Teacher's Guide to Using Engineering Design in Science Teaching and Learning

Elementary School Edition

Written by: Celeste Baine

Activities Designed by: Lia Cunningham

Project Design Team:
Rachel Aazzerah
Ken Cone
Cheryl Kleckner
Jo Oshiro
Bruce Schafer

Special Thanks to our Advisory Panel:
Andy Byerley
Gail Gerdemann
Leslie Graham
Owen Griffiths
Kristi Healy
Bradford Hill
Richard Hoffman
Lesley Johnson
Ginger Redlinger
Michael Rockow
Lynda Sanders
Stephen Scannell
Meagan Sternberg

With Help From:
Nick Giampietro

For more information contact:
Industry Partnerships Dept
Oregon University System
PO Box 751, IAFF
Portland, OR 97207

Table of Contents

Objective - to further the implementation of the Engineering Design portion of the Science Standards in Oregon classrooms and improve teachers' effectiveness at teaching science.

Why this Guide Exists..4

Overview and Introduction..5

- Goals of the Guide
- Oregon Science Content Standards
  a. Scientific Inquiry Process & Engineering Design Process
  b. Oregon Engineering Design Core and Content Standards
- Oregon Essential Skills
- Next Generation Science Standards

Why use the Engineering Design Process?..9

- Motivating Students to Learn Science
- Acquiring Essential Skills While Learning Science

Engineering Design Process Description 11

- Engineering Design Process Overview
- Scientific Inquiry vs. the Engineering Design Process

Application to Science in Elementary School 13

- Engineering Design Process for Grades 1-3
- Engineering Design Process for Grades 4-5
- What the Students Should Learn About the Process

Connecting the Engineering Design Process 16

- Connecting Engineering Design to Learning Life Science – Hand Pollinator Activity
- Connecting Engineering Design to Learning Earth and Space Science – A Brick for a Pig Activity

Conclusion – What now? Next Steps..20

Key Terms 21

Additonal Resources..22

Why this Guide Exists

A change is coming – Educators in many states are discovering that engineering is a great way to support, improve and enhance the teaching of science. Oregon started riding this wave in 2009 when it added Engineering Design as one of four core standards in its Science Standards. Using the Engineering Design process gives teachers an additional way to succeed with 21st Century students. It can lead to increased student retention, engagement and confidence. This guide will help teachers use Engineering Design to reinforce science content in the classroom.

Oregon is one of 26 states providing leadership in the Next Generation Science Standards (NGSS) development process. Oregon has shown a strong commitment to standards-based learning through its adoption of the Common Core State Standards (CCSS). Oregon's current standards are based on some of the same research that underlies the ongoing development of the NGSS.

http://cicobb.typepad.com/es/2012/05/index.html

http://www.achieve.org/ngss-states

Because Engineering Design is in the Oregon standards and engineering practices will be in the NGSS, the time is right for Oregon to use the Engineering Design process to teach science alongside the Scientific Inquiry process. Incorporating Engineering Design will not only benefit Oregon students immediately it will help prepare Oregon teachers for what's coming next – the Next Generation Science Standards.

Overview and Introduction

Goals of the Guide

This guide was developed in collaboration between the Industry Partnerships Department of the Oregon University System and the Oregon Department of Education (“ODE”) to further the implementation of the Engineering Design portion of the Oregon Science Content Standards (the ‘Standards”) in classrooms and improve teachers’ effectiveness at teaching science.

The NGSS take engineering design further by including Scientific and Engineering Practices:

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, information and computer technology, 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.

While this primer focuses on Oregon’s current standards, it also anticipates the NGSS’s use of scientific and engineering practices.

Oregon Science Content Standards

The Oregon Science Content Standards define the scientific content, knowledge, and process skills that all Oregon students are expected to learn during science instruction in K-8 and high school. The adopted science content standards include four core standards at each grade from kindergarten through eighth grade and for high school. These core standards provide the major unifying concepts and processes that will be the primary focus of teaching and learning across the grades. Underneath each of these core standards are from one to seven content standards, which provide the details necessary for instruction and assessment.

Since 2009, the Standards have included Engineering Design as a core Science Process Skill. In the context of the Standards, the term **Engineering Design describes the concept of using the application of scientific principles to everyday problems.** Engineering Design is a key skill and describes what students should know about how engineers use science as well as providing a way for students to learn about science in addition to Scientific Inquiry.

