Attachment 1

# STE Progress Report

**Of the** ***Science and Technology/Engineering Curriculum Framework* Review Panel**

**Massachusetts Department of Elementary and Secondary Education**

The STE Review Panel suggests the following recommendations to revise the *Massachusetts* *Science and Technology/Engineering Curriculum Framework* (the *Framework*):

1. **Improve the progression of science and technology/engineering (STE) concepts and skills across grade spans, particularly those at Pre-K–8.**
   1. Coherent progressions of concepts and skills should be developed for each STE topic based on pre-conception,[[1]](#footnote-1) conceptual change, and learning progression research. In the development of the current *Framework*, professional judgment and experience was used to sequence standards to build understanding of more and more complex concepts over time. Through the use of recent research that has begun to identify learning progressions[[2]](#footnote-2) for particular scientific topics, progressions of concepts can be adjusted to better support student learning across grade spans or strands. Summaries of research about how students learn most of the topics in the STE standards, referred to as “concept and skill progressions,” have been commissioned (available at http://www.doe.mass.edu/omste/ste/default.html). These summaries will be a key resource to guide the revision of standards by assuring a cognitive foundation and a cohesive progression of concepts and skills across grades.
   2. The specificity of the current standards is variable and should be adjusted to be consistent within a particular grade span. For example, in the *force and motion* topic the current high school Introductory Physics standard #1.4, “Interpret and apply Newton’s three laws of motion” is a broad standard in comparison to most of the other high school standards in this topic. A revision of this standard should separate and articulate each of Newton’s three laws to be more specific and consistent with the other high school standards.
2. **Strategically integrate science and technology/engineering skills with concepts in standards across the strands.**

The current *Framework* limits science skills[[3]](#footnote-3) to an introductory section and a separate set of four high school standards. Listing these separately leave unclear how particular skills and concepts actually relate in a way that reinforces conceptual learning; developing STE skills and learning STE concepts are mutually reinforcing (Michaels et al, 2008; NAGB, 2008; NRC, 2005). The revised standards should integrate STE skills with particular concepts, in the standards, articulated as performance expectations (the form of our standards).

* 1. To assure learning of broadly applicable STE skills, such as predicting, investigating, designing, or modeling, the active verbs in STE standards should strategically reflect those skills. These STE skills can be aligned with the *cognitive process dimension* of Bloom’s Revised Taxonomy (Anderson & Krathwohl, 2001). For example, a life science standard that integrates the scientific skill of being able to *formulate a hypothesis* with the scientific concept of *migration* might read “Formulate a hypothesis explaining how changes in the environment could cause some plants and animals to move to new locations (migration).” Another example, in earth and space science, integrates the skill of being able to *model scientific phenomena* and the concept of *phases of the moon*: “Use a celestial model to illustrate and explain how the relative position and size of the sun, Earth, and moon result in the phases of the moon and eclipses as observed from the Earth.”

Decisions about which STE skills will be used with which specific concept will be made to reinforce student learning of the concept. While integrated into standards with concepts, these STE skills will also be listed separately in the *Framework* narrative to illustrate their universal applicability. Teachers are not limited to the matches indicated in the standards but can expand beyond those in ways that fit their context.

* 1. Narrative should be maintained in the *Framework* to indicate the importance of engaging students in the full inquiry and design processes throughout STE instruction (Michaels et al, 2008; NRC, 2006; BSCS, 2006; NRC, 2005; NRC, 2000). This is currently articulated in the *Inquiry, Experimentation, and Design in the Classroom* section and *Guiding Principle V* within the *Framework*.
  2. Narrative should be added to the *Framework* to illustrate how the integration of STE skills into standards and instruction leads to substantial alignment to 21st century skills. When STE skills are integrated with concepts and into instruction there is particular alignment to the 21st century skills of *creativity and innovation*, *critical thinking and problem solving*, *communication*, *information and media literacy*, and *productivity and accountability* (Partnership for 21st Century Skills, 2009). When students consistently use STE skills as advocated in 2a and 2b above, they *are* engaging in these 21st century skills.

