APPENDIX C – A DRAFT Definition of College and Career Readiness in Science

The *Next Generation Science Standards (NGSS)* are being developed based on the National Research Council's *A Framework for K-12 Science Education*. The *Framework* defined scientific literacy for all K-12 students by identifying Science and Engineering Practice, Crosscutting Concepts, and Disciplinary Core Ideas that will enable all student to make scientifically sound decisions about the world in which they live. At this stage of the NGSS development, in addition to scientific literacy, it is also critical to define what is meant by "college and career readiness" (CCR) in science. All states have made college and career readiness a goal of their K-12 education systems overall.

Historically, this discussion has taken place in mathematics and English language arts. As states seek to improve the quality and rigor of their standards in other subjects, the discussion has expanded. To that end, a group of experts in scientific disciplines, science education, and workforce readiness met and drafted the following working definition of college and career readiness in science, taking into account the context provided as a result of the development of the Common Core State Standards (CCSS) in Mathematics and ELA/Literacy, while acknowledging the unique nature of science and its increasingly critical role in the future of our society and economy.

College and Career Ready Students can demonstrate evidence of:

1. Applying a blend of Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas (DCIs) to make sense of the world and approach problems not previously encountered by the student, new situations, new phenomena, and new information;
2. Self-directed planning, monitoring, and evaluation;
3. Applying knowledge more flexibly across various disciplines through the continual exploration of Science and Engineering Practices, Crosscutting Concepts, and DCIs;
4. Employing valid and reliable research strategies; and
5. Exhibiting evidence of the effective transfer of mathematics and disciplinary literacy skills to science.

This working definition for college and career readiness in science is based on the following assumptions.

1. As indicated in *A Framework for K-12 Science Education*, students are expected to operate at the nexus of the three dimensions of science: 1) Science and Engineering Practice; 2) Crosscutting Concepts; and 3) DCIs.
2. The learning expectations are equivalent for college and career.
3. A student is ready to enter and succeed in coursework beyond high school in science and technical subjects that lead to a degree or credential. This includes the military and

credentialing that can occur during the high school experience such as credentialing programs, dual enrollment programs, and advanced placement courses.

It is important to note that these criteria were built partly on a body of research about the general needs of workforce readiness, such as students' ability to think critically and demonstrate skills necessary to be successful in the 21st century. While the research around college and career readiness in math and literacy is quite robust, the research on the content needed to be successful in entry level post-secondary science courses is still primitive. Some research has correlated student success to the number of courses/years of science and even the level of mathematics, but in-depth studies into the content necessary for all students to be successful and prepared for post-secondary success is in its infancy. Therefore, the draft definition put forth by the broad-based *College and Career Readiness in Science Advisory and Review Committee* is based on the best available research as well as their own professional experience.

Attendees of the *College and Career Readiness Advisory and Review Meeting* convened by Achieve found that students receiving instruction covering the Science and Engineering Practices, Disciplinary Core Ideas (DCIs), and crosscutting concepts from the *Framework* would be considered science literate and these skills were at the correct level for college and career readiness at the completion of instruction.

College and Career Readiness – A Changing Landscape

A transformation in college science education is underway, informed by how students learn. Calls to change teaching practice in higher education come from many quarters and share a vision with *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2011). Key elements include an emphasis on the interdisciplinary nature of science and engineering, a limited number of core ideas, the importance of integrating science and engineering practices with concepts, and student-centered approaches to instruction, rather than traditional lecture, to support students in developing problem-solving skills and conceptual understanding (PCAST, 2012; Singer, Nielsen, & Schweingruber, 2012). The convergence of K-12 and undergraduate science and engineering learning goals offers the promise of greater K-16 alignment and the confidence that the Next Generation Science Standards (NGSS) will prepare students well for next generation college learning.