Scientific Inquiry Process & Engineering Design Process

Within Oregon's *Science Standards Framework: The big ideas organized by science discipline and core strand*, Scientific Inquiry and Engineering Design are both considered Science Process Skills. Students use inquiry-based science when they apply scientific reasoning and critical thinking to support conclusions or explanations with evidence from their investigations and students use the engineering design process when they define problems and design solutions to support conclusions or explanations with evidence from their investigations.

Overview and Introduction

Oregon Engineering Design Core and Content Standards

Grade	Core Standards	Engineering Design Content Standards
Grade K	Engineering design is used to design and build things.	• Create structures using natural or designed materials and simple tools. • Show how components of designed structures can be disassembled and reassembled.
Grade 1	Engineering design is used to design and build things to meet a need.	• Identify basic tools used in engineering design. • Demonstrate that designed structures have parts that work together to perform a function. • Show how tools are used to complete tasks every day.
Grade 2	Engineering design is a process used to design and build things to solve problems or address needs.	• Use tools to construct a simple designed structure out of common objects and materials. • Work with a team to complete a designed structure that can be shared with others. • Describe an engineering design that is used to solve a problem or address a need.
Grade 3	Engineering design is a process that uses science to solve problems or address needs or aspirations.	• Identify a problem that can be addressed through engineering design, propose a potential solution, and design a prototype. • Describe how recent inventions have significantly changed the way people live. • Give examples of inventions that enable scientists to observe things that are too small or too far away.
Grade 4	Engineering design is a process of using science principles to solve problems generated by needs and aspirations.	• Identify a problem that can be addressed through engineering design using science principles. • Design, construct, and test a prototype of a possible solution to a problem using appropriate tools, materials, and resources. • Explain how the solution to one problem may create other problems.
Grade 5	Engineering design is a process of using science principles to make modifications in the world to meet human needs and aspirations.	• Using science principles, describe a solution to a need or problem given criteria and constraints. • Design and build a prototype of a proposed engineering solution and identify factors such as cost, safety, appearance, environmental impact, and what will happen if the solution fails. • Explain that inventions may lead to other inventions and once an invention exists, people may think of novel ways of using it.

Oregon Essential Skills

Beginning in 2012, Oregon students must demonstrate proficiency in identified Essential Skills. These are 21st century skills needed for success in college, the workplace, and civic life. The

Overview and Introduction

State Board of Education approved three assessment options for students to demonstrate Essential Skill proficiency: (1) OAKS state test, or (2) local assessments consistent with state criteria, or (3) other approved standardized tests (e.g. SAT, PLAN, ACT, PSAT, Work Keys, COMPASS, ASSETT).

Students who use Engineering Design to learn science will also be building essential skills. By the very nature of engineering design, students will be required to read and comprehend a variety of text, write clearly and accurately, and to apply mathematics to projects outside of their math textbook. Engineering design requires students to listen actively, speak clearly and coherently (team-based projects), think critically and analytically, and often to use technology such as a computer and computer software to help solve a problem. If students focus on solving problems to make a better world, they will also be developing the essential skills of demonstrating civic and community engagement and global literacy.

Essential Skills Required for Graduating Class**	Essential Skills to be Phased-In Over Subsequent Years
2012: Read and comprehend a variety of text 2013: Write clearly and accurately 2014: Apply mathematics in a variety of settings **Revised ES timeline adopted by the State Board Aug. 2009.	• Listen actively and speak clearly and coherently • Think critically and analytically • Use technology to learn, live, and work • Demonstrate civic and community engagement • Demonstrate global literacy • Demonstrate personal management and teamwork skills

Next Generation Science Standards

Twenty-six states, including Oregon, participated in the development of the Next Generation Science Standards. According to Leslie Payne of the American Society of Civil Engineers, "The framework for the new standards emphasizes first and foremost the new vision that K-12 science education should reflect real world interconnections in science, including active engagement in scientific AND engineering practices, and the application of intersecting concepts to improve understanding of core ideas. Perhaps most important is the idea that scientific and engineering practices should be included in learning experiences that span student's educational development from the very beginning of their school years. This is a major departure from previous standards that did not integrate scientific principles, engineering application or core concepts from the various disciplines of science learning."

Why use the Engineering Design Process?

Motivating Students to Learn Science

One positive aspect of using the Engineering Design process is that students begin to look at problems, issues and constraints from multiple viewpoints and in relationship to an assortment of situations and scenarios. New problems may arise from one solution, and those problems may lead to new ideas and solutions. There are also usually several different solutions to each problem. A solution may be designed for a particular audience (a passenger van to transport a large family) or it may be more general (a vehicle that can carry up to 5 people). Both solutions work for the problem of transporting people from point A to point B. Good engineering design considers people's needs (gas mileage, size of people or cargo, time spent in the vehicle, etc.) to determine the best solution.

