

Engineering is Everywhere (E²)

Welcome Message!

Thank you for participating in *Engineering is Everywhere* (E²) with Dr. Tyler Ley. Dr. Ley is a civil engineer at Oklahoma State University with a passion for concrete... that's right, concrete! Join us as Dr. Ley introduces this versatile and widely utilized material (which covers much of the earth's surface) and emphasizes the role of engineers in improving the world all around us!

This unique curriculum pathway and accompanying activity trunk offers hands-on opportunities for up to 30 students to explore how microstructures are important to structural and material engineers. Three video lectures and hands-on activities encourage students to explore how engineers, like Dr. Ley, use math and science to improve their designs.

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Videos also available at: <http://www.engineeringiseverywhere.com>



Lesson 1: Introduction to Engineering

Lesson Time Requirements (1 hour total):

Video Lecture: 15 minutes

Activity: 30-45 minutes

Provided Materials:

Writing Pens (provided in kit; one per student)

Handouts for each student- Types of Engineers

E² DVD

Optional Materials (not provided):

Digital Cameras (one per group)

Access to computers (one computer per group)

Driving Questions: *What is engineering? Where is the engineering in our everyday lives?*

Learning Goals: By the end of this lesson, students will develop an appreciation for the variety of engineering careers, the work of engineers, and an awareness of engineering in the world all around us.

Learning Objectives:

By this end of this, students will be able to:

- Identify different types of engineers.
- Describe the work of engineers.
- Recognize engineer-designed objects in their daily lives.

Lesson Overview: The video lesson introduces Dr. Tyler Ley, a Civil Engineer at Oklahoma State University. Hands-on activities before and after the video lesson engage students in reverse engineering and scavenger hunts to explore the work of engineers.

Lesson Sequence:

- 1) **Engagement & Exploration: Simple yet genius designs (10 minutes)-**
 - a. Challenge each student to take apart and reassemble a pen to discover the elements of design. This part of the lesson is designed to arouse a sense of interest in the way simple objects like pens have intricate design features.
 - i. Encourage students to individually investigate their pen and to pay close attention to the form and function of each part.
 - ii. Next, encourage students to share their observations and discoveries with their group members (this may begin to happen naturally).
 - b. Prompt the groups to consider a number of design features:
 - i. How do the parts fit together to make a functioning pen?
 - ii. Why doesn't the ink run out of the pen? (Note: *Dr. Ley's video will answer this question in the next lesson segment: Explanation*)
 - iii. How does a clicking mechanism on a pen work? How else could a clicking mechanism work?

- iv. What did you learn by using reverse engineering? Why might it be important to carefully examine a machine before disassembling it?

2) Explanation: Introduction to Engineering video (15 minutes)

- a. Introduce the video segment for this lesson by saying, “Now let’s explore more about the people who design other objects that we use every day.”
- b. Distribute the handout, “Definitions of Engineer Career Specializations,” which describes the work of different types of engineers. Encourage students to take notes about the work of each engineer during the video.
- c. Play Track One of the DVD. In this video segment, Dr. Ley introduce his career interests and helps students understand the work of many types of Engineers (electrical, mechanical, materials, chemical, biomedical, industrial, material, mechanical, and structural). Additionally, Dr. Ley shares his real-life innovations with concrete and his passion to improve the world by making things safer and cheaper!
- d. At the end of the video, Dr. Ley challenges students to a Scavenger Hunt. Please find some suggested strategies in the Elaboration section below.

3) Elaboration: The Scavenger Hunt (20 minutes)

- a. a. For this portion of the activity, invite students to identify engineer-designed items in their own school building and then share their findings with the group. Explain the rules of the challenge to the students before they begin Dr. Ley’s “scavenger hunt challenge”. Emphasize that the purpose of the activity is for the students to find examples of engineering in the built world around them. Challenge each group to choose one object/item/design to share with the class by answering following questions: (Note: You might want to prompt students’ thinking by providing the questions ahead of time and asking them to write-out their answers.)
 - i. Where is the engineering in your object?
 - ii. What is the object used for?
 - iii. What are the parts of the objects used for?
 - iv. What special design considerations were made?
 - v. What type(s) of engineer do you think were involved in the design?
- c. If possible, take the students outside the classroom and allow their natural interests to guide their choice of examples. Depending on the available time and classroom schedule, you might ask students to make these observations as individual homework assignments or as groups during trips between lunch or recess. Another option would be to give students digital cameras to record their objects and share later with the class.

