between high school science and postsecondary expectations beyond ACT's data. Given the lack of empirical evidence in the field, the most fruitful path to support college and career readiness in science is to involve postsecondary faculty working with high school faculty to align content expectations.

From an international perspective, science content plays a prominent role in preparing K–12 students. In its international science benchmarking study of 10 countries (Canada [Ontario], Chinese Taipei, England, Finland, Hong Kong, Hungary, Ireland, Japan, Singapore, and South Korea) Achieve found evidence of strong science content, including far more attention to physical science concepts in primary and lower secondary grades than is typical of most states in the United States (Achieve, 2010, p. 59). However, the presentation of content is different than in the United States. Standards in 7 of the 10 countries present integrated science content (content

drawn from the major disciplines) each year from primary through grade 10, allowing students to specialize later in high school (Achieve, 2010, p. 42). These countries clearly see that a minimum amount of science knowledge is necessary for all students to become scientifically literate. Requiring that all students study integrated science content through grade 10 before enrolling in discipline-specific courses is a significant departure from the current structures in most U.S. states. Importantly, an integrated program through grade 10 also speaks to the possibility of capitalizing on student interest. Students could choose to pursue a course of study later in high school that fully prepares them for postsecondary careers, such as entry-level positions in health-related fields. Singapore has pursued this approach to great advantage. In making recommendations to the Carnegie's Commission on Mathematics and Science Education, mathematics expert Phillip Daro observed that Singapore's educational system "illustrates how it is possible to design multiple pathways to college entrance while still serving more specialized interests in the student population" (Carnegie Corporation of New York, 2009, p. 25).

Students need to be able to make sense of the world and approach problems not previously encountered—new situations, new phenomena, and new information. To achieve this level of proficiency students need a solid grasp of key science concepts and the ability to relate that knowledge across disciplines. Finally, as seen in the next section, students will need to be able to apply and communicate that knowledge flexibly across various disciplines, proficiencies they can acquire through the continual exploration of DCIs, science and engineering practices, and crosscutting concepts.

IMPORTANCE OF SCIENCE AND ENGINEERING PRACTICES IN COLLEGE AND CAREER READINESS IN SCIENCE

Empirical data and related research show direct support for students engaging in, and being held accountable for, proficiency in the science and engineering practices. The NRC has published a great deal of research in the recent past that supports the need for students to engage in science and engineering practices as they learn content. While no one document prior to the *Framework* includes all eight of the science and engineering practices described in the *Framework*, they are clear in the literature as a whole. Documents supporting the practices in the *Framework* include *Taking Science to School*; *Ready, Set, SCIENCE!*; and *America's Lab Report*. Findings from *Taking Science to School* (NRC, 2007, p. 342) show that students learn science more effectively when they actively engage in the practices of science. Linn and Hsi (2000) (as cited in the NRC's *America's Lab Report* [2005]) found that a quality integrated experience with practice and content led not only to greater mastery, but importantly, also more interest in science.

Streamlining the overwhelming amount of science content to target essential key ideas was the first but not the only challenge in building the *Framework*. In identifying and characterizing science and engineering practices, developers had to confront common classroom instructional practices where students are told that there is "a scientific method," typically presented as a fixed linear sequence of steps that students apply in a superficial or scripted way.

> This approach often obscures or distorts the processes of inquiry as they are practiced by scientists. Practices, such as reasoning carefully about the implications

> of models and theories; framing questions and hypotheses so that they can be productively investigated; systematically analyzing and integrating data to serve as evidence to evaluate claims; and communicating and critiquing ideas in a scientific community are vital parts of inquiry. However, they tend to be missed when students are taught a scripted procedure designed to obtain a particular result in a decontextualized investigation. Furthermore, these higher-level reasoning and problem-solving practices require a reasonable depth of familiarity with the content of a given scientific topic if students are to engage in them in a meaningful way. Debates over content versus process are not in step with the current views of the nature of science…. Science is seen as a fundamentally social enterprise that is aimed at advancing knowledge through the development of theories and models that have explanatory and predictive power and that are grounded in evidence. In practice this means that content and process are deeply intertwined. (NRC, 2012b, p. 127)