Addressing pressing challenges related to food, energy, environment, and health care require all the ingenuity our society can muster, including substantive contributions from science. Creative solutions will require integration of physical sciences, biology, engineering, and mathematics by individuals able to work at the interfaces of their disciplines. *A New Biologist for the 21st Century* describes such an individual "not as a scientist who knows a little about all disciplines, but a scientist with a deep knowledge in one discipline and a basic 'fluency' in several" (NRC 2009, 20). *The Engineer of 2020* envisions "an engineering profession that will rapidly embrace the potentialities offered by creativity, invention, and cross-disciplinary fertilization to create and accommodate new fields of endeavor, including those that require openness to interdisciplinary efforts with non-engineering disciplines" (NRC, 2004, 50). Sharp and colleagues (2011, 8) consider this new work across disciplines to be revolutionary, calling it "convergence" that arises from true intellectual cross-pollination between the life sciences and the physical sciences and engineering, extending far beyond sharing tool sets.

Cross-disciplinary convergence requires new approaches to collaborative research teams and changes in science and engineering education (Sharp & Langer, 2011). Blueprints for cross-disciplinary science education are detailed in *Vision and Change in Undergraduate Biology Education* and a set of competencies for premedical undergraduates, *Scientific Foundations for Future Physicians* (AAAS, 2011; AAMC, 2009). The full integration of cross-cutting concepts in the NGSS prepares students for future college learning at disciplinary interfaces.

Calls for increased cross-disciplinary learning uniformly emphasize the importance of deep disciplinary understanding accompanied by the ability to work across the disciplines. There is agreement that the path to this deeper learning is through a limited number of core ideas (NRC, 2002, 2007, 2011). Guided by research on student learning, the new Advanced Placement science curriculum emphasizes a limited number of big ideas (Wood, 2009). For example, the four big ideas in the AP biology curriculum, implemented in Fall 2012, map onto the four core life science ideas in the *Framework* and also the five core concepts in *Vision and Change* (NRC, 2011; AAAS, 2011). Within education sections of disciplinary research societies similar thinking is emerging, as exemplified by a set of core ideas for undergraduate plant biology education informed by the *Framework* and *Vision and Change* (ASPB, 2012).

The third strand of the *Framework*, science and engineering practices, is also receiving increased attention in higher education. In engineering, the focus on practice is informed by theory on learning and linked to learning concepts (Redish & Smith, 2008; ABET, 2009). The AP curriculum, *Vision and Change*, and the *Scientific Foundations for Future Physicians* identify overlapping science practices that have coherence with the *Framework*. For example, the importance of modeling emerges in the life science documents, is used as an exemplar in Redish and Smith's (2008) work on skill development in engineering, and is built into both the Common Core Math Standards and the *Framework*.

At the college level, multiple groups have independently converged upon complementary and often shared goals for science and engineering education that emphasize cross-disciplinary concepts, core ideas, and science and engineering practices. These transformative events are synergistic with the vision for K-12 science and engineering learning developed in the *Framework* and NGSS. Some states have begun making progress aligning K-16 efforts at this opportune time (Adams, 2012).

Implementing the new vision for college science and engineering education requires substantial change in teaching practice and there are encouraging signs that this shift is beginning. The President's Council of Advisors on Science and Technology's highest priority recommendation for transforming the first two years of college learning in science, technology, engineering, and mathematics (STEM) is to "catalyze widespread adoption of empirically validated teaching practices" (PCAST 2012). And the National Research Council produced an analysis of effective science and engineering practices, informed by a growing body of evidence on undergraduate learning and teaching (Singer, Nielsen, & Schweingruber, 2012). Effective instruction includes well-implemented approaches that are supported by research findings and actively engage students in their own learning. Examples include interactive lectures, student group work, and real world problem solving and activities. Students at all levels have difficulties solving problems and using discipline-specific representations the way experts do. Several strategies can help students progress towards more expert-like thinking. In addition, there are instructional techniques that can help students develop correct understanding about phenomena involving very small or very large scales of time and space. These strategies are more effective in enhancing learning than only using traditional lecture.