By solving problems that consider the needs of people, the doors to creativity open wide and student **engagement increases**. As students build skills in using Engineering Design to learn science, they no longer need to sit back and wait for instructions. Instead, they explore, create, design, innovate, imagine, test and evaluate their solutions. The advantages of using Engineering Design to teach science are similar to using Scientific Inquiry: students see connections to the world around them at the same time they develop problem solving skills that they can use in school and throughout their life.

According to Cary Sneider, a leading science educator and one of the writers of the Next Generation Science Standards, understanding engineering is essential for all citizens, workers, and consumers in a modern democracy. If the U.S. is to continue to play a significant role in the world economy, it is imperative that students be exposed to engineering design and problem solving thought processes. He goes on to say that the capability to formulate and solve problems is a valuable life skill. By including Engineering Design in the Oregon State Standards, students will have access to a wider range of viable careers because they will be prepared to take the appropriate courses in high school. Exposure to engineering design is also an important equity tool for girls and minority students.

Acquiring Essential Skills While Learning Science

Engineering is ideal for integrating math and science. Using the Engineering Design process is an opportunity to provide a hands-on lesson that allows students to confront their preconceptions about scientific phenomena and how it relates to important learning

Why use the Engineering Design Process?

goals. Lessons that engage students in Engineering Design can be effective whether they are structured or very "open," with students pursuing answers to their own questions. According to *Effective Science Instruction: What Does Research Tell Us?* (Bainilower, et al, 2010) , "Whatever the mode of instruction, the research suggests that students are most likely to learn if teachers encourage them to think about ideas aligned to concrete learning goals and relate those ideas to real-life phenomena."

One of the reasons that students' understanding of science is increased is because of the immersion that hands-on learning offers. **Engineering design can provide the hook to motivate students**, addressing something they have wondered or wanted to know about. Learning science can then be enhanced by building on that knowledge and encouraging students to relate their design to real-world problems and applications (Bainilower, et al, 2010).

As part of the requirements for graduating high school in 2014, an additional element of Oregon's Essential Skills will be required: Apply mathematics in a variety of settings. Engineering design in the context of learning science is one such setting. Engineers use mathematics to analyze problems and develop solutions as well as test and analyze these solutions. The Engineering Design process can serve as a bridge between math and science and offers students a real-world way of thinking through and solving problems. Students benefit by acquiring a deeper understanding of science content at the same time they develop one of the essential skills needed to graduate.

Learning and using the Engineering Design process will help students develop the skill to solve practical problems and also help develop the ability to read and comprehend a variety of texts, another essential skill required for graduation. Activity instructions are typically written in language that is somewhat technical, challenging students to lift their comprehension skills to a higher level. Students learn methods used by engineers to design and document their work. This allows them to read and comprehend a variety of text, write clearly and accurately and communicate their design – all skills that are part of Oregon's graduation requirements because they are important life skills.

Engineering Design Process Description

Engineering Design Process Overview

Professional engineers use a variety of processes to solve problems. In the context of teaching and learning science we can simplify these processes into a step-by-step problem solving template. In the Oregon Science Standards this process is called Engineering Design and this process is a sister to the Science Inquiry process for teaching science. Just as the Science Inquiry process involves articulating a question and investigating possible answers to the question (leading to a better understanding of natural phenomena), the Engineering Design process involves articulating a problem and investigating possible solutions to the problem (leading to a better solution to the problem). In other words, engineering design is a way to put science to work to solve problems.

Engineering Design Process – Grades 1-3	Engineering Design Process – Grades 4-5
1. Identify a problem	1. Define a problem or a need
2. Propose a potential solution	2. List criteria and constraints
3. Design a prototype	3. Describe a possible solution using science principles
	4. Design and construct a possible solution
	5. Describe the cost, safety, appearance and environmental impact of the solution as well as what will happen if it fails.

The Engineering Design process is not a rigid set of rules for solving every problem but more of a tool to focus and direct the process of problem solving and ways of thinking. Each problem is different and the solution may or may not go through each step in the process. For example, a student may discover in the process of researching a problem that there is already a solution available. The solution to the problem may involve using or adapting an existing solution.

In the Oregon Standards, the first step in the Engineering Design process is to define a problem associated with a need. In practice, this first step includes learning as much as possible about the problem or opportunity.

Engineering Design Process Description

Scientific Inquiry vs. the Engineering Design Process

Theodore von Karman once said:

"Scientists study the world as it is, engineers create the world that never has been."