Historically, College Board emphasized content in its advanced placement science examinations, but is now giving increased attention to the practices that scientists routinely use. To wit: "Central to science is the goal of establishing lines of evidence and using that evidence to develop and refine testable explanations and make predictions about natural phenomena. Standards documents must reflect this goal of science by focusing on developing, in all students, the competencies necessary for constructing testable, evidence-based explanations and predictions" (College Board, 2010, p. 4). The new Advanced Placement (AP) Biology Exam and the relatively new *Standards for College Success* (SCS) reflect the new perspective in that both utilize scientific practices extensively. Both the AP redesign and the SCS identify performance expectations requiring practice and content to be in context of one another. Given the research that led College Board to make these decisions, the NRC utilized these two projects as a basis for the development of the *Framework*. College Board work and now the NGSS focus on understanding rather than memorization because greater understanding has been found to positively influence college performance (Tai et al., 2005, 2006). College Board states: "In order for a student to be college-ready in science, he or she must: (1) have knowledge of the overarching ideas in the science disciplines (i.e., earth and space science, life science, physical science, and engineering) and how the practices of science are situated within this content; (2) have a rich understanding of the nature and epistemology of science, scientific discourse, and the integration of science, technology, and society; (3) have metacognitive skills and self-efficacy related to the practices of science" (College Board, 2010, p. 3). This definition and the underlying research leave no doubt as to science practices being a critical component of readiness.

ACT's evidence for incorporating science practices derives from extensive years of collecting and analyzing data with regard to judging the preparedness of high school graduates for postsecondary science courses. ACT conducts a national curriculum survey every 3 years that compares expectations of introductory level postsecondary instructors with what is actually taught by middle and high school teachers and uses the results to update teacher information and the ACT assessments. The past two surveys have shown that postsecondary instructors greatly value the use of process or inquiry skills (science and engineering practices in the language of NGSS), and, in fact, value these skills equally to content. ACT notes [*sic*]: "Postsecondary expectations clearly state the process and inquiry skill in science are critical as well as rigorous

understanding of fundamental (not advanced) science topics" (ACT, 2011, p. 9). In their college placement services ACT also uses empirical data derived from the performance of college students to set the ACT College Readiness Benchmarks. Students who meet a benchmark on the ACT test or ACT Compass have approximately a 50 percent chance of receiving a B or better in their introductory level Biology course (ACT, 2013).

While ACT's position on college and career readiness in science acknowledges the need for students to pursue a rigorous program of science courses in high school, ACT also calls for integrating practices, based on their survey results. Notably, the ACT assessment focuses more on skill application than content. ACT (2011) states, "The Science Test, on the EXPLORE, PLAN, and ACT tests, measures the student's interpretation, analysis, evaluation, reasoning, and problem-solving skills required in the natural sciences. The test assumes that students are in the process of taking the core science course of study (three years or more of science in high school) that will prepare them for college-level work, and have completed a course in Biology and a course in Physical Science and/or Earth Science by the time they take the ACT" (p. 20). The ACT's WorkKeys Applied Technology Assessment also values these skills and empirically affirms that knowledge and usage of these skills better prepares students for career options than content knowledge alone.

College Board's and ACT's position with regard to the critical role of practices in preparing students for success in college-level science is echoed by David Conley in his book *College Knowledge* (2005). He identified students' ability to conduct meaningful research and use practices that lead toward quality research as a college- and career-ready indicator, stating that successful students:

- Formulate research questions and develop a plan for research.
- Use research to support and develop their own opinions.
- Identify claims in their work that require outside support or validation.

