A Vision of Science and Technology/Engineering Education

Science and Technology/Engineering Education for All Students: The Vision

Our world has never been so complex, and scientific and technological reasoning have never been so necessary to make sense of it all. It is self-evident that science, technology, and engineering (STE) are central to the lives of all Massachusetts citizens when they analyze current events, make informed decisions about healthcare, or decide to support public development of community infrastructure. By the end of grade 12, *all* students must have an appreciation for the wonder of science, possess sufficient knowledge of science and engineering to engage in public discussions on related issues, and be careful consumers of scientific and technological information and products in their everyday lives. Students' STE experience should encourage and facilitate engagement in STE to prepare them for the reality that most careers require some scientific or technical preparation, and to increase their interest in and consideration of careers in science, technology, engineering, and mathematics (STEM). All students, regardless of their future education plan and career path, must have an engaging, relevant, rigorous, and coherent pre-K–12 STE education to be prepared for citizenship, continuing education, and careers.

Qualities of Science and Technology/Engineering Education for All Students

Student engagement with science and technology/engineering is a critical emphasis that can only be achieved through quality curriculum and instruction. The standards attend to relevance, rigor, and coherence, each of which has a corresponding implication for curriculum and instruction:

Emphasis in STE Standards	Implication for Curriculum and Instruction
Relevance: Organized around core explanatory ideas that explain the world around us	The goal of teaching focuses on students analyzing and explaining phenomena and experience
Rigor: Central role for science and engineering practices *with* concepts	Inquiry- and design-based learning involves regular engagement with practices to build, use, and apply knowledge
Coherence: Ideas and practices build over time and among disciplines	Teaching involves building a coherent storyline over time and among disciplines

Engagement

Students need regular opportunities to experience the dynamic, interdisciplinary nature of science and technology/engineering. Curriculum and instruction should instill wonder in students about the world around them through engaging and exciting learning experiences. Students should develop a passion about the natural and designed world and model the inquisitive, analytical, and skeptical nature of science. These goals can only be achieved through a rich and varied STE curriculum that includes thoughtful hands-on and minds-on activities, laboratories, investigations, and design challenges. Students take ownership and responsibility in their learning when they have a role in making decisions and reflecting on their learning. Active engagement in learning promotes a "growth mindset" that allows students to feel they can access content and develop skills, and thus succeed in STE. Instruction designed for student engagement is key to achieving this.

Relevance

Students often want to know why they are learning content in the classroom that seems unrelated to the real world. To understand the world around them, and be more interested in learning about it, they must have opportunities to apply their learning to relevant situations and contexts. The STE standards emphasize the application of knowledge and skills that students need to be analytical thinkers and problem solvers for issues that are crucial in today's world. Relevance in curriculum and instruction is also about meeting the needs of diverse learners, including minorities, females, and those on Individualized Education Program, of low socioeconomic status, or otherwise not traditionally represented in science, technology, and engineering.

To focus on relevance, the STE standards emphasize fewer core ideas over lists of discrete knowledge. For example, understanding the function of living systems includes understanding the role of feedback mechanisms. Feedback mechanisms in organisms allow them to remain stable and stay alive by making changes to maintain appropriate internal conditions even as external conditions change. A similar principle applies to ecosystems and to designed systems such as home heating and cooling systems. This focus on interactions in living systems is different from an emphasis on identification of body parts or components of an ecosystem. A focus on core ideas helps students to understand mechanisms and causes underlying a range of phenomena and apply their content understandings to real-world and novel situations (NRC, 2012).

Knowledge alone is not enough: students need to be able to act on that knowledge. Students need to be able to apply science and engineering practices—skills that let them analyze a natural phenomenon or designed system and determine underlying mechanisms and causes—in civic, college, and career contexts. Coupling practice with content gives the context for performance, whereas practices alone are activities and content alone is memorization. Quality STE education must attend to both in order for students to successfully apply their learning to understand and analyze their world.

Rigor

Rigor in STE teaching and learning is achieved by relating conceptual understanding of core ideas (content), science and engineering practices (skills), and application of those to the natural and designed world. Such rigor is how students will be able to apply or transfer their school learning to civic, college, and career contexts. The STE standards are explicitly designed to relate these three aspects in learning outcomes; curriculum and instruction should do so as well.