1. **Adjust the STE standards to reflect a reasonable scope, increase the overall rigor, and provide for updated topic coverage*.***
   1. The overall scope of the standards should remain the same or, if possible, decrease. The overall scope of the standards refers to the range and depth of concepts and skills students are expected to learn. The scope of the standards should reasonably allow for at least one multi-week, in-depth investigation of a topic each year (Schwartz et al, 2008).[[4]](#footnote-4)
   2. The overall rigor of the standards, particularly for grades Pre-K–8, should be increased to be more uniform across grade levels. The rigor of a standard can be assessed by using Bloom’s Revised Taxonomy to analyze its *cognitive demand level* (Anderson & Krathwohl, 2001). Currently, most STE standards (particularly Pre-K–8) are written to “remember” or “understand” levels of cognitive demand, and few expect students to “apply,” “analyze,” “evaluate,” or “create.” These more rigorous levels of cognitive demand are central to a 21st century curriculum (see 2c above).
   3. Narrative should be added to the *Framework* to highlight the value of learning standards through their application to scientific, technologic, and social contexts (for example, biotechnology, the environment, or nanotechnology). Students generally learn STE concepts and skills best when instruction is designed around relevant and engaging contexts or applications (NRC, 2000). This should be emphasized through narrative text in both the *Framework’s* Guiding Principles and introductory sections.
2. **Incorporate the standards for Literacy in Science and Technical Subjects from the recently approved *English Language Arts (ELA) Framework*.**
   1. The standards for Literacy in Science and Technical Subjects from the *ELA Framework* should be included directly in the *STE Framework*.
   2. Narrative should be added to the *Framework* to highlight the standards for Literacy in Science and Technical Subjects. The Guiding Principle on the importance of literacy in science should be adjusted to reference these standards and additional text should be added the Framework’s introductory sections to emphasize the interdependent nature of STE and literacy instruction.
3. **Present Pre-K–2, 3–5 and 6–8 STE standards as grade-span standards *with recommendations for* grade-by-grade standards.**

Continuing grade-span standards allows for continued variation of curricular design, while coding standards to specific grades supports alignment of curricula across schools and districts. Grade-by-grade standards can support students who move between schools or districts, particularly in urban districts where student mobility is common. While there is not a research base articulating what specific grade a scientific or technology/engineering concept should be introduced,[[5]](#footnote-5) the judgment of experienced educators with strong content area knowledge can inform this task. In the initial public survey (MA ESE, 2009; n=462), 57% of those who teach grades Pre-K–8 suggested grade-by-grade standards should be articulated,[[6]](#footnote-6) but there was an overall theme that curricular flexibility is important. This is especially the case in middle schools where about half implement an integrated curriculum and about half implement a discipline-specific curriculum[[7]](#footnote-7) (MA ESE, 2009). In addition, the grades 5 and 8 STE MCAS tests will continue to assess the standards for all three years of each grade span. As the Department will be presenting standards electronically in addition to a printed framework, districts will be able to query standards from either perspective.

* 1. The Pre-K–2, 3–5 and 6–8 standards should be presented as grade-span *with recommendations for* grade-by-grade standards. While grade-span standards maintain options for curricular flexibility, grade-by-grade standards will provide alignment for those who choose it.
  2. Without specific research to guide the development of grade-by-grade standards, determining which particular standard belongs in a specific grade should rely on the following guidelines:
     1. A concept should not be introduced at a grade level earlier than the summary of research (concept and skill progression) suggests is reasonable.
     2. Each *topic* within a grade level should allow for *curricular depth*: a set of related standards that can form a quality unit of study for that topic (NRC, 2007; USED, 2006). Achieving a desired depth of student learning of a topic will generally require multiple related standards in the grade.
     3. Each *grade level* should have standards that allow for *curricular coherence*: the possibility of curricular interrelationships or integration of standards and topics within or across instructional units (NRC, 2007; USED, 2006).
     4. Opportunity-to-learn gaps of 3 or more years should be avoided.
     5. Consideration should be made for when the student has the necessary mathematics to successfully engage with a particular science standard.

1. **Provide recommendations in the *Framework* that support college and career readiness in science and technology/engineering, including desired STE practices[[8]](#footnote-8) and possible course taking options.**

College and career readiness is the result of consistent STE instruction over time, building on student’s early dispositions of investigation and design to achieve certain practices, skills, and conceptual understandings. Effective STE instruction provides students exposure to a breadth of subject knowledge and skills as well as a depth of learning through extended investigation and design necessary for college and career readiness in STE. The revised *Framework* needs to go beyond the current *Framework* which does not make recommendations for high school courses beyond the “introductory” 9th or 10th grade standards nor systematically addresses career and college readiness.