Both engineering and science involve obtaining knowledge and using a set of practices.

According to *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* by The National Research Council, "the major goal of engineering is to solve problems that arise from a specific human need or desire. To do this, engineers rely on their knowledge of science and mathematics as well as their understanding of the engineering design process." Specifying what is needed and designing a solution for it provides students with an opportunity to practice the application of their understanding of science. The design process is also an important way for K-12 students to develop an understanding of engineering as a discipline and as a possible career path. The work of engineers, like the work of scientists, involves both individual and cooperative effort.

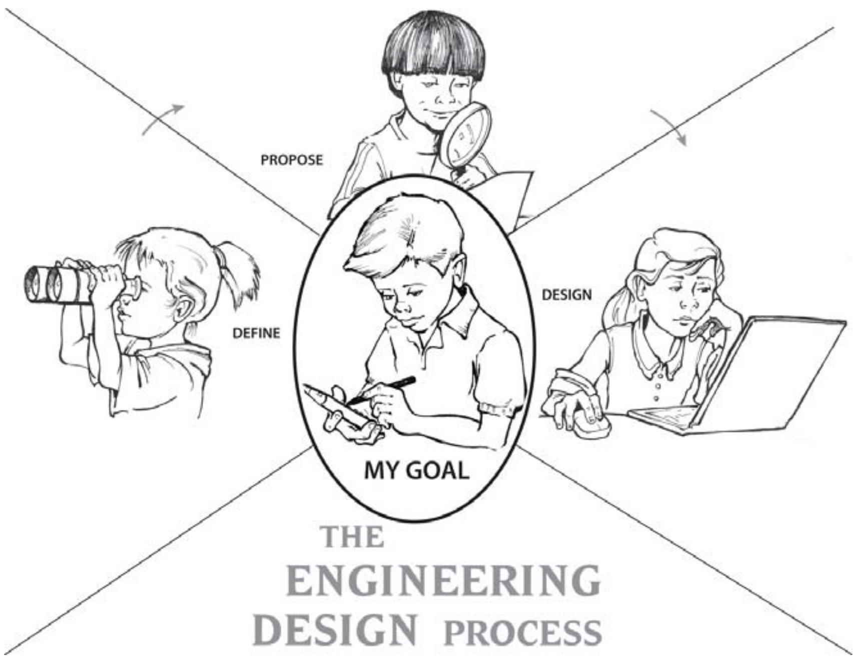
Engineering and science are similar in that both involve creative processes, and neither uses just one method.

Scientific Inquiry	Engineering Design
• The goal of science is to develop a set of coherent and mutually consistent theoretical descriptions of the world that can provide explanations over a wide range of phenomena.	• The goal of engineering is to evaluate prospective designs and then produce the most effective design for meeting the specifications and constraints.
• Not necessarily driven by immediate practical needs. Could be driven by curiosity or with the aim of answering a question about the world or understanding an observed pattern.	• Driven by practical human needs.
• For science, developing such explanations about the world constitutes success in and of itself, regardless of whether it has an immediate practical application.	• For engineering, success is measured by the extent to which a human need or want has been addressed.

Application to Science in Elementary School

Engineering Design Process for Grades 1-3

1. Identify a problem. Engineering begins with a problem that needs to be solved, such as "How can we make sure people are safe in an earthquake? or "How can candy bars become healthier?" or "What can we do to sleep better each night?" At this stage, you want your students to ask questions to clarify the problem.



The Oregon Administrative Rules do not require 1st or 2nd grade students to produce a work sample. Nevertheless you may want to introduce your students to the idea of keeping a workbook. The 1st and 2nd grade standard uses the word "structure" rather than "prototype" so your template should probably do so as well. The 1st grade standard also emphasizes the relationship of the parts of a structure to the function of the structure. While this may sound complicated it can be as simple as a roof keeping the rain out and a window letting light in.

There is a reference to using tools in the 1st grade standard. Such tools would probably be simple things like scissors to cut construction paper or a bread knife to spread modeling clay. However you decide to teach engineering design, you should still have your students use the steps described in the standard:

- Identify tools that can be used to build things.
- Demonstrate how parts of a structure relate to its function
- Show how tools are used.

Application to Science in Elementary School

The 2nd grade standard also refers to working with a team, so you may want to have each student complete a worksheet about the project that they can share with other students on their team. Or, you could have the members of each team share a notebook.