Coherence

Quality STE education is purposefully designed to support a progression of learning over time. STE education begins early, when children are natural investigators who build and ask questions in many contexts. This should be nurtured through subsequent years. Students should be engaged in developing and applying the science and engineering practices with the core ideas throughout pre-K–12. Every grade's STE education should build on the prior year, support the development of more sophisticated skills, increase the opportunity to relate and use multiple practices at once, and provide more sophisticated concepts and tasks in which to apply the practices. Integration of practices with concepts in purposeful ways throughout pre-K–12 ensures that all students have the opportunity to learn and apply scientific and technical reasoning in a wide array of contexts and situations that they need for postsecondary success. This can only happen if curriculum and instruction is purposefully designed to be coherent across time.

Three Important Goals for All Students: Civic Participation, College Preparation, and Career Readiness

The goal of STE education is to develop scientifically and technologically literate citizens who can solve complex, multidisciplinary problems and apply analytical reasoning and innovative thinking to real-world applications needed for civic participation, college preparation, and career readiness.

Civic Participation

High-quality science and technology/engineering education relates student interests and experiences to real-world problems and decisions. Research demonstrates the importance of embracing diversity as a means of enhancing learning about science and the world, especially as society becomes progressively more diverse (NRC, 2012, p. 29). Leveraging multiple relevant societal contexts from STE including nature, the history of science, cultural and technological perspectives, and community issues, promotes equity, deepens understanding through application, and builds student identity as members of active civic and STE communities.

College Preparation

A quality STE education that integrates concepts and practices is critical to college preparation. The College Board has highlighted the value of science and engineering practices in its work to define college 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 *Standards for College Success* (College Board, 2009) and redesigned Advanced Placement (AP) science courses (e.g., AP Biology Exam [College Board, 2015]) reflect the need to integrate science practices. College Board expectations focus on understanding, rather than memorization, and on the use of that understanding in the context of practices.

ACT has shown that postsecondary instructors greatly value the use of process or inquiry skills (science and engineering practices)—in fact, that they value these skills equally to fundamental 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). The critical role of practices in preparing students for success in college-level science is further echoed by David Conley in *College Knowledge* (2005). Conley's surveys of higher education faculty identified students' ability to conduct meaningful research and use practices that lead toward quality research as a key college- and career-ready indicator.

The *Admissions Standards for the Massachusetts University System and the University of Massachusetts* (www.mass.edu/forstufam/admissions/admissionsstandards.asp) also emphasize the need to include both concepts and practices. They state that three science courses, incorporating laboratory work, must be completed in order to fulfill the minimum science requirement for admission to the Commonwealth's four-year public institutions. All high school courses based on the standards presented in this document should include substantive laboratory and/or fieldwork (see Appendix VII) to allow all students the opportunity to meet or exceed this requirement.

Career Readiness

Most jobs and postsecondary opportunities that provide a living wage now require an increased amount of scientific and technical proficiency. The skills and background that students learn through their STE education serve as the foundation for solving problems and understanding issues they will encounter in their careers and will provide the intellectual tools needed to develop strategies for dealing with these issues. The use of various forms of modeling and problem solving, both learned through STE practices, applies to an infinite number of career paths, including those that not typically characterized as STE.

For those considering STEM careers, science and engineering practices are also receiving increased attention in the context of STEM career preparation. A strong foundation in K–12 engagement and learning will keep these opportunities open for students to pursue. The redesigned AP science curricula, the American Association for the Advancement of Science (AAAS) publication *Vision and Change* (2011), and the *Scientific Foundations for Future Physicians* (AAMC and HHMI, 2009) identify overlapping science practices as key to postsecondary opportunities.

Students' pre-K–12 STE experience should encourage and facilitate active engagement, relevant contexts, rigorous expectations, and coherence to prepare them for the range of careers that now require some scientific and technical preparation, and to increase students' interest in and consideration of STEM-specific careers.