Science and engineering practices are also receiving increased attention in higher education. For example, recent "studies are converging on a view of engineering education that not only requires students to develop a grasp of traditional engineering fundamentals, such as mechanics, dynamics, mathematics, and technology, but also to develop the skills associated with learning to imbed this knowledge in real-world situations. This not only demands skills of creativity, teamwork, and design, but in global collaboration, communication, management, economics, and ethics. Furthermore, the rapid pace of change of technology seems fated to continue for many decades to come. This will require the engineers we are training today to learn to be lifelong learners and to learn to develop "adaptive expertise" (Hatano and Inagaki, 1986; Pellegrino, 2006; Redish and Smith, 2008, p. 2).

The AP science curricula, the AAAS publication *Vision and Change*, and the *Scientific Foundations for Future Physicians* identify overlapping science practices that are in line with the *Framework*. For example, the importance of modeling emerges in the life science documents and is used as an exemplar in Redish and Smith's (2008) work on skill development in engineering, noted above. Modeling is also built into both the Common Core State Standards (CCSS) for Mathematics and the *Framework*.

As noted earlier, making science accessible to a far greater number of students than is now the case is a critical issue. A growing body of evidence suggests that student engagement in practices helps reduce achievement gaps (Barton et al., 2008; Brotman and Moore, 2008; Enfield et al., 2008; Lee et al., 2005; Page, 2007). Specifically, one study found no significant difference in performance between subgroups (gender, ethnicity, or economically disadvantaged) when inquiry was used in instruction, as opposed to traditional classroom instruction where a significant achievement gap between subgroups of students was found (Wilson et al., 2010). In addition, Lee and colleagues (2006) found that while student achievement increased overall with inquiry-focused instruction, students from non-mainstreamed or less privileged backgrounds showed much higher gains than their mainstreamed, more privileged counterparts (Lee et al., 2006).

From an international perspective, science and engineering practices are seen as necessary for literacy as well as proficiency. The OECD's *Programme for International Student Assessment 2015 Scientific Literacy Assessment Framework* (2012) states that a scientifically literate person is able to engage in discourse by explaining phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically. It is worth noting that in Japan, a nation whose students outscore U.S. students on both PISA and TIMSS, classroom activity patterns are quite different than those characteristic of U.S. classrooms. Japanese students contribute their ideas in solving problems collectively and critically discuss alternative solutions to problems. Students in classroom environments like these come to expect that these public, social acts of reasoning and dialogue are a regular part of classroom life and learning across the disciplines (Linn, 2000; Stigler and Hiebert, 1999).

At the other end of the educational spectrum, Coles conducted research on the science content knowledge and skills necessary for both higher education and the workforce in the United Kingdom by interviewing groups from each sector. He found that employers and higher education professionals have more in common than not in their views of what science skills makes one qualified for their specific sector, noting: "[t]he number of components common to employers and higher education tutors is about twice the number of components specific to employers and about twice the number of components specific to tutors in higher education." Young and Glanfield (1998) add support to this finding, stating, "under the impact of information technology, the skills needed in different occupational sectors are converging as more and more jobs demand generic and abstract rather than sector-specific skills" (p. 7).

Graduates of 2- and 4-year colleges have as their goal securing employment and being successful on the job. Listening to what employers seek in candidates is critical because the skills employers seek need to be learned over the course of a K-postsecondary education. A number of recent reports point to gaps in preparation for work. One study earmarked five assets that are important to employers but hardest to find in candidates: These, in rank order, are Communication Skills, Positive Attitude, Adaptable to Change, Teamwork Skills, and Strategic Thinking and Analytics (Millennial Branding and Experience Inc., 2012). Another study asked employers to rate the importance of candidate skills/qualities. The results resonate with the previous study as employers cited, in rank order, the following top five abilities: work in a team structure, verbally communicate with persons inside and outside the organization, make decisions and solve problems, obtain and process information, plan, and organize and prioritize

work (National Association of Colleges and Employers, 2012). Still another study found that 95 percent of all employers surveyed say they give hiring preference to graduates with skills that will enable them to contribute to innovation in the workplace, reflecting concern for the nation's continuing ability to compete (The Association of American Colleges and Universities, 2013). These skills are likely to be acquired when students engage in projects based on the science and engineering practices and core content described in the *Framework* and prescribed in the performance expectations of the NGSS.

