Appendix V
The Case for an Integrated Approach in Grades Pre-K–8

The goal of a quality STE education is to produce scientifically and technologically literate citizens who can solve complex, multidisciplinary problems through analytical and innovative thinking in real-world applications needed for college and career success. An integrated model for the Massachusetts pre-K to grade 8 STE standards reflects:

- That science is complex and multidisciplinary.
- Research on learning in science that shows expert knowledge develops through interdisciplinary connections, not isolated concepts or practices.
- Effective research-based practices for curriculum and instruction in science and engineering.

Science as Complex and Multidisciplinary

The nature of STE is complex and multidisciplinary. Scientists and engineers typically do not work in isolated disciplines of physics, biology, or engineering: they create networks of professionals within and across disciplines who can contribute knowledge, share ideas and methods, and critique explanations and evidence. This is also the case when citizens collaborate to apply scientific and technical knowledge to community or workplace applications. Important practices, such as engaging in argument from evidence, modeling, and communicating information, do not occur in isolation but are always in the context of disciplinary concepts and rely on feedback from within and across scientific, technical, and workplace communities. Students' understanding of science, technology, and engineering as interdisciplinary and interconnected is enhanced by basing the pre-K to grade 8 standards in an integrated model with multiple disciplines at each grade. The cross-disciplinary aspects reflected through the nature of science and crosscutting concepts reinforce the multidisciplinary nature of STE (also see Appendix VIII).

Research on Learning in Science

Learning theory research shows that expert knowledge is developed more effectively when learning is contextualized in interdisciplinary real-world connections than through isolated content or practice (e.g., NRC, 2012; Schwartz et al., 2009). An integrated STE curriculum that reflects what we know about the learning of science and how mastery develops over time promotes deeper learning in science (e.g., Wilson et al., 2010). Students develop understanding more effectively while learning content and practices together (e.g., NRC, 2005, 2009, 2012). Learning progressions recognize that learning requires revision of *networks* of understanding, not revision of individual concepts (or misconceptions) (e.g., Alonzo & Gotwals, 2012; Corcoran et al., 2009; NRC, 2012). If teachers understand where their students are in their understanding of core ideas, and anticipate what students' misconceptions and struggles may be (e.g., Banilower et al., 2010; Driver et al., 1985, 1994; Keeley et al., 2005; Stanford University, 2012), they can better differentiate instruction and provide scaffolding that allows students to develop an integrated, deeper understanding of the STE content.

Attention to progressions of learning requires us to consider what concepts or skills a student must learn first to effectively learn subsequent concepts. There are many such considerations *within* disciplines, where the standards are built on progressions of specific disciplinary core ideas, and others *across or between* disciplines. Attention to a progression of learning highlights how concepts are sequenced and relate; this is a cognitive perspective that is distinct from a curricular perspective in which many other connections or relationships can be made to define related sets of concepts for curriculum and instruction. The strand maps (see Appendix IV) highlight cognitive connections. These provide guidance for ensuring that prerequisite concepts are established before others are taught to support the learning of core ideas over time. This includes considerations of the mathematics and literacy standards necessary to learn a particular STE standard.

Students should engage with science and engineering practices and concepts that range across disciplines. Following this model through grade 8 allows students to build coherent understandings and skills based upon coherent progressions of learning. In this way, the integrated approach to the teaching and learning of science in pre-K to grade 8 respects learning as a purposeful progression.

Effective Science Curricula and Instruction

The Guiding Principles discuss the qualities of effective STE programs, highlighting the need for coherence, connections, and relevance. Effective science curricula and instruction help pre-K to grade 8 students to interrelate and apply science disciplines, link to their prior knowledge, and analyze the world around them. Purposeful design of curricula and instruction scaffolds students to understand the natural world in an increasingly scientifically accurate way and understand the nature of science.

A Curricular Decision

A course curriculum should reflect a rationale, assumption, or belief about how students best engage with the entire set of core ideas and practices. That rationale, assumption, or belief explains and guides the placement of certain topics together in a particular grade and the sequence of topics over years. These are often represented as grade-level themes, grade-span storylines, and/or sequential knowledge construction that puts each particular topic into a context and makes learning more relevant for students. Pre-K to grade 5 curricula and instruction are often designed in an integrated approach by theme; the same is true for grade 6–8 curricula. The standards for grades pre-K–8 have been articulated from this perspective, with a thematic rationale for each set of standards for each grade. Note that just putting standards from multiple disciplines in one grade does not necessarily result in integrated units of study: it allows for and even promotes that, but it is up to districts, schools, and curriculum developers to determine the nature of the integration through particular curriculum design. This approach provides a theme to each grade that informs curricula, but does not define or constrain local curricular design.

The particular distribution of pre-K–5 STE standards is consistent with the NGSS. Massachusetts has added an introductory paragraph to each grade to articulate its theme. Standards from each discipline are generally aligned to the grade-level theme.

The middle school standards also include an integration of disciplines in each grade, organized by a theme. Middle school curriculum design is more variable, although an integrated approach is the most common. There are two common structures for middle school course design: those that *integrate* the disciplines and those that are *discipline-specific*, focusing on one discipline each year. Massachusetts Student Course Schedule data from the 2012–2013 school year for middle school science showed that the vast majority of schools appear to take an integrated approach at each grade. About 195,000 students were in integrated middle school science courses versus about 23,500 students in discipline-specific middle school science courses (please note there are some inconsistencies with how schools use course codes, so there is some variability in the data). There is not, however, any noticeably consistent or prevalent model for how integrated courses are defined, constructed, or organized across districts. There is also no consistency in which discipline-specific course sequence is used. An analysis of standards from 10 internationally competitive countries indicates that 7 of those 10 design integrated sequences from elementary through middle and even early high school (Achieve, 2010). Given this evidence and the rationales presented above, the grade 6–8 standards are presented as integrated standards organized around a coherent theme.

Please note that state assessment (MCAS) will remain at grade 5 and grade 8 and assess the full three-year *grade-span* in each case. Given this, districts can continue to organize the grade-by-grade standards in any number of configurations to meet their locally designed curriculum. Presenting the standards by grade level is intended to provide more continuity and consistency across schools and districts, enhance support for resource development and sharing, and better address challenges such as student transience.

Conclusion

A pre-K to grade 8 integrated model allows students to be equally prepared to enter introductory physics, Earth and space science, biology, or technology/engineering in grade 9 without a gap of a year or longer of being engaged in some of the core ideas of each domain. The specific and deliberate sequencing of the standards can lead purposefully to the high school standards for each STE discipline.

Presenting standards by grade provides clear and consistent guidance for pre-K to grade 8 and allows districts and schools to align curricula, instruction, assessment, and professional development to particular grades. Districts and schools will be able to share STE curriculum resources, teacher professional development, district determined measures, and other resources. If a student transfers between schools or districts in the state, there would be a common pathway and, hopefully, a less abrupt change or gap in his/her science learning. An integrated approach for pre-K–8 reflects the multidisciplinary nature of STE and research on science learning, curricula, and instruction.

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