Engineering Embedded in K-12 NGSS

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Developed for the Introduction to the Next Generation Science Standards, Michigan State University, May 28, 2013
Session Objectives

- Develop an Understanding of NGSS Performance Expectations
- Use one example as a model for learning
“Engineering” – any engagement in a systematic practice of design to achieve solutions to particular human problems.

Engaging in the practices of engineering helps students understand the work of engineers as well as the links between engineering and science.

We live in a natural world and a built world – all citizens should learn the engineering design practices that have supported the transformation of the natural world into the built world.
Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success and constraints or limits.

Designing solutions to engineering problems begins with generating a number of different possible solutions, then evaluating potential solutions to see which ones best meet the criteria and constraints of the problem.

Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important.
Engineering Standards
(Appendix I Engineering Design In NGSS)

Define
Specify criteria and constraints that a possible solution to a simple problem must meet

Optimize
Improve a solution based on results of simple tests, including failure points

Develop solutions
Research and explore multiple possible solutions

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Locate K-2 Standards
(NGSS Topics)

Grade K-2

- Introduces students to “problems” as situations that people want to change
- Use of tools and materials to solve simple problems
- Use different representations to convey solutions, and compare different solutions to a problem and determine which is best
- Students in all grade levels are not expected to come up with original solutions, although original solutions are always welcome
- Emphasis is on thinking through the needs or goals that need to be met, and which solutions best meet those needs and goals

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Locate 3-5 Standards
(NGSS Topics)

Grade 3-5

- engineering design engages students in more formalized problem solving
- define a problem using criteria for success and constraints or limits of possible solutions
- research and consider multiple possible solutions to a given problem
- generate and test solutions
- optimize solutions by revising them several times based on tests to obtain the best possible design
Locate 6-8 Standards (NGSS Topics)

Grade 6-8

- sharpen the focus of problems by precisely specifying criteria and constraints of successful solutions
- account for problem needs and the larger context within which the problem is defined, including limits to possible solutions
- identify elements of different solutions and combine them to create new solutions
- use systematic methods to compare different solutions to see which best meet criteria and constraints
- test and revise solutions a number of times in order to arrive at an optimal design

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Grade 9-12

- engages students in complex problems that include issues of social and global significance
- problems need to be broken down into simpler problems to be tackled one at a time
- expected to quantify criteria and constraints so that it will be possible to use quantitative methods to compare the potential of different solutions
- emphasis is on identifying the best solution to a problem, which often involves researching how others have solved it before
- mathematics and/or computer simulations are used to test solutions under different conditions, prioritize criteria, consider trade-offs, and assess social and environmental impacts

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pause...
Structure of NGSS

- Expressed as *Performance Expectations* (PEs)
- *Integrate* practices, core ideas, and crosscutting concepts
- Statements of what is to be assessed
- Require demonstration of *knowledge-in-use*
- NOT instructional strategies
- NOT lesson objectives
- State what students should be able to do at the *end of instruction*
- Organized by Topic and by DCI (See chart)
How to Read a PE

“NGSS Structure” Supporting document on NGSS page


Inside the NGSS Box – Content Description (NSTA)

http://nstahosted.org/pdfs/ngss/InsideTheNGSSBox.pdf

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How to Read a PE

- Select one PE. **3-5-ETS1-1**. (In 3-5-ETS1 Engineering Design)
- Read the PE, the clarification statement, and the assessment boundary.
- Read the applicable DCI in the foundation box.
- Check *Appendix I* for ETS progression.
How to Read a PE

- Read the **associated practice** in the foundation box.
- Check *Appendix F* for Practice progression.
- Read the associated crosscutting concept (CCC) in the foundation box.
- Check *Appendix G* for CCC progression.
Strategies for Planning Instruction

- Scaffold the development of understanding expressed in the PE(s).
- Develop a series of learning tasks that blend together various practices, core ideas, and CCC.
- Integrate.
- Consider prior knowledge.
  - Preconception and misconceptions

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Developing a Lesson

3-5-ETS1 Engineering Design

Question 1: What performance expectations are related and can be included in instruction within the lessons/unit? (Cluster PEs)

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3-5-ETS1 Engineering Design

Question 1: What performance expectations are related and can be included in instruction within the lessons/unit? (Cluster PEs)

- **Engineering** 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3

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Question 2: What are the performance expectations, clarification statements, and assessment boundaries and how are they related in terms of instructional practices?

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Question 2: What are the performance expectations, clarification statements, and assessment boundaries and how are they related in terms of instructional practices?

1. Define a simple design problem reflecting a need that includes criteria for success and constraints.

2. Generate and compare multiple possible solutions.

3. Plan and carry out fair tests identifying failure points for model or prototype improvement.

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Question 3: What are the disciplinary core idea(s), practices, and crosscutting concepts coded to the performance expectations and how will they drive instruction?
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3-5-ETS1 Engineering Design

Question 3: What are the disciplinary core idea(s), practices, and crosscutting concepts coded to the performance expectations and how will they drive instruction?
“Engineering” – any engagement in a systematic practice of design to achieve solutions to particular human problems.

Define
Specify criteria and constraints that a possible solution to a simple problem must meet

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Improve a solution based on results of simple tests, including failure points

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Research and explore multiple possible solutions

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3-5-ETS1 Engineering Design

Question 1: What performance expectations are related and can be included in instruction within the lessons/unit? (Cluster PEs)

- Engineering 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3
- Earth’s Systems 5-ESS2-1, 5-ESS2-2
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ETS1.A: Defining and Delimiting Engineering Problems

needs

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Safe Drinking Water is Essential

Overview

Clean drinking water is a basic human need. Unfortunately, more than one in six people still lack reliable access to this precious resource. The problem is particularly acute in the developing world.