IMPORTANCE OF MATHEMATICS FOR COLLEGE AND CAREER READINESS IN SCIENCE

The *Framework* calls out mathematical thinking as a specific practice for good reason. "Mathematics is the bedrock of science, engineering and technology—it is the ability to quantitatively describe and measure objects, events, and processes that makes science so powerful in extending human knowledge. Moreover, because of the rapid and almost unimaginable increase in the power of computers, advances in science now depend routinely on techniques of mathematical models, remote imaging, data mining, and probabilistic calculations that were unthinkable a decade ago" (Achieve, 2010, p. 53).

Complementing the research supporting the integration of practices and disciplinary content in science education, research on math education suggests that instruction should not only emphasize core ideas, but also emphasize inquiry, relevance, and a multilayered vision of proficiency (Carnegie Corporation of New York, 2009).

From the international perspective, the lack of inclusion of mathematics explicitly in science standards was found to be a shortcoming in the countries studied (Achieve, 2010). In a review of the top performing countries based on PISA, reviewers found that mathematics integration was left to mathematics standards and curriculum documents. It is important to be aware that the math-science connection is not obvious to students. How science standards address and incorporate mathematics can make a difference in how easily students develop quantitative habits of mind. As a result, in developing the NGSS, explicit steps were taken to include mathematics in the development of the standards to help ensure students would receive a coherent education in two mutually supportive content areas. In fact the NGSS identify related Common Core State Standards for Mathematics for each science standard.

In addition to the inclusion of mathematics in the practices, there is evidence that mathematics is a key predictor of success in college science. While there is limited empirical data about the exact boundaries of college and career readiness in science, there has been data that supports a direct correlation between mathematics and success in college course work, or even the likelihood of successfully graduating with a 4-year degree. Proficiency in mathematics is a critical component of high school preparation leading to college success: "the highest level of mathematics reached in high school continues to be a key marker in precollegiate momentum, with the tipping point of momentum toward a bachelor's degree now firmly above Algebra 2" (Adelman, 2006, p. xix).

Sadler and Tai (2007) found that the number of years of mathematics was a significant predictor of college success across all college science subjects. Further, they found that more advanced mathematics in high school was a "pillar" that supports success in college science coursework. In like vein, Conley found college- and career-ready graduates had a firm grasp on mathematics and the ability to apply it across other disciplines. In addition, he found in surveys with college faculty that mathematics was considered an even better predictor of college science than high school science courses. Beyond success in postsecondary science, "there is a strong correlation between preparedness for college mathematics and the actual completion of a college degree. Students who need remediation in mathematics are considered at risk for academic failure and for retention and perseverance in their post-secondary education" (Ali and Jenkins, 2002, p. 11). The combination of the CCSS and the NGSS provide all students the opportunity for advanced studies in mathematics and science. The NGSS were developed specifically taking into account the new mathematics expectations described in the CCSS.

Experts at home and abroad understand that mathematics is key to understanding and communicating scientific ideas. In the words of mathematician and educator Sol Garfunkel on the future of American students, "We know that their future will involve many different jobs and the need to master current and future technologies. We know that they will need creativity, independence, imagination, and problem-solving abilities in addition to skills proficiency. In other words, students will increasingly need mathematical understanding and awareness of the tools mathematics provides in order to achieve their career goals" (Garfunkel, 2009).

It is easy to see why mathematics is, and will continue to be, a quality indicator of success. If there are any prerequisites to postsecondary science courses, it is usually a mathematics requirement. Students who are prepared for postsecondary education will be able to exhibit evidence of the effective transfer of mathematics and disciplinary literacy skills to science. As the NGSS move into adoption and implementation, work to develop specific examples of the further integration of mathematics and science will be critical.

INTEGRATION OF PRACTICE AND CORE IDEAS

Neither rigorous content nor science and engineering practices alone are sufficient for success in postsecondary institutions and careers. Rather it is the wedding of the practices to core content that increases student learning, as the *Framework* underscores: "Learning is defined as the combination of both knowledge and practice, not separate content and process learning goals" (p. 254). Additional research backs up the NRC's assertion. While practices are found in literature to be important predictors of achievement in science (Conley, 2005; Redish and Smith, 2008; von Secker, 2002; Wilson et al., 2010), it is also clear that students should use them in the context of quality and rigorous content.