However you decide to teach engineering design, you should still have your students use the steps described in the standard:

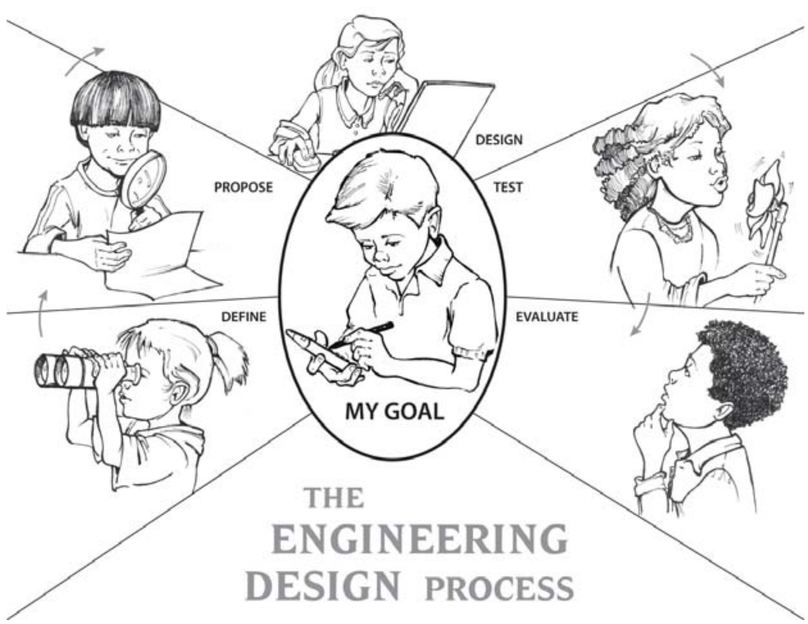
- Use tools to construct a simple designed stricter out of common objects and materials.
- Work with a team to complete a designed structure that can be shared with others.
- Describe an engineering design that is used to solve a problem or address a need.

2. Propose a Potential Solution. Potential solutions to the problem can both be drawn ideas and a description in words. Labeling the drawing to describe its parts and their function is a good idea.

3. Design a Prototype. The students should build something that represents their potential solution. They should then draw and describe what they actually built which may be smaller or use less expensive materials than their original idea (potential solution).

Engineering Design Process for Grades 4-5

1. Define a problem or need. Engineering begins with a problem that needs to be solved, such as "How can we make sure people are safe in an earthquake? or "How can candy bars become healthier?" or "What can we do to sleep better each night?" At this stage, you want your students to ask questions to clarify the problem.



Application to Science in Elementary School

2. List criteria and constraints. Students should list and describe the criteria and constraints associated with the problem being solved. In some cases you may provide some or all of these things and their job is to paraphrase what you have provided. In others cases you may ask them to come up with criteria and constraints based on their experience with the category of problem you have assigned. They may also want to survey possible users of the solution to better understand their needs or do library or web research on the need.

3. Describe a possible solution using science principles. Students should describe a possible solution that uses science principles.

4. Design and construct a possible solution. The student should use drawings and words to describe what the solution looks like and how it works. Students should then build the solution or something like it.

5. Describe the cost, safety, appearance and environmental impact of the solution as well as what will happen if it fails. The student should explain how much it would cost to build or manufacture the solution and how safe or unsafe it would be to use the solution. They should also explain how building the solution or using it might affect the environment. Most solutions don't work all the time especially if they are used in new ways so the student should describe what would happen if the solution fails. While the 5th grade standard does not mention testing the solution, any tests the student performs on the solution should be described.

What the Students Should Learn About the Process

The most basic level of the engineering design process, a level that all elementary school students should be comfortable doing, is to identify and define a problem or need. They should be able to propose potential solutions and design a prototype.

Assessing students' understanding of the engineering design process is important to understanding how to best create learning environments that successfully use engineering design in the classroom.

On the OPAS website, there are three activities that have been compiled to assist using the Engineering Design Process to teach Physical Science, Life Science and Earth and Space Science in elementary school. Each activity provides an intriguing scenario, teaching guide, student handouts, and vocabulary alerts. The activities are each aligned to the Engineering Design portion of the Oregon State Standards to facilitate easy adoption into the classroom.

Application to Science in Elementary School

Connecting Engineering Design to Learning Life Science

Hand Pollinator Design Challenge - Grades K-2

In this engineering lesson, based on a hand pollinator for cherry trees lesson by Donna Rainboth, students will learn about pollination and the engineering process by designing hand pollinators for model apple trees.

The lesson is divided into two parts.