4) Evaluation: (15 minutes)

- a. Organize students into small groups to create a list of different types of engineers and the work that they do.
- b. Have students look around the classroom/school to provide specific examples of how engineers played a role in their school environment.

Possible Lesson Extensions

- 1) Read more about the design and history of the Ballpoint Pen:
<http://www.enotes.com/ballpoint-pen-reference/ballpoint-pen>
- 2) Ask students to draw cross-section diagrams during the initial ball point pen engagement. Find easy to copy “Gadget Inspector” worksheets provided by the WUP Center at:
http://wupcenter.mtu.edu/education/familysciencenight/lesson_plans/Gadget_Inspector_Gr_5-6.pdf
- 3) Take it to the next level with the “Get it Write” Challenge by Try Engineering. Handouts on the design history of the pen inspire students to create their own designs and then build them using everyday items. Find handouts and instructions at:
http://www.tryengineering.org/index.php?page=lesson_disqus&lesson=95
- 4) This website might challenge groups of students in a computer station. Encourage students to learn more about the Greatest Engineering Achievements of 21st century at: <http://www.greatachievements.org/>
- 5) Make the literacy connection with this virtual magazine which includes fun articles on engineering for kids. Browse this magazine online at:
<http://students.egfi-k12.org/read-the-magazine.htm>
- 6) Learn about innovations in sustainable cities with this interactive scavenger hunt animation created by the American Society of Civil Engineers:
<http://www.asceville.org/scgame.html>

More about Careers in Engineering

- 1) This short animated video is designed to emphasize, *Engineers are cool!* Got 5 minutes of down-time, show them this video:
http://www.youtube.com/watch?feature=player_embedded&v=DGmIkYw19gg#!
- 2) Make a literacy connection by encouraging students to read “Interviews with Engineers” and then watch short video clips:
<http://www.engineergirl.org/>
- 3) NOVA’s award winning *Secret Life of Scientists and Engineers* is particularly engaging as it introduces the work and personal lives of young engineers:
<http://www.pbs.org/wgbh/nova/secretlife/>
- 4) Encourage students to consider their favorite engineering career. There are over 200 types of engineers described at *Engineering from A-Z*, provided by Native Access to Engineering: <http://www.nativeaccess.com/all-about-engineering/engineering-a-to-z>

Lesson 2: Structural Engineering and Math Concepts

Lesson Time Requirements:

Video Lecture: 10 minutes

Activity: 35-45 minutes

Provided Materials:

Two tall sticks (demonstration models with different slope)

Blocks (provided in kit; 25 blocks per student)

Putty (provided in kit; 1/2 walnut-size amount for each student)

E² DVD

Driving Question: *How do structural engineers use math to build safer structures?*

Learning Goal/s: By the end of this lesson, students will develop an appreciation for the important role of mathematics and design in the work of structural engineers. Students will be able to describe considerations engineers make in terms of bracing and support.

Learning Objective(s):

By the end of this lesson, students will be able to:

- Design a tower of blocks.
- Describe slope.
- Identify ways a structural engineer uses math to build safer structures.
- Describe the career of a structural engineer.

Lesson Overview: In this lesson, Dr. Ley introduces one way structural engineers apply mathematics through the concept of *slope*. The lesson engages students in block tower building challenges to learn more about loading constraints, slope, and imperfections in building materials.

Lesson Sequence:

1) **Engagement & Exploration: How High Can you Stack the Blocks? (15 minutes)**

- a. Begin by asking students to work individually to build block towers. Give each student exactly 25 blocks. Ask the students to see how tall they can stack the single blocks in a tower. (Note: The goal here is for the students recognize the challenges in building a block tower.)
- b. Next, to encourage further discussion and new iterations in design, ask the students to get into groups to work on their towers. Now, encourage them to work together and test new ideas to design, arrange, and stabilize the towers.
- c. Walk around and review the accomplishments of student groups. You might record each group's tallest tower records and announce the final results with the whole class.