* 1. The *Framework* should include a list of STE-focused practices (in addition to the concepts and skills) that contribute to college and career readiness (Conley, 2005). STE practices include, for example, *curiosity, attention to evidence, analytical reasoning, precision and accuracy, problem solving,* and *ethical decision-making*.
  2. The *Framework* should recommend that students take a minimum of 3, and ideally 4, lab-based high school science and technology/engineering courses. MassCore recommends a minimum of 3 lab-based STE courses (MA ESE, 2008).
  3. To achieve a breadth of STE learning, the *Framework* should recommend that high school students have an opportunity to learn at least three STE disciplines. This may be accomplished by taking any combination of “introductory” and upper-level elective courses. Common pathways include: a) 3 “introductory” high school courses; or b) 2 “introductory” high school courses and a different elective course. The Review Panel will not recommend a particular sequence of high school STE courses.
  4. To achieve a depth of STE learning,each of the 5 “introductory” high school courses in the *Framework* should provide students with an opportunity to investigate at least one topic in-depth (Schwartz et al, 2008). Each upper level elective course should continue to provide opportunities for in-depth study and investigation.

Students should also have the opportunity to complete a capstone STE project in their final years of high school. This could be completed during an upper level elective course, as a separate experience in school, or through engagement with an out-of school STE opportunity. Such experiences may be an internship, science fair project, or online collaboration on an STE investigation. The *Framework* can include a rubric with general criteria or characteristics that define a successful capstone project.

1. **Maintain, update, or add the following resources within the *Framework* to support STE programs, curricula, and instruction:**
   1. Assumed time and basic materials for STE instruction at each grade span
   2. Explicit connections to other subject areas, particularly mathematics
   3. Updated glossary to include both STE terms and cognitive terminology
   4. Sample course syllabi for upper-level STE electives
   5. Statement of the value and use of instructional technology in STE
   6. Essential questions to guide curriculum planning
   7. Update of STE websites and electronic resources
2. **Dovetail our revision process to align with the development of model standards for science and engineering, to be developed in collaboration with states, national science and engineering organizations, and Achieve.**

Several national organizations, including the National Research Council (NRC), the National Science Teachers Association, the American Association for the Advancement of Science, the National Association of Boards of Education, and Achieve, Inc., will convene to develop model standards for science and engineering for states to consider adopting. The process will begin with the NRC, which is producing *A Conceptual Framework for New Science Education Standards*, to guide the development of model standards for science and engineering. Achieve will then convene states and the national organizations, starting this spring, and follow a process similar to the one used for the Common Core standards.

Our Department’s goal is to provide leadership in the development of the model standards, using the work of our STE Review Panel and the expertise of ESE staff. Our participation will help to inform the Board as they deliberate on adopting an updated *Framework* in 2012.

**References**

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1. Understandings students have developed through direct experience with the world that often do not reflect scientific understanding. Also referred to as misconceptions or alternate conceptions. (Michaels et al., 2008). [↑](#footnote-ref-1)
2. Learning progressions articulate the reconceptualizations students typically experience as they come to understand and use core scientific concepts and skills over time (Corcoran et al, 2009; NRC, 2007). [↑](#footnote-ref-2)
3. National science education organizations use the term “scientific practices” to mean “inquiry skills,” to distinguish inquiry skill outcomes (“practices”) from inquiry methodologies (instruction). More recently the Mathematics Common Core standards have begun using the term “mathematical practices” in a way equivalent to science education’s use of “habits of mind.” The mixed uses of these terms across subjects may cause some confusion. [↑](#footnote-ref-3)
4. Please see recommendation #5d on college and career readiness (p. 4) for further discussion of this point. [↑](#footnote-ref-4)
5. The concept and skill progressions only provide conceptual shifts *within* a topic, not the specific standard-by-standard sequence or associated grade in which each concept should be learned. [↑](#footnote-ref-5)
6. 66% for those who teach grades Pre-K–5 and 49% for teachers of grades 6-8. [↑](#footnote-ref-6)
7. In an integrated curriculum, several topics from each strand are taught each year; in a discipline-specific approach one strand is taught each year (for example, 6th grade Earth Science, 7th Life Science, then 8th Physical Science). [↑](#footnote-ref-7)
8. Equivalent to the Common Core Mathematics standards for “mathematical practices.” [↑](#footnote-ref-8)