Improving college teaching practice has moved beyond reports and analysis of evidence to implementation. The Association of American Universities launched an Undergraduate STEM Education Initiative to help their member institutions assess and share best practices and to create incentive structures leading to the adoption of effective teaching practices by their faculty (AAU, 2011). The Association of Public and Land Grant Institutions is working with 132 public institutions across 45 states on their Science and Mathematics Teacher Imperative which partners science and mathematics faculty with faculty in colleges of education to change undergraduate teaching practice (APLU, 2012). And, the Association of American Colleges and Universities and Project Kaleidoscope are working with teams of faculty, administrators, and assessment experts to develop a framework that colleges and universities can use to measure their effectiveness in promoting more learner-centered campus cultures (PKAL, 2012). At the level of university systems and universities, learning and teaching centers continue to expand and support faculty in implementing new teaching practices.

Whether a college student of the future is in a bricks and mortar classroom or laboratory or learning science and engineering through a massive open online course (MOOC), the learning environment will be increasingly determined by what is known about effective instructional practice. Further, what is taught will be much more than content. College science and engineering education will tend toward disciplinary intersections, focus on core concepts, and integrate practices into instruction. The NGSS will prepare students for this college of tomorrow.

Challenges Associated with CCR in Science

College- and Career-Readiness in science presents different challenges than those posed in determining college- and career-readiness in mathematics and English language arts (ELA). The Common Core State Standards defined college- and career-readiness according to the following:

a. "College ready" indicates preparation for credit-bearing course work in two- or four-year colleges, without the need for remediation and with a strong chance for earning credit toward a designated program or degree.
b. "Career ready" indicates preparation for entry-level positions in quality jobs and career pathways that often require further education and training.

This definition poses challenges in science for several reasons. First, there are very few remediation courses in universities, colleges, technical schools, or programs in science. Students generally take a credit-bearing science course because there is no real alternative. Second, most postsecondary options do not include a placement test to determine the appropriate level of science course for which a student should enroll. Again, there are very few courses that do not bear credit for the students taking them. More often, students determine their science level by either interest or mathematics levels. Third, while determining college- and career-readiness in mathematics and ELA were no easy feat, there was a general consensus of the post-secondary target courses. For mathematics, the most common entry-level course is College Algebra while students generally take Freshman Composition for the entry-level ELA credit. In science, there is no such target nor are there pre-requisites to what students take as entry-level science courses. Fourth, and perhaps most significantly, the role of science in college and career is changing dramatically and the new standards must stand ready to meet that change. Among students who are interested in science, there are those who go to college and experience success. However, there are still large numbers of students initially interested in science or STEM careers who drop their freshman course or change to non-science majors presumably due to poor preparation. As workforce needs continue to shift toward more technically based requirements, having a scientifically literate workforce becomes more critical. If the United States is to retain its place in the global economy, the pipeline preparing more scientifically literate students is critical. The pipeline can best be filled by preparing all students and allowing each student the opportunity to pursue science or STEM as a career. At this point, there is a shortage of students entering, remaining and completing the pipeline. To enhance the output, more students must have the preparation needed to allow them entry into these fields. In particular, there is still a significant gap between majority and minority students. Lee and Buxton found, "… in 2006, Blacks, Hispanics, and American Indians/Alaska Natives earned a total of 17 percent of bachelor's degrees in science and engineering, 12 percent of the master's degrees, and 10 percent of the doctoral degrees. While each of these percentages is an increase compared to a decade earlier, they indicate persistent gaps when compared to the increasing population of non-mainstream students in our schools. For women there is a similar pattern of lower representation at successively higher levels of education. In 2006, women earned half of the bachelor's degrees in science and engineering, 45 percent of the master's degrees, and 38 percent of the doctoral degrees."

Given the direction of the workforce and the changing landscape in post-secondary in general, the Next Generation Science Standards must be developed for the future workforce and post-secondary requirements as opposed to the current ones.

Overview of Research Supporting this College- and Career-Readiness in Science Definition

Attendees of the *College and Career Readiness Advisory and Review Meeting* convened by Achieve found that students receiving instruction covering the Science and Engineering Practices, DCIs, and crosscutting concepts from the *Framework* would be considered science literate and these skills were at the correct level for college and career readiness at the completion of instruction.