- d. Prompt students to consider the following design features:
 - i. Why do the blocks fall over (compared to a solid piece)?
 - ii. How were you able to improve your stacking efforts?
- 2) **Explanation: Structural Engineering and Math Concepts video (15 minutes)**
 - a. Prompt students viewing by saying, “Now let’s explore how math helps structural engineers in building safe, strong structures.”
 - b. Play Track Two of the DVD. This video describes the role of math in helping structural engineers in building safe, strong structures. Dr. Ley brings angles and fractions to life by introducing the concept of slope. Dr. Ley invites students to consider how concrete is used to stabilize large buildings and structures, despite imperfections in building materials.
 - c. **After the video**, walk around and allow the students to try to balance the tall sticks (demonstration models) described in the video and examine the angle cut that allows the stick tower to tumble.
- 3) **Elaboration: Using Mortar to Build Towers (20 minutes)**
 - a. Distribute the putty so students experiment with how “mortar” enables sturdier block towers. Encourage students to experiment with applying the putty in between the blocks. As students begin to experience success, prompt them to work in groups (so they will have more blocks) to build a higher tower.
 - b. After sharing the group records, again ask the students to consider:
 - a. What strategies allow you to build higher?
 - b. Did you encounter any problems using the putty?
 - c. What limitations or problems do engineers face when designing buildings (for example cost, availability of material, and environment)?
- 4) **Evaluation: Teacher Reflection on Student Learning (10 minutes)**
 - a. Have students define *slope* in their own words (they could record these in their science journals or on a piece of paper).
 - b. Ask students to describe the career of a structural engineer.
 - c. Organize students into small groups to discuss the role structural engineers play in their everyday lives. For example, what role do engineers play in making different buildings?

Possible Lesson Extensions

- 1) Having too much fun to stop building towers now? Take the Design Squad “High Rise” challenge to---Build a Tower that Supports a Tennis Ball:
http://pbskids.org/designsquad/parentseducators/resources/high_rise.html
- 2) Pull out your classroom Lego sets and learn more about loading, bracing, and support. Read about “5 Things LEGO Blocks Can Teach You About Structural Engineering” by HowStuffWorks:
<http://science.howstuffworks.com/engineering/structural/5-things-lego-blocks-teach-structural-engineering.htm>

- 3) Read more about how “Scientists Discover Maximum Height of a Lego Tower” using math: <http://uk.games.yahoo.com/blogs/plugged-in/scientists-discover-maximum-height-lego-tower-005843413.html>
- 4) Learn more about stable and unstable structures by investigating what makes bridges collapse, and then brainstorming design solutions:
<http://www.discoveryeducation.com/teachers/free-lesson-plans/stable-and-unstable-structures.cfm>

More about Slope

- 1) Watch this clip from the Sword in the Stone and ask students to find examples of slope: <http://www.youtube.com/watch?v=gTuKRovG5P0>
- 2) Calculate the slope of different roofs of houses. Get the handouts and a calculator skills component at:
<http://its.guilford.k12.nc.us/act/grade8/act8.asp?ID=724>
- 3) Build textbook ramps and calculate the slope of the fastest test cars.
<http://www.learnnc.org/lp/editions/on-track/7050>

Lesson 3: Materials Engineering and Science Concepts

Driving Question: *How do Materials Engineers use science?*

Lesson Time Requirements:

Video Lecture: 15 minutes

Activity: 30-45 minutes

Provided Materials: (for six groups)

SmartScopes (require software download and computer with USB port)

Computers (with SmartScope Software installed)

A variety of materials to view (including sponge, concrete, and wood pieces)

Straw bundles for demonstration

*****Note:** You may need to have your school computer technician install the software for these microscopes on computers for you. As such, please plan for this lesson ahead of time so that computers will communicate with the microscopes.

Driving Question: *How do materials engineers use their knowledge of microstructures to improve products and structures?*

Learning Goal:

At the end of this lesson, students will have an appreciation for microstructures and why these properties are important to Materials Engineers.

Learning Objectives: At the end of this lesson, the students will be able to:

- Describe the work of a Materials Engineer.
- Use a microscope to observe the internal structure of different materials.
- Understand the importance of microstructure to Materials Engineers.

Lesson Overview:

The SmartScope is an innovative science toy with a unique twist on the traditional microscope. Students begin by learning how to use this hand-held microscope and explore the properties of concrete and other building materials. Dr. Ley shows how material scientists apply the principles of microstructure.