1. Part one is a reading activity. The article, "A Hand Pollinator for Joanie Appleseed," describes the process of pollination and provides a context for the activity to follow: Joanie Appleseed, Jonny Appleseed's great-great granddaughter owns an apple orchard in Hood River, Oregon, but this year, because it has been especially cold and wet, honey bee populations are low. Since there are not enough natural pollinators to pollinate her orchards, she asks the students to design hand pollinators for her to use instead.
2. In part two, students use the engineering process to design, build, and test hand pollinators for a model apple tree. The activity focuses on the development of solutions step of the engineering process as well as the construction, test, and evaluation of prototypes step. Students will make several different hand pollinators based on the materials available. They will test and evaluate them systematically to see which is most effective at picking up and depositing pollen, then, time permitting, they will redesign their most effective hand pollinator to see if they can make it even better.

Tying it all together

Following is a table of how the ***Hand Pollinator*** lesson relates to the Engineering Design Process, the Oregon Engineering Design Standards, and the Life Science Standards. The steps exemplify how scientific inquiry and the engineering design process overlap to create meaningful lessons for students. This table is only a general guide – you may find more correlations and connections as you move through the lesson.

Connecting the Engineering Design Process

Steps of the EDP for Grades 1-3	**Engineering Design Standard Correlation**	**Life Science Standard Correlation**	**Hand Pollinator Correlations** *See the "Hand Pollinator" student handout*
Identify a problem	3.4D.1 Identify a problem.	N/A	There are not enough natural pollinators like birds and bees to pollinate all the trees in Joanie Appleseed's orchard.
2. Propose a potential solution	2.4D.3 Describe an engineering design that is used to solve a problem or address a need. 3.4D.1 Propose a potential solution.	N 1.1L.1 Compare and contrast characteristics among individuals within one plant or animal group. 1.1P.1 Compare and contrast physical properties and composition of objects. 2.1L.1 Compare and contrast characteristics and behaviors of plants and animals and the environments where they live. 2.2L.1 Describe life cycles of living things.	Solution ideas can include using tape or glue, erasers, pipe cleaners, pom poms or feathers for the head and straws, woodsies, stir sticks or other materials for the handle.
3. Design a prototype	1.4D.2 Demonstrate that designed structures have parts that work together to perform a function. 2.4D.1 Use tools to construct a simple designed structure out of common objects and materials. 2.4D.2 Work with a team to complete a designed structure that can be shared with others. 3.4D.1 Design a prototype.	N/A	Students grab materials to make three hand pollinators and begin building.

Connecting the Engineering Design Process

Connecting Engineering Design to Learning Earth and Space Science

A Brick For a Pig Design Activity - Grades 3-5

This engineering design lesson presents the scenario of the three little pigs not living happily ever-after together. They want to build two more brick houses but they have no money for bricks. Students are asked to help the pigs with their problem, by designing and making bricks for them out of natural materials. In addition to practicing the engineering design process, students will learn about the properties and uses of natural materials, the effect weathering and erosion has on Earth's materials and surfaces, and the importance of matching a material's properties to its uses so that you have the best tool for the job.

The lesson is divided into three parts.

1. The first part is a reading activity that presents students with the scenario as well introduces the key vocabulary and scientific concepts of the lesson.
2. Part two is a teacher demonstration highlighting different types and properties of brick mixtures.
3. In part three, students will use what they learned to design, build, and evaluate their own bricks.

Tying it all together

Following is a table of how the ***A Brick For a Pig*** lesson relates to the Engineering Design process, the Oregon Engineering Design Standards, and the Earth and Space Science Standards. The steps exemplify how scientific inquiry and the engineering design process overlap to create meaningful lessons for students. This table is only a general guide – you may find more correlations and connections as you move through the lesson.

Steps of the EDP for Grades 1-3	**Engineering Design Standard Correlation**	**Earth and Space Science Standard Correlation**	**A Brick For a Pig Activity Correlations** *See the "A Brick for a Pig Engineering Design Activity" student handout*
1. Identify a problem	3.4D.1 Identify a problem that can be addressed through engineering design.	1.1E.1 Describe characteristics and physical properties of Earth materials.	The three pigs need to build two more houses so they can live separately – they fight too much and have no money.
2. Propose a potential solution	2.4D.3 Describe an engineering design that is used to solve a problem or address a need. 3.4D.1 Propose a potential solution.	1.1E.1 Describe characteristics and physical properties of Earth materials.	Students are asked to help the pigs with their problem by designing and making bricks out of water, glue, sand, and large and small gravel. Potential solutions will include different amounts and ingredients for each brick to get the perfect "recipe".
3. Design a prototype	2.4D.1 Use tools to construct a simple designed structure out of common objects and materials. 2.4D.2 Work with a team to complete a designed structure that can be shared. 3.4D.1 Design a prototype.	1.1E.1 Describe characteristics and physical properties of Earth materials.	Students grab materials to make three bricks and begin building.

