Failure: Seeds of Innovation

Provided by TryEngineering - www.tryengineering.org

Lesson Focus
Lesson focuses on how failure is part of the engineering process. Students work in teams and learn about many inventions and advances in engineering were brought about after a mistake or failure. Students research an example of such an innovation and develop a presentation related to how the tenacity of the engineer allowed him or her to move past a failure and into the realm of innovation. Students reflect on the value of moving on after a failure or setback, present the results of their research to the class, and provide examples of how the innovation they researched has impacted society -- only because the engineer didn't give up.

Lesson Synopsis
The "Failure: Seeds of Innovation" lesson explores how mistakes and failures can often lead to engineering successes and improvements in materials, machines, and systems. Teams explore many examples of how tenacity can lead to innovation, and then research a product, system, or material to determine the many points where mistakes or challenges rose in the way of progress. Teams develop a presentation on their product, how it came to be, and present to the class. Teams also reflect on the experience, and prepare a summary report.

Age Levels
8-18.

Objectives
- Learn how engineering can help solve society's challenges.
- Learn about teamwork.
- Learn about problem solving.

Anticipated Learner Outcomes
As a result of this activity, students should develop an understanding of:
- innovation
- engineering
- teamwork

Lesson Activities
Students explore how mistakes and failures are a part of engineering and explore many examples of how engineers and others created materials, products, and processes after facing a failure or mistake. Students work in teams to research and present about a product, materials, or process -- they explore the people involved, the challenges they faced, and the hurdles that had to be overcome in order to succeed. They present their research to the class, participate in discussions with other teams, and complete a reflection sheet.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Silly Putty Timeline (www.sillyputty.com/history_101/timeline/timeline.htm)
- NASA Apollo Program (www.nasa.gov/mission_pages/apollo)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)
- ITEA Standards for Technological Literacy (www.iteaconnect.org/TAA)

Recommended Reading

- They All Laughed... From Light Bulbs to Lasers: The Fascinating Stories Behind the Great Inventions That Have Changed Our Lives (ISBN: 978-0060924157)
- Mistakes that Worked (ISBN: 978-0385320436)
- Invention by Design; How Engineers Get from Thought to Thing (ISBN: 978-0674463684)
- Success through Failure: The Paradox of Design (ISBN: 978-0691136424)
- The Evolution of Useful Things: How Everyday Artifacts-From Forks and Pins to Paper Clips and Zippers-Came to be as They are (ISBN: 978-0679740391)

Optional Writing Activity

- Have students write an essay or a paragraph about a time when they made a mistake which turned into something positive.
- For older, or more advanced students, have teams participate in a technical debate about the success vs. failures of the Apollo 13 mission. Students research the mission from a technical vantage point, determine which side of the debate their team will take, prepare a presentation defending their position, and present to the class. Resources on Apollo 13 in particular and the Apollo program in general are at www.nasa.gov/mission_pages/apollo/missions/apollo13.html.

For Teachers:
Teacher Resources

◆ **Lesson Goal**

The "Failure: Seeds of Innovation" lesson focuses on how failure is part of the engineering process. Students work in teams and learn about many inventions and advances in engineering were brought about after a mistake or failure. Students work in teams to research and present about a product, material, or process -- they explore the people involved, the challenges they faced, and the hurdles that had to be overcome in order to succeed. They present their research to the class, participate in discussions with other teams, and complete a reflection sheet. Students reflect on the value of moving on after a failure or setback, present the results of their research to the class, and provide examples of how the innovation they researched has impacted society -- only because the engineer didn't give up.

◆ **Lesson Objectives**

- Learn how engineering can help solve society's challenges.
- Learn about teamwork.
- Learn about problem solving.

◆ **Materials**

- Student Resource Sheets
- Student Worksheets
- Student Team Materials: access to internet is very helpful.

◆ **Procedure**

1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, consider asking the students whether they have ever failed at something or made a huge mistake. Ask them if they went on to success if they pursued after they had a challenge or setback.
3. Teams of 3-4 students will consider their challenge, and as a team agree on which product or process they will research to determine how mistakes were made along the way that ultimately improved the product.
4. Teams complete their research, develop a presentation, and present to class.
5. Teams observe other students present, and complete a reflection sheet.

◆ **Time Needed**

One to two 45 minute sessions.

Note: For younger students, consider having them research the technical challenges of the U.S. Apollo 13 mission (see www.nasa.gov/mission_pages/apollo/missions/apollo13.html) and consider how international spaceflight might have changed if NASA engineers had given up.

Failure: Seeds of Innovation

Student Resource:
How Failure and Mistakes Can Lead to Success

Believe it or not, many of the technologies and solutions we count on today came about because someone made a mistake. Failure is a part of engineering and design. It is what one does when faced with a failure that can lay the seeds for success.