College and Career Ready Students can demonstrate evidence of:

1. Applying a blend of Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas to make sense of the world and approach problems not previously encountered by the student, new situations, new phenomena, and new

information;

The National Research Council notes that the *Framework for K-12 Science Education* includes Deeper Learning and 21st Century Skills, such as constructing and evaluating evidence-based arguments as well as non-routine problem solving. Furthermore, the Organization for Economic Co-operation and Development's (OECD's) *Programme for International Student Assessment 2015 Scientific Literacy Assessment Framework* notes 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.

2. Self-directed planning, monitoring, and evaluation;

The United States Department of Education's Support for States Employability Standards in CTE and Adult Education program created an Employability Skills Framework that cited "Plans and Organizes" as a critical thinking skill that improves employability. Also the William and Flora Hewlett Foundation's Deeper Learning Skills include "Learn How to Learn" or self-directed learning. Some examples of this are using teacher feedback and test results to guide future learning and study habits. Finally, The National Research Council's *A Framework for K-12 Science Education* states that deeper learning and 21st Century Skills also include self-development, critical thinking, motivation, and persistence.

3. Applying knowledge more flexibly across various disciplines through the continual exploration of Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas;

David Conley (2005) discusses how a college-ready curriculum includes concepts of biology, chemistry, and physics. ACT and College Board have also found that students should have instruction in life, physical, and earth/space sciences. Both organizations also made clear the importance of contextualizing science and engineering practices in these areas. *A Framework for K-12 Science Education* asserts that a core idea for science instruction should "have broad importance across multiple sciences or engineering disciplines…" In addition, the Framework states that the crosscutting concepts were selected because of their value across the different scientific disciplines and engineering.

4. Employing valid and reliable research strategies; and

David Conley (2010) also writes that a college- and career-ready student is able to identify all possible sources for research, can collect information from a variety of places, and can distinguish different levels of "credibility, utility, and veracity" of the resources' information. Moreover, a college- and career-ready student understands the ethics of collecting research and can synthesize information appropriately.

Conley (2005) provides greater detail regarding what this means in his book *College Knowledge*. He states 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

5. Exhibiting evidence of the effective transfer of mathematics and disciplinary literacy skills to science.

The Common Core State Standards were developed to better prepare K-12 students in the United States for college entrance and careers. They place particular importance on argument in the standards. Appendix A of the Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects states "the Standards put particular emphasis on students' ability to write sound arguments on substantive topics and issues, as this ability is critical."

Assumptions of the Definition Substantiated with Research

This definition for college and career readiness in science is based on the following assumptions.

1. As indicated in *A Framework for K-12 Science Education*, students are expected to operate at the nexus of the three dimensions of science: 1) Science and Engineering Practice; 2) Crosscutting Concepts; and 3) DCIs.

> "The three dimensions of the framework, which constitute the major conclusions of this report, are presented in separate chapters. However, in order to facilitate students' learning, the dimensions must be woven together in standards, curricula, instruction, and assessments. When they explore particular ideas from Dimension 3, students will do so by engaging in practices articulated in Dimension 1 and should be helped to make connections to the crosscutting concepts in Dimension 2." (National Research Council, 2011)

2. The learning expectations are equivalent for college and career.

The *College and Career Readiness Advisory and Review Meeting* attendees stated deliberate thought should be given to ensuring the NGSS contains the skills and concepts needed for entering college freshman and for entry-level certificate programs. As stated earlier, the science and engineering practices and crosscutting concepts outlined in the *Framework* are appropriate for all students. Additional work needs to be done to determine the areas of overlap or support in the Common Core State Standards and career pathways.

Coles conducted research on the science content knowledge 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 in their views of what science knowledge makes one qualified for their specific sector, noting that "[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 support this further by stating that "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."