One often overlooked aspect of combining demanding practices with strong content in standards is the effect on rigor. Even the most demanding of content is diluted if the expected student performance is basically dependent on rote memorization, i.e., calls for students to "describe," "identify," "recall," "define," "state," or "recognize." It is also well to keep in mind that calling for application of mathematics in a performance generally raises the level of rigor.

An instructive illustration is a learning outcome from Kansas's previous Science Education Standards (Kansas adopted the NGSS as their new state science education standards in June 2013) as compared with a related NGSS performance expectation.

Kansas 2007 Science Education Standards, Grades 8–11, Chemistry, HS.2A.2.2	NGSS Physical Sciences Grades 9–12, HS-PS1-1
"The student understands the periodic table lists elements according to increasing atomic number. This table organizes physical and chemical trends by groups, periods, and sub-categories."	"Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms."

While the organization of the periodic table is addressed by both sets of standards, it is clear that the NGSS raise the level of rigor by calling for a more demanding performance than does this example from the 2007 Kansas standards.

Another illustration can be found in Kansas's previous Biology standards:

Kansas 2007 Science Education Standards, Grades 8–11, Biology, HS.3.3.4	NGSS Life Sciences Grades 9–12, HS-LS3-3
"The student understands organisms vary widely within and between populations. Variation allows for natural selection to occur."	"Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population."

Calling for students to apply math concepts in explaining trait variation, as the NGSS do, bumps up the rigor of the expected student performance. Incorporating practices with content seems to have a positive effect on ensuring all students learn content at a deep level. Researchers found that students in project-based science classrooms performed better than comparison students on designing fair tests, justifying claims with evidence, and generating explanations. They also exhibited more negotiation and collaboration in their group work and a greater tendency to monitor and evaluate their work (Kolodner et al., 2003). In addition, von Secker (2002) found a greater content mastery and retention when teachers use inquiry-oriented practices. Results from the 2011 National Assessment of Educational Progress (NAEP) in science corroborate the positive effect on learning content when science practices are used in conjunction with content. On the eighth-grade teacher questionnaire, teachers reported how often their students engaged in hands-on activities or investigations in science by selecting one of four responses: "never or hardly ever," "once or twice month," "once or twice a week," or "every day or almost every day." Students who did hands-on projects every day or almost every day scored higher on average than those who did hands-on projects less frequently (NCES, 2011, p. 10). Furthermore, among higher-achieving grade 8 students who scored above the 75th percentile, 77 percent had teachers who reported that their students engage in hands-on activities once a week or more (NCES, 2011, p. 11).

The research regarding the value of integrating practices with content is compelling: preparedness for postsecondary work should be rooted in a student's ability to use science and engineering practices in the context of rigorous content. Using the practices in absence of content

is akin to asking students to learn the steps in the so-called scientific method. That will not result in preparedness but rather is likely to result in students continuing to have a disjointed view of science and a lack of ability to pursue their own interests or research today's problems. Students proficient in applying the practices in context will be able to apply a blend of science and engineering practices, crosscutting concepts, and DCIs to make sense of the world and approach problems not previously encountered, engage in self-directed planning, monitoring, and evaluation, and employ valid and reliable research strategies.

Prior to the release of the NGSS, most U.S. states had standards that did not clearly integrate inquiry and content. This integration of science process skills and domain-specific knowledge is still often missing from the classroom. Many standards, curriculum documents, and textbooks have separate sections on inquiry and science practices, and research indicates that many teachers follow the lead of these resources by teaching practices separately from conceptual content (NRC, 2007). Often, when students engage in science and engineering practices through laboratory experiments, these experiences have been isolated from the flow of classroom instruction and lacking in clear learning goals tied to content knowledge (NRC, 2005). Standards that balance and integrate inquiry and content can enhance student learning and better prepare them for success in postsecondary institutions and careers. As research has repeatedly shown that standards can have a large influence on curriculum, instruction, and assessment (Berland and McNeill, 2010; Krajcik et al., 2008; NRC, 2007), it is important for standards to specify the learning outcomes we expect from students, including that they can use practices to demonstrate knowledge of core ideas.