Connecting the Engineering Design Process

Steps of the EDP for Grades 4-5	**Engineering Design Standard Correlation**	**Earth and Space Science Standard Correlation**	**A Brick For a Pig Activity Correlations** *See the "A Brick for a Pig Engineering Design Activity" student handout*
1. Define a problem or a need	4.4D.1 Identify a problem that can be addressed through engineering design using science principles.	1.1E.1 Describe characteristics and physical properties of Earth materials.	The three pigs need to build two more houses so they can live separately – they fight too much and have no money.
2. List criteria and constraints	5.4D.1 Using science principles, describe a solution to a need or problem given criteria and constraints.	N/A	Criteria: 1. Bricks and other construction materials need to be strong to hold the weight of a structure. 2. They also need to stand-up to the elements like rain and wind. 3. Bricks should also be light enough to use easily while building. 4. Some people also think it's important that bricks should be attractive since they form the outside of a structure. Constraints: Limited materials
3. Describe a possible solution using science principles	5.4D.1 Using science principles, describe a solution to a need or problem.	1.1E.1 Describe characteristics and physical properties of Earth materials. 4.1E.1 Identify properties, uses, and availability of Earth materials.	Solution ideas can include using different amounts of glue, sand, water, and gravel. Solutions should be based on the properties or characteristics of materials that allow the design to meet the criteria and constraints.
4. Design and construct a possible solution	4.4D.2 Design and construct a prototype of a possible solution to a problem. 5.4D.2 Design and build a prototype of a proposed engineering solution.	4.1E.1 Identify properties, uses, and availability of Earth materials. 4.2E.1 Compare and contrast the changes in the surface of the Earth that are due to slow and rapidprocesses.	Design and build three bricks.
5. Describe the cost, safety, appearance and environmental impact of the solution as well as what will happen if the solution fails.	5.4D.1 Using science principles, describe a solution to a need or problem given criteria and constraints.	1.1E.1 Describe characteristics and physical properties of Earth materials. 4.1E.1 Identify properties, uses, and availability of Earth materials. 4.2E.1 Compare and contrast the changes in the surface of the Earth that are due to slow and rapidprocesses.	Students evaluate their designs to determine the best brick overall on handout.

Conclusion

What now, next steps

The next step is to participate in a training conducted by a facilitator who will provide activities that can be taken back to the classroom, as well as sample work samples, engineering design charts and references, templates and checklists. In late 2012 the Oregon University System offered school districts a competitive grant opportunity that provides winning school districts and schools small incentive grants to assist them in offering these workshops to their teachers. Similar grant opportunities may be offered in the future and some schools and school districts may decide to offer the workshops on their own. For information on this possibility, please contact XXXX@ous.edu. Teachers who attend a workshop will be given the opportunity to think about how they teach, draw upon the collective wisdom of their colleagues, participate in hands-on activities and walk away with Engineering Design Process lessons to be used in their school with their materials.

If you cannot attend a workshop or want to get started immediately, the next steps are considering how to adapt what you have learned from this primer to existing and new science lessons. Get together with your colleagues to brainstorm. Use the Engineering Design process to develop a method for deploying engineering design in the classroom.

The Engineering Design Process	Possibilities
1. Define the problem or need	Adapting what you have learned from this primer
2. Identify the criteria, constraints and priorities	Criteria: using the engineering design process to teach science Constraints: materials, time, collaboration Priorities: Students use the process to learn science concepts
3. Describe relevant scientific principles and knowledge	Use what you know about science instruction to adapt the lessons
4. Investigate possible solutions	Research on the Internet to see what others are doing or collaborate with a colleague.
5. Design and construct a proposed solution	Modify the lesson.

Key Terms

Constraints — Limits on possible solutions. When we solve a practical problem we usually have limits on how big the solution can be, how much it can cost, how easy it is to use, etc.

Criteria — The things your solution should do. Engineering problems are usually described in terms of a set of goals that become the criteria against which we judge possible solutions.

Design (noun) – A plan for a product, process, or system created to solve a problem.

Design (verb) — The process of modifying or inventing a product, process, or system to solve a problem.

Invention – The first occurrence of a new technology designed to solve a problem or meet a need. Invention is closely related to innovation. An invention often indicates an intent to market the product or to protect the intellectual property with a patent or other process.

