

## High School Engineering Design

At the high school level students are expected to engage with major global issues at the interface of science, technology, society and the environment, and to bring to bear the kinds of analytical and strategic thinking that prior training and increased maturity make possible. As in prior levels, these capabilities can be thought of in three stages—defining the problem, developing possible solutions, and improving designs.

**Defining the problem** at the high school level requires both qualitative and quantitative analysis. For example, the need to provide food and fresh water for future generations comes into sharp focus when considering the speed at which world population is growing, and conditions in countries that have experienced famine. While high school students are not expected to solve these challenges, they are expected to begin thinking about them as problems that can be addressed, at least in part, through engineering.

**Developing possible solutions** for major global problems begins by breaking them down into smaller problems that can be tackled with engineering methods. To evaluate potential solutions students are expected to not only consider a wide range of criteria, but to also recognize that criteria need to be prioritized. For example, public safety or environmental protection may be more important than cost or even functionality. Decisions on priorities can then guide tradeoff choices.

**Improving designs** at the high school level may involve sophisticated methods, such as using computer simulations to model proposed solutions. Students are expected to use such methods to take into account a range of criteria and constraints, to try and anticipate possible societal and environmental impacts, and to test the validity of their simulations by comparison to the real world.

Connections with other science disciplines help high school students develop these capabilities in various contexts. For example, in the life sciences students are expected to design, evaluate, and refine a solution for reducing human impact on the environment (HS-LS2-7) and to create or revise a simulation to test solutions for mitigating adverse impacts of human activity on biodiversity (HS-LS4-6). In the physical sciences students solve problems by applying their engineering capabilities along with their knowledge of conditions for chemical reactions (HS-PS1-6), forces during collisions (HS-PS2-3), and conversion of energy from one form to another (HS-PS3-3). In the Earth and space sciences students apply their engineering capabilities to reduce human impacts on Earth systems, and improve social and environmental cost-benefit ratios (HS-ESS3-2, HS-ESS3-4).

By the end of 12<sup>th</sup> grade students are expected to achieve all four HS-ETS1 performance expectations (HS-ETS1-1, HS-ETS1-2, HS-ETS1-3, and HS-ETS1-4) related to a single problem in order to understand the interrelated processes of engineering design. These include analyzing major global challenges, quantifying criteria and constraints for solutions; breaking down a complex problem into smaller, more manageable problems, evaluating alternative solutions based on prioritized criteria and trade-offs, and using a computer simulation to model the impact of proposed solutions. While the performance expectations shown in High School Engineering Design couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices that lead to the performance expectations.

# HS-ETS1 Engineering Design

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Students who demonstrate understanding can:

- HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.**
- HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**
- HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.**
- HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Asking Questions and Defining Problems</b> Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.</p> <ul style="list-style-type: none"> <li>▪ Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)</li> </ul> <p><b>Using Mathematics and Computational Thinking</b> Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>▪ Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4)</li> </ul> <p><b>Constructing Explanations and Designing Solutions</b> Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories.</p> <ul style="list-style-type: none"> <li>▪ Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2)</li> <li>▪ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3)</li> </ul>	<p><b>ETS1.A: Defining and Delimiting Engineering Problems</b></p> <ul style="list-style-type: none"> <li>▪ Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)</li> <li>▪ Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)</li> </ul> <p><b>ETS1.B: Developing Possible Solutions</b></p> <ul style="list-style-type: none"> <li>▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)</li> <li>▪ Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)</li> </ul> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <ul style="list-style-type: none"> <li>▪ Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)</li> </ul>	<p><b>Systems and System Models</b></p> <ul style="list-style-type: none"> <li>▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-ETS1-4)</li> </ul> <hr style="border-top: 1px dashed black;"/> <p style="text-align: center;"><b>Connections to Engineering, Technology, and Applications of Science</b></p> <p><b>Influence of Science, Engineering, and Technology on Society and the Natural World</b></p> <ul style="list-style-type: none"> <li>▪ New technologies can have deep impacts on society and the environment, including some that were not anticipated. A analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3)</li> </ul>
<p><i>Connections to HS-ETS1.A: Defining and Delimiting Engineering Problems include:</i>  <b>Physical Science:</b> HS-PS2-3, HS-PS3-3</p> <p><i>Connections to HS-ETS1.B: Designing Solutions to Engineering Problems include:</i>  <b>Earth and Space Science:</b> HS-ESS3-2, HS-ESS3-4, <b>Life Science:</b> HS-LS2-7, HS-LS4-6</p> <p><i>Connections to HS-ETS1.C: Optimizing the Design Solution include:</i>  <b>Physical Science:</b> HS-PS1-6, HS-PS2-3</p>		
<p><i>Articulation of DCIs across grade-bands: <b>MS.ETS1.A</b> (HS-ETS1-1), (HS-ETS1-2), (HS-ETS1-3), (HS-ETS1-4); <b>MS.ETS1.B</b> (HS-ETS1-2), (HS-ETS1-3), (HS-ETS1-4); <b>MS.ETS1.C</b> (HS-ETS1-2), (HS-ETS1-4)</i></p>		
<p><i>Common Core State Standards Connections:</i></p> <p><b>ELA/Literacy –</b></p> <p><b>RST.11-12.7</b> Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1), (HS-ETS1-3)</p> <p><b>RST.11-12.8</b> Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1), (HS-ETS1-3)</p> <p><b>RST.11-12.9</b> Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1), (HS-ETS1-3)</p> <p><b>Mathematics –</b></p> <p><b>MP.2</b> Reason abstractly and quantitatively. (HS-ETS1-1), (HS-ETS1-3), (HS-ETS1-4)</p> <p><b>MP.4</b> Model with mathematics. (HS-ETS1-1), (HS-ETS1-2), (HS-ETS1-3), (HS-ETS1-4)</p>		