The Case for an Integrated, Grade-by-Grade Approach for Pre-K–8

The goal of a quality science and technology/engineering education is to produce scientifically and technologically literate citizens who can solve complex, multi-disciplinary problems through analytical and innovative thinking in real-world applications needed for college and career success. An integrated model to the Massachusetts Pre-K to grade 8 science and technology/engineering standards reflect:

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

Science as Complex and Multidisciplinary

The nature of science and technology/engineering is complex and multidisciplinary. Scientists and engineers do not work in isolation in their own discipline of physics, biology, or engineering, but 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 like 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. Student 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 science and technology/engineering.

Research on Learning in Science

Learning theory research shows expert knowledge base develops better through interdisciplinary real-world connections then through isolated content or practice (e.g., NRC, 2012; Schwartz, et al., 2009). Integrated science and technology/engineering 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 more effectively develop understanding while learning content and practices together (e.g., NRC, 2005; NRC, 2009; NRC, 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., 2008, 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., Driver, et al., 1994; Driver, et al., 1985; Keeley, et al., 2005; Stanford University, 2012), they are better able to differentiate instruction and provide scaffolding that allows students to develop an integrated and deeper understanding of the science and technology/engineering content.

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.

Cognitive progressions
Attention to cognitive progressions requires us to consider student learning needs and what concepts or skills need to be learned 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 cognitive perspective highlights how concepts are sequenced and relate; this 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 (presented separately) highlight cognitive connections. These provide guidance to ensuring that pre-requisite 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 science and technology/engineering standard.

Effective Science Instruction and Curriculum

Effective science instruction can take many forms but includes similar components. According to a Center on Instruction report, *Effective Science Instruction: What does the Research Tell Us?* (Banilower, et al., 2010), research-based effective practices of curriculum and instruction include considerations of:

- student motivation;
- eliciting students' prior knowledge;
- intellectual engagement;
- use of evidence to critique claims; and
- sense-making.

Framing science and technology/engineering curriculum around engaging, relevant, and real-world interdisciplinary questions increases student motivation, intellectual engagement and sense-making.

There are a number of instructional models and curricular design approaches that can be used to achieve instruction with such features. Project-Based Learning (PBL) is one example that can be used to shape curriculum. In a PBL approach students go through an extended process of inquiry or design in response to a complex question, problem, or challenge. Because of the interdisciplinary nature of PBL it requires students to draw from many disciplines when understanding the construct of a problem. PBL is centered on student and teacher collaboration and application of academic knowledge and skills. While engaged in PBL, students are engaged in science and engineering practices, as well as cross-disciplinary concepts; students engage in reading and writing informational text and mathematics depending upon the driving question of the project. A PBL approach allows for some student choice and voice that promotes motivation and educational equity. PBL includes a process of revision and reflection that requires students learn how to communicate and receive instructive feedback and to think about their own cognition and understanding.

With effective science curriculum and instruction that helps Pre-K to grade 8 students build their understanding and skills and makes connections and links to their prior knowledge, students can come to understand the natural world in a more scientifically accurate way and understand the nature of science.

A Curricular Decision

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 enhances the relevancy of learning for students. Pre-K to grade 5 curriculum and instruction is often designed in an integrated approach by theme. The draft revised standards for grades K–5 have been articulated from this perspective, with a thematic rational for each set of standards for each grade. The grade-by-grade distribution of science and technology/engineering standards presented in the draft revised standards reflect the placement of standards in the Next Generation Science Standards.

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 focus on a specific discipline each year (discipline-specific). Massachusetts Student Course Schedule (SCS) data from the 2012-2013 school year for middle school science shows 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 not consistency in which discipline-specific course sequence is used. An analysis of standards from ten internationally competitive countries indicates that seven of those ten design integrated sequences from elementary through middle and even early high school (Achieve, 2010). Given this evidence the grade 6-8 standards are presented as integrated standards.

Please note that state assessment (MCAS) is very likely to remain at grade 5 and grade 8, and assess the full 3-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 draft revised standards by grade level is intended to provide more continuity and consistency across schools and districts, enhancing support for resources development and sharing, and better addressing challenges such as student transience. Also 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.

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 9th grade 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 science and technology/engineering discipline.

Presenting standards by grade provides clear and consistent guidance for Pre-K to grade 8 that allows districts and schools to align curriculum, instruction, assessment, and professional development to particular grades. Districts and schools will be able to share science and technology/engineering 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 science and technology/engineering and research on science learning, curriculum and instruction.

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