This project examines the state of the world’s water supply and what can be done to improve it. It is divided into sections on sources, treatment, and distribution of drinking water.

The sources section reveals where water is found on...
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ETS1.A: Defining and Delimiting Engineering Problems

Needs

Success

“How might we provide access to clean water?”

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ETS1.B: Developing Possible Solutions

Criteria
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ETS1.B: Developing Possible Solutions

Criteria

Constraints

Brainstorming

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ETS1.C: Optimizing the Design Solution

Design 1 ➔ test ➔ Design 2 ➔ test ➔ Design 3

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3-5-ETS1 Engineering Design

Question 4: What understandings need to be developed for students to be successful in the performance expectation(s)?

What content ideas will they need to know and what skills will they need to learn?
<table>
<thead>
<tr>
<th>Practice: Asking Questions and Defining Problems</th>
<th>Students need to have experiences to produce these understandings:</th>
<th>So they can perform well on tasks of this nature:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1)</td>
<td>(Define) Students need experiences where they define a design problem for a human need or desire by specifying the criteria and constraints that their solution must meet. (Constraints) Students need experiences learning about constraints. They need to be able to identify and discriminate what the term constraint means in relation to time, materials, and cost, in both everyday language and in the special or technical language of engineering. They need to be able to conceptually describe different examples of what are and what are not constraints for different design solutions. Students need experiences working with different design problems to experience how materials, time, and costs act as constraints in different situations. (Criteria) Students need experiences learning about engineering success stories based on how the design solution meets the desired features or criteria of a solution. They need to be able to identify and discriminate what the terms success, desired features, and criteria mean in the regular language of everyday activities and in the specialized and technical language of an engineering project. Students need to contrast the idea of success to examples of failures and how these failed projects were determined to be failures using criteria. Students need to be able to conceptually describe different examples of what are and what are not successful projects based on the criteria for success for different design solutions. Students need experiences working with different design problems to experience setting and considering successful criteria for designs. (Compare) Students need experiences comparing and evaluating different designed objects, process or systems. Students need to work with different engineering solutions to get experience evaluating the design in relation to the criteria for success. Students need chances to evaluate the design of different engineering solutions based on how well each design takes constraints into account.</td>
<td>3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. 3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.</td>
</tr>
</tbody>
</table>
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3-5-ETS1 Engineering Design

Question 5: What Science and Engineering Practices are appropriate with the instruction of the disciplinary core ideas?

(See Appendix F for description of Practices for the 3-5 grade band.)

• See Table 1 - Understandings

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To prepare students to demonstrate their knowledge, skills, or dispositions with these:

**Practice: Asking Questions and Defining Problems**
Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1)

**ETS1.A: Defining and Delimiting Engineering Problems**
Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1)

<table>
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3-5-ETS1 Engineering Design

Question 6: What are the lesson level expectations (learning performances) and how will they build to meet the performance expectations?

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Developing a Lesson

3-5-ETS1 Engineering Design

Question 7: What assessment (formative and summative) will provide evidence of the understanding and/or ability to perform lesson level expectations (learning performances)?

- See Table 2 – Learning Performances
<table>
<thead>
<tr>
<th><strong>Learning Performance</strong></th>
<th><strong>Acceptable Evidence</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will review current event media materials for water use in developing nations or nations impacted by natural disaster to describe the needs and the problems associated with human impacts on the supply of clean water.</td>
<td>Written reviews that include the identified needs and the resulting problems that are clearly associated with human impacts on the supply of clean water.</td>
</tr>
<tr>
<td>Students will describe the qualities of “clean” water in comparison to dirty water to identify the criteria for successfully producing clean water.</td>
<td>Written descriptions of clean water using language and concepts from the EPA description of drinkable water. A clear and labeled drawing comparing clean to dirty water.</td>
</tr>
<tr>
<td>Students will specify the constraints associated with providing clean water to a community in a developing nation or a nation impacted by a natural disaster.</td>
<td>Identification of constraints that are clearly associated on the conditions present in the community by identifying ideas described in a written description of the community.</td>
</tr>
<tr>
<td>Students will define a simple design problem associated with meeting the water needs of a community in a developing nation or a nation impacted by a natural disaster, that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.</td>
<td>A written “Design Problem Statement” that includes the identified users, their needs and insights that are extracted or synthesized from research on the conditions present in a community in a developing nation or a nation impacted by a natural disaster.</td>
</tr>
</tbody>
</table>
Developing a Lesson

3-5-ETS1 Engineering Design

Question 8: What is the storyline that helps learners apply what they know, build new, sophisticated ideas from observation and evidence, and use information to solve an engineering problem?
Developing a Lesson Story

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Developing a Lesson

3-5-ETS1 Engineering Design

Question 9: How do the lessons and tasks help students move towards an understanding of the performance expectation(s)?
Questions?
Example Curricula

Please contact your local ISD or Math Science Center

- Engineering is Elementary - [www.eie.org/](http://www.eie.org/)
  (Local- EMU, MTU, UM)
- Project Lead the Way - [www.pltw.org/](http://www.pltw.org/)
  (Local- EMU,)
- Ford Partnership for Advanced Studies (PAS) - [fordpas.org/](http://fordpas.org/)

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For More Information

All NGSS official documents are available at

http://www.nextgenscience.org/

NGSS at NSTA

Standards and Supporting Materials Tab

http://www.nsta.org/about/standardsupdate/standards.aspx

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For More Information

- All of today’s session materials will be available at

http://ngss-michigan.org/
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