Massachusetts' Definition of College and Career Readiness

The Massachusetts definition for college and career readiness (www.doe.mass.edu/ccr/) includes subject-specific components that articulate essential learning competencies (for mathematics and English language arts, currently). The essential competencies for STE, developed during the standards revision process with input from many stakeholders, define the STE component:

> Essential Competencies: Learning
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> Students who are college and career ready in Science and Technology/Engineering will demonstrate the academic knowledge, skills, and practices necessary to enter into and succeed in entry-level, credit-bearing science, engineering or technical courses; certificate or workplace training programs requiring an equivalent level of science; or a comparable entry-level science or technical course at the institution. College and career ready students in Science and Technology/Engineering will be academically prepared to:
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> - Analyze scientific phenomena and solve technical problems in real-world contexts using relevant science and engineering practices and disciplinary core ideas.
> - Use appropriate scientific and technical reasoning to support, critique, and communicate scientific and technical claims and decisions.
> - Appropriately apply relevant mathematics in scientific and technical contexts.

Summary

A student's ability to engage in scientific and technical reasoning through relevant experience results in better understanding of science and engineering, increased mastery of sophisticated subject matter, a better ability to explain the world, and increased interest in STEM fields. These are key outcomes for successful engagement in civic, college, or career contexts.

Key Features of the STE Standards to Promote the Vision

The science and technology/engineering standards are intended to drive engaging, relevant, rigorous, and coherent instruction that emphasizes student mastery of both disciplinary core ideas (concepts) and application of science and engineering practices (skills) to support student readiness for citizenship, college, and careers. The STE standards embody several key features to support this goal, including a number of features consistent with Massachusetts' mathematics and English language arts (ELA) standards:

1. *The standards focus on conceptual understanding and application of concepts.* The standards are focused on a limited set of disciplinary core ideas that build across grades and lead to conceptual understanding and application of concepts. They are written to both articulate the broad concepts *and* key components that specify expected learning. In particular, the disciplinary core ideas emphasize the principles students need to analyze and explain natural phenomena and designed systems they experience in the world.
2. *Integration of disciplinary core ideas and practices reflects the interconnected nature of science and engineering.* The standards integrate disciplinary core ideas with scientific and engineering practices. The integration of disciplinary core ideas and practices reflects how science and engineering are applied and practiced every day. It is shown to enhance student learning of both and results in rigorous learning expectations aligned with similar expectations in mathematics and ELA standards.
3. *The standards emphasize preparation for postsecondary success for citizenship, college, and careers.* The standards include science and engineering practices necessary to engage in scientific and technical reasoning, a key aspect of civic participation as well as college and career readiness. The standards articulate core ideas and practices students need to succeed in entry-level, credit-bearing science, engineering, or technical courses in college or university; certificate or workplace training programs requiring an equivalent level of science; or comparable entry-level science or technical courses, as well as jobs and postsecondary opportunities that require scientific and technical proficiency to earn a living wage.
4. *STE core ideas and practices progress coherently from pre-K to high school.* The standards emphasize a focused and coherent progression of concepts and skills from grade span to grade span, allowing for a dynamic process of knowledge and skill building throughout a student's scientific education. The progression gives students the opportunity to learn more sophisticated material and reconceptualize their understanding of how the natural and designed world work, leading to the scientific and technical understanding and reasoning skills needed for postsecondary success.
5. *Each discipline is included in grade-level standards for pre-K to grade 8.* To achieve consistency across schools and districts and to facilitate collaboration, resource sharing, and effective education for transient populations, the pre-K to grade 8 standards are presented by grade level. All four disciplines (earth and space science, life science, physical science, and technology/engineering) are included in each grade to encourage integration across the year and through curriculum. This reflects the nature of science and engineering as experienced in every-day life and allows attention to crosscutting concepts that aid analysis of the world.

6. *The STE standards are coordinated with the Commonwealth's ELA and mathematics standards.* The STE standards require the use and application of ELA and mathematics to support STE learning. The three sets of standards overlap in meaningful and substantive ways, particularly in regard to practices that are consistent across all three, and offer an opportunity for all students to better apply and learn STE.

The Massachusetts economy, individual career paths, and civic life are all very dynamic; students' education needs to be too. Quality science and technology/engineering education is needed at all grade levels and should be a key emphasis of every academic program. An encompassing pre-K to high school STE learning experience is essential for students to be prepared for citizenship, college, and careers.

References

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