In the 21st century, the importance of understanding science and engineering has played an increasingly substantial role in a person being a productive member of society. STEM is a continually expanding field that offers all students career opportunities if students have the necessary skill set. An estimated 70 percent of STEM jobs will require a bachelor's degree or more by 2018, with an estimated 90 percent requiring some kind of postsecondary degree. Recent research by Georgetown University Center on Education and the Workforce (2011) has found that "STEM is the third-most education-intensive occupational cluster, exceeded only by Healthcare Professional occupations and Education occupations" (*STEM*, pg. 22). Additionally, according to Complete College America, 43.3 percent of postsecondary certificates are awarded in healthcare and related fields. In more and more cases, citizens' ability to acquire technical jobs and progress in their chosen career field is based significantly on their ability to be successful in postsecondary science or STEM education.

Simultaneously, STEM has become more prevalent in the K-12 arena as more jobs require science, technology, engineering, and mathematics understanding. Many programs have been developed in partnerships between K-12, post-secondary education, and business. These programs tend to address skills and often recommend the sciences needed for successful completion of the programs. For instance, plans of study developed by The National Association of State Directors of Career Technical Education Consortium (NASDCTEc) recommends high school courses for all 16 identified "career clusters" including four science credits for each of the 16 clusters. Further, NASDCTEc recommends biology for 15 clusters, physics for 12 clusters, chemistry for 12 clusters, and earth science or some other introductory course for 12 clusters.

Career preparation has been informed by the recent development of data sources on skills required for employment. The U.S. Department of Education created the Employability Skills Matrix for CTE and Adult Education to house information on different educational program requirements. The Applied Academic Skills information used in this matrix compiles data from 10 resources by various authors, including the U.S. Department of Labor, the University of Tennessee, ACT, the Partnership for 21st Century Skills, and others. A total of 6 out of these 10 resources cite using scientific principles and procedures as critical academic skills needed for employability.

One of these six resources is the O*NET® Resource Center, sponsored by the U.S. Department of Labor. The O*NET® Resource Center uses a content model which "provides a framework that identifies the most important types of information about work and integrates them into a theoretically and empirically sound system." Part of this content model presents *Worker Requirements*, one of which lists specific subjects in education. This list of subjects includes physical science, biological science, and applied science.

Public higher education institution admissions requirements differ by state. Flagship public universities in 35 states require at least three credits of science in entry requirements (1 state requires 0 credits, 14 require 2 credits, 33 require 3 credits, and 2 require 4 credits). In addition, flagship universities in 40 states have science credit entry requirements that align with graduation requirements. There are some institutions whose entry requirements do not align with their state's graduation requirements because the institutions specify additional science courses (Achieve data). Some higher education institutions require only a number of science credits while other institutions have specific course prerequisites. Beginning with the incoming freshman class of 2017, to be eligible for admission to a four-year public institution of higher education in Massachusetts, students are required to take three years of lab-based science in high school, including the natural/physical sciences or technology/engineering courses.

3. A student is ready to enter and succeed in coursework beyond high school in science and technical subjects that lead to a degree or credential. This includes the military and credentialing that can occur during the high school experience such as credentialing programs, dual enrollment programs, and advanced placement courses.

Postsecondary certificates are becoming more common in the United States. Certificates are not to be confused with industry-specific certifications (awarded by companies like Microsoft or Cisco). Instead, these certificates are awarded by two- and four-year colleges and are often classified by the length of time it takes to complete a given program. Additionally, progress in chosen career fields is related to the type of postsecondary certificate earned. Complete College America (2010) found that "[l]ong-term certificates have significantly higher labor market value than short-term certificates because of their greater technical and academic rigor, and because of the wider range of job-related skills they provide graduates. Certificates of one year or more are consistently linked to increased earnings." Additionally, the report states that these certificates better position graduates for immediate success and serve as launching pads for future achievements. The number of individuals earning certificates has increased from about 2 percent of adults in 1984 to nearly 12 percent of adults in 2009. The Georgetown University Center on Education and the Workforce (2011) states, "[a]t its core, innovation still depends on a solid foundation of basic research in the physical, biological, and mathematical sciences as well as in engineering. But the economic value of innovation has shifted toward applications customized to meet critical individual and social needs".

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