ASCD EXPRESS — IDEAS FROM THE FIELD

Generation STEM
January 30, 2014 | Volume **9** | Issue **9**

The Four C's of Next Generation Engineering Standards

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One of the goals of a 21st century education is learning that embraces the "four *C*s": collaboration, critical thinking, creativity, and communication (Partnership for 21st Century Skills, 2004). In many ways, the Next Generation Science Standards lay out a vision of science education that embraces a project-based STEM education connected to these four *C*s, and this is particularly evident in the sections of the standards under "engineering design" and "science and engineering practices." These standards present an exciting opportunity to teach engineering not just as another content area of stuff to be read about, memorized, and related in a standardized lab report or essay, but also as an active process in which students produce divergent results.

Science and Engineering Practices

Although many educators may be tempted to dive directly into the specific engineering standards by grade level, it's important to first consider how your instruction will develop the eight Science and Engineering Practices across the K–12 continuum. Students should engage in

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

At first glance, this list may seem like an overly wordy restatement of the scientific method (to which many science educators will groan and refer to William McComas's [1997] myth-busting declaration that there is no such thing as *the* scientific method; scientists use many methods.). But instead of teaching students how to make observations, classify objectives, or make inferences in isolated lessons, these eight practices are meant to be integrated holistically into instruction. The practices are designed to be active, not passive.

For example, engineering is about developing solutions to a human need or problem. There is never just one solution to these problems; there are always competing solutions that depend on constraints and values. So all engineering problems begin with requiring students to define the problem they are trying to solve. This should engage students in creative thinking about how to clearly identify and communicate a problem, and as students develop a prototype of their engineering design, they will engage in creative thinking and collaboration.
Students will also use the four *C*s to analyze and interpret data, refine their designs as they discover shortcomings or new needs, and then defend their proposed solution in terms of cost-benefit analysis, analysis of risk, concerns about aesthetics, and predictions about market reception. This requires not only clear communication, but also collaboration on the part of team

members to analyze the design from various perspectives, critical thinking about what the arguments will be against a certain design, and creativity in terms of how to make a persuasive argument.

Engineering Design Standards

Exploring the eight Science and Engineering Practices first will give the standards much more context and significance. The Engineering Design Standards are organized into bands for grades 3–5, 6–8, and 9–12. In the upper elementary grades, students are asked to use their creativity and critical thinking to define a simple problem and specify constraints as well as criteria for success (3-5-ETS1-1), generate multiple solutions to their chosen problem and compare them (3-5-ETS1-2), and plan and carry out "fair tests" comparing the solutions (3-5-ETS1-3).

Middle schoolers have four standards that require similar steps as they define a problem and its constraints, but they also need to use greater precision while referring to specific scientific principles and effects on people and the natural environment (MS-ETS1-1). This requires a higher degree of critical thinking as students consider the knowledge base of the entire scientific enterprise, not just their own thoughts. Students again need to evaluate competing prototypes and designs systematically (MS-ETS1-2) and use data as a basis for judgment (MS-ETS1-3). An extension for middle school students is to develop a model that can use iterative testing and modification of the design (MS-ETS1-4). Throughout the work within these standards, students will need to draw on creativity and collaboration to adapt their designs and think beyond their own biases and worldview about how to solve a particular problem.

The high school standards call for students to specify a global challenge using both qualitative and quantitative constraints and criteria (HS-ETS1-1). Global thinking requires collaboration and communication with a wider audience than just the classroom. Students must break down a complex, real-world problem into smaller, manageable problems (HS-ETS1-2), which is a perfect vehicle to teach collaboration skills because real problems are rarely solved by a single person. Students are also asked extend their critical-thinking skills and draw on cross-disciplinary knowledge as they prioritize design criteria and trade-offs (HS-ETS1-3) and use computer simulations to model the effects of their design (HS-ETS1-4).

Whether or not your state adopts the Next Generation Science Standards, the standards can be a guide for teachers to incorporate critical, 21st century skills into their STEM curricula. Engineering, specifically, should be viewed as problem-solving time, not just an additional content area to master. As students define problems and develop and refine solutions based on their own criteria and limitations, they will better be able to think critically and creatively as they solve problems now, and in the future.

References

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