Lesson Sequence:

- 1) **Engagement and Exploration: I Observe. . . Looking for Clues about how things are made (15 minutes)**
 - a. Organize student groups such that small student groups are each seated around a SmartScope/computer work space.
 - b. Begin by introducing the students to the SmartScope features. Help students understand how to change the resolution and adjust the focus. (Note: Refer to the manual provided with the SmartScope for additional features. For example, the instrument software also allows students to snap pictures and video, as well as add text descriptions.

- c. Guide small group exploration of the concrete and sponge pieces under the SmartScope. Ask the students to consider the following questions:
 - i. What are your predictions about how the concrete piece and the sponge will look under a microscope?
 - ii. In what way will concrete and sponge be similar or different?
 - d. Lead the class exploration of various cuts of the wood pieces under the SmartScope. Ask the students to consider the following questions:
 - i. What are your predictions about how the wood will look under a microscope?
 - ii. Why do different sides of the wood pieces look different? What might this tell us about the microstructure of trees?
- 2) **Explanation: Materials Engineer and Science Concepts Video (15 minutes)**
- a. Introduce the video by saying, “Now let’s explore how scientific observations and testing help materials engineers improve products and structures.”
 - b. Play Track Three of the DVD. Dr. Ley brings microstructures to life by exploring a number of everyday items, building materials, and other textiles. He illustrates how understanding microstructures can give us clues about how things work at a larger level. (Note: Dr. Ley is using an *Eyeclops* microscope which is different from though similar to the SmartScope.)
 - c. **After the video**, allow the students to explore the short sticks and straw bundles described by Dr. Ley. (Note: The straw bundles model the different cuts of wood; one is against the grain and one is with the grain.) You may also allow one student to demonstrate the difference between the strength of the short sticks (one will “snap” and one will not as illustrated by Dr. Ley in the video).
- 3) **Elaboration: I predict. . .A Microstructure Exploration (30-45 minutes)**
- a. This part of the lesson is designed to arouse interest in the students as young scientists. (Note: The E² kit includes a variety of materials to begin student exploration, but you may also suggest that students bring materials from home to investigate with the SmartScope.)
 - b. Organize students in small, SmartScope/computer work spaces. Encourage students to take turns leading the SmartScope observation of the microstructure of the items provided. Challenge the students to look for clues about how things are made. Ask students to predict what their object will look like, view the item under the SmartScope, and then describe the properties microstructures.
- 4) **Evaluation: (15 minutes)**
- a. Begin by having students reflect in their journals about how the microstructure of a material affects its performance. Follow-up by having students share their responses in a small groups.
 - b. Allow time for students to demonstrate an item to classmates and describe it using the prompt, “I Observe. . .”

- c. Finally, ask students to consider the following:
 - i. What observations about the microstructures of your objects surprised you most?
 - ii. How does understanding the smaller parts of the object help you understand how the whole item works?
 - iii. What new thoughts do you have about why engineers might be interested in microstructures?

Possible Lesson Extensions:

- 1) Have your students role-play as Scanning Probe Microscopes to learn more about how engineers understand the shapes of objects they cannot see:
http://tryengineering.org/lesson_detail.php?lesson=97
- 2) “Zoom in” for a closer look by exploring microstructures that even light microscopes cannot see! This virtual lab introduces Electron Microscopes as a way to learn about types of cells:
<http://www.discoveryeducation.com/teachers/free-lesson-plans/virtual-electron-microscope.cfm>
- 3) Learn more about how microstructures and nanotechnology influence engineering design by working with students to design and test waterproof fabrics:
<http://teachers.egfi-k12.org/nano-waterproofing/>
- 4) Make the literacy connection by reading about the history of microscopes:
<http://micro.magnet.fsu.edu/primer/museum/index.html>
- 5) Here are some template student worksheets for drawing images they view under microscopes:
<http://www.lauracandler.com/filecabinet/science/micropix.pdf>

More about Concrete and Building Materials

- 1) Check out “Building Big” online Material lab, with a fun section on the properties of building materials, including wood, plastic, aluminum, brick, concrete, cast iron, and steel:
<http://www.pbs.org/wgbh/buildingbig/lab/materials.html>
- 2) This collection of lessons and kits for purchase from Materials World Modules will help your students learn more about designing, comparing, and testing different types of concrete:
<http://www.materialsworldmodules.org/modules/concrete.shtml>