Modifications – Changes to a design that are intended to improve performance. Making modifications to a design is a normal step in the design process since the first design is almost never perfect.

Need — The reason why we want to solve a problem. Most engineering problems relate to a need that relates to people, society or the world around us.

Practical – The characteristic that a problem or solution has a real world application.

Problem — Something that needs to be solved and usually the goal of an engineering design project. Most engineering projects relate to a practical problem that provides a benefit to people or improves upon an existing solution.

Prototype – A first or not yet final working model of a design that is usually constructed to test performance or other criteria.

Solution — In relation to using the engineering design process, a solution is a possible way of solving a practical problem.

Structure — Similar to prototype in this context except that it more likely that the structure will be a model of something that would be larger in real life.

Additional Resources

Methods and tools to produce work samples

- Oregon Elementary School Engineering Design Scoring Guides and notebook templates
  Web reference: www.ode.state.or.us/search/page/?id=32 or tinyurl.com/l8prupx
- Oregon Science Inquiry and Engineering Design Work Sample Resources: tinyurl.com/SIEDWS
- Engineering Design Work Sample Justification Sheet for scoring student work
  Web reference: tinyurl.com/cqof2dy
- Secondary Sample Student Language Engineering Design Scoring Template. This document represents one good approach for assisting students in developing a work sample using engineering design. Many other approaches are also possible. This template has been successfully used by several teachers in Oregon to help students produce Engineering Design Work Samples.
  Web reference: tinyurl.com/ctkoxmz
- Grades K-3: The Engineering Design Process Poster/Handout
  Web reference: http://www.ode.state.or.us/search/page/?id=32
- Grades K-3: The Engineering Design Process Poster/Handout Template
  Web reference: http://www.ode.state.or.us/search/page/?id=32
- Grades K-3: Engineering Design Notebook Template Instructions
  Web reference: http://www.ode.state.or.us/search/page/?id=32
- Grades K-3: Engineering Design Notebook Template
  Web reference: http://www.ode.state.or.us/search/page/?id=32
- Grades 4-5: The Engineering Design Process Poster/Handout
  Web reference: http://www.ode.state.or.us/search/page/?id=32
- Grades 4-5: The Engineering Design Process Poster/Handout Template
  Web reference: http://www.ode.state.or.us/search/page/?id=32
- Grades 4-5: Engineering Design Notebook Template Instructions
  Web reference: http://www.ode.state.or.us/search/page/?id=32
- Grades 4-5: Engineering Design Notebook Template
  Web reference: http://www.ode.state.or.us/search/page/?id=32

Additional Resources

Web Resources

- Elementary School sample activities: http://opas.ous.edu/EDOSC/Materials.php
- Request for application http://www.oregonetic.org/grant-info/
- Engineering Design Core and Content Standards for all bands available on: Pages 25 and 26 of http://bit.ly/V0nf7C
- Next Generation Science Standards www.nextgenscience.org
- *Scientific and Engineering Practices in K-12 Classrooms: Understanding a Framework for K-12 Science Education* by Rodger W. Bybee: http://bit.ly/UDeO6G

Pre-Engineering Curriculum and Projects

- Engineering is Elementary - This project develops curricular materials in engineering and technology education for children in grades K-5 (www.mos.org).
- Materials World Modules - Materials World Modules focus on materials engineering – books, kits and training for middle and high school students. (www.materialsworldmodules.org)
- Salvadori Center - The Salvadori Center focuses on improving children's content understanding and problem-solving skills by using project-based learning that focuses on the built environment. (www.salvadori.org)
- Stuff That Works - Stuff That Works is technology curriculum for the elementary grades. (citytechnology.ccny.cuny.edu)
- Children Designing and Engineering - Produced by the College of New Jersey, Children Designing and Engineering are teacher instructional guides that describe how to adapt activities for different populations, and provide hints for managing design-based learning (www.childrendesigning.org).
- Teachengineering.org - Funded as part of the NSF-supported National Science Digital Library (NSDL) to provide educational resources for STEM (science, technology, engineering and mathematics) education. TeachEngineering.org is a searchable, web-based digital library collection populated with standards-based engineering curricula for use by K-12 teachers and engineering faculty. (www.teachengineering.org)
- Design Squad - Design Squad is a reality-based competition show aimed at kids and people of all ages. Its goal is to get viewers excited about engineering and the design process. The series has free engineering resources you can use in classrooms, after-school programs, and event settings to get middle school kids excited about engineering. (www.designsquad.org)