CONCLUSION

Economic and education statistics make it clear that the United States is not educating enough students who can succeed in a global information economy fueled by advances and innovation in science, engineering, and technology. Research findings indicate that our current system of science education, which places more value on science as a knowledge base than as a way of thinking, is ineffective. Too few students are experiencing success in postsecondary institutions and therefore lack the wherewithal to qualify for gainful employment, including STEM fields, where the nation is seeing the most growth in jobs. They are, in effect, being closed out of middle class opportunities. However, as the research studies referenced in this appendix indicate, there is a more productive path to follow in science education that entails linking important core content to the practices that scientists and engineers use as they go about their work. This shift in emphasis requires that we control the amount and kind of content, giving priority to powerful concepts that have currency because of their utility in explaining phenomena, predicting outcomes or displaying broad applicability in many fields, and that we use the practices in conjunction with core content throughout the grades.

The *Framework* identifies the content students are expected to know in order to be scientifically literate and to have an adequate foundation for further study and that content was deemed appropriate for success in college and career by science education experts and postsecondary instructors and employers. The *Framework* also describes the practices that characterize science and engineering work and explains what they look like in primary, upper elementary, and in middle and high school classrooms.

To reiterate, during the development of the NGSS, states remained focused on the vision of the *Framework* from the NRC, staying true to the cornerstones of rigorous core content, science and engineering practices, and links to mathematics. To ensure fidelity to that vision, teams of postsecondary faculty and business professionals from across the 26 lead states were convened to review the standards in terms of practice and content. Like the NRC, these groups confirmed that the design and development of the NGSS were guided by the best available evidence to ensure that students who meet the standards have the knowledge and skills to succeed in entry level science courses in technical training programs and in 2- and 4-year colleges. The evidence indicates this can best be accomplished through an approach that promotes in-depth understanding of a focused set of core concepts and interdisciplinary ideas, integrated with the regular application of those understandings through the practices of scientific inquiry.

Benchmarking has become a central concept in improving systems. And many countries are looking to Singapore as a model. Singapore's Educational System is recognized today as "world class," but that is a relatively recent turn of events. In just a slightly longer time period than it took the United States to relinquish its leadership role in terms of percent of students earning high school diplomas and postsecondary degrees, Singapore went from an impoverished nation with a largely illiterate population to being a model in education, a major telecommunications hub, and a leader in consumer electronics, pharmaceuticals, financial services, and information technology. Singapore's metamorphosis is attributed to its exemplary program of ensuring that most students are educated to take advantage of growing opportunities for employment in STEM fields. Because of the differences in size, scope, and complexity, it is difficult to imagine the United States fully implementing Singapore's system. However, much of education in the United States is controlled by states, and they could individually use Singapore's model to good advantage.

It is worth noting that as part of the education policy shift, "the government developed in 2004 the 'Teach Less, Learn More Initiative,' which moved instruction further away from rote memorization and repetitive tasks on which it had originally focused to deeper conceptual understanding and problem-based learning" (CIEB, 2012). Instruction has shifted toward one that includes active engagement with science practices (CIEB, 2012). This stance certainly resonates with that taken by the *Framework* and the NGSS.

In closing, when it comes to developing standards, rigorous content is an important indicator of student readiness for success in postsecondary education and careers, but it is not enough. Proficiency with science and engineering practices is also an indicator of readiness, but it is not sufficient in the absence of rigorous content. In the end, as the research shows, it is the science and engineering practices learned in conjunction with rigorous content that best prepares students for success in postsecondary education and careers. More research is needed around the alignment of high school and postsecondary expectations, course pathways, and flexible options that engage students' interests and best prepare students for postsecondary and career opportunities.

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