◆ Microwave

Take the microwave oven for example. It was not developed because someone was trying to engineer a faster way of cooking. In fact, the idea of using microwave energy to cook food was accidentally discovered by Percy LeBaron Spencer of the Raytheon Company who was experimenting with and testing a magnetron. While he was working and had stored a candy bar in his pocket for a snack. Percy was working in an area where he was exposed to microwaves, and found that the candy bar had melted all over his pocket. Instead of being distracted by the mess, he realized that microwave heating could raise the internal temperature of many foods -- and then research found that it could cook far more rapidly than a conventional oven.

◆ Post-It Notes

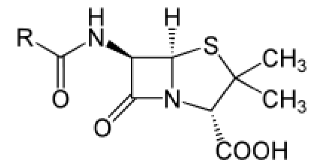
Post-It Notes are another example of how not giving up in the face of failure can lead to innovation. In 1968, Dr. Spencer Silver, a chemist at 3M in the United States, was trying to develop a new and stronger glue. Instead, he developed a weaker adhesive that pulled off instead of staying put. Six years later, a colleague of Dr. Silver, Art Fry, remembered the light adhesive when he was daydreaming about how he wished his bookmark would stay put in his church hymnal. The rest is history. 3M launched the product in stores in 1977 in four cities under the name "Press 'n Peel," but its results were disappointing. Then, a year later, in 1978, 3M issued free samples to residents of Boise, Idaho, and 95 percent of the people who tried them said that they would buy the product. On April 6, 1980, the product debuted in US stores as "Post-It Notes." In 1981, Post-Its were launched in Canada and Europe. Today, it is tough to find an office or home that doesn't use them. By the way, the yellow color of original Post-It Notes was also an accident -- the lab next-door to the Post-it team had a bunch of scrap yellow paper, which the team initially used.

◆ Silly Putty

Silly Putty was also created from a failure. According to the Silly Putty website, James Wright, an engineer working for GE's lab in New Haven, CT was working to develop a substitute for rubber when it was hard to come by in the US during World War II. Wright failed in his attempt in 1943, because his boric acid and silicone oil combination produced something not rubbery at all, but a gooey substance that lost its shape when left alone -- exactly a success. But, GE kept looking for a use for the material, and for six years sent it out to other engineers to collaborate. The new material ended up with Ruth Fallgatter, who owned a toy store. She teamed up with a marketing person, Peter Hodgson, and they started selling the material in eggs under the name Silly Putty. More than 300 million eggs have been sold since 1950!

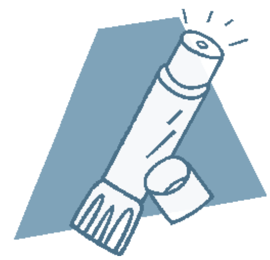
Student Resource: How Failure and Mistakes Can Lead to Success (continued)

◆ Penicillin



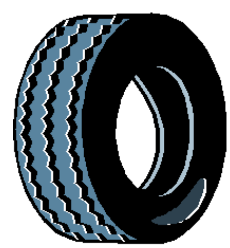
Scottish bacteriologist Alexander Fleming (1881-1955) discovered penicillin quite by accident in 1928. He was conducting research using several petri dishes of bacteria cultures, and by mistake he left one of the dishes uncovered for a few days. He then noticed that it was contaminated with a mold -- he had made a mistake. As he was throwing the mess out, he then happened to notice that the mold was actually dissolving the bacteria that were near to it. This mistake lead to success in that penicillin, as he called it, has proved to be one of the greatest advances in medicine. It's a good thing he took a closer look before throwing out his mistake.

◆ Super Glue



In 1942, Harry Coover and his team at Eastman Kodak were trying to create a new form of clear plastic….but his experiments were failing because the resulting material was too sticky. The material was a cyanoacrylates -- then nine years later, Coover was working with another Kodak team investigating heat-resistant polymers for jet canopies when cyanoacrylates were once again tested and -- once again -- were too sticky. That time though, Coover thought about the failings of the material and realized that he had discovered a unique adhesive. In 1958, the adhesive was introduced for sale as "Super Glue." And, Coover was also the first to recognize and patent cyanoacrylates as a tissue adhesive. It was first used during the Vietnam War to temporarily patch internal organs of injured soldiers until a more complete surgery could be performed.

◆ Vulcanization of Rubber



In 1839, Charles Goodyear was experimenting with the properties of gum elastic, and accidentally dropped some rubber that was mixed with sulfur on a hot stove. He was surprised to find that the specimen, being carelessly brought into contact with a hot stove, charred like leather. He had inadvertently discovered the process of vulcanization, which is instrumental to the strength and safety of tires. Vulcanization is a chemical process for converting rubber or related polymers into more durable materials via the addition of sulfur or other equivalent "curatives." In addition to tires, many products are made with vulcanized rubber, such as soles of some shores, hoses, and hockey pucks.

◆ Liquid Paper

Bette Graham was a secretary who unfortunately was not a very good or accurate typist. Instead of being thwarted by her failure, she thought about how artists often paint over their paintings, and invented a quick drying "paint" to cover her typing mistakes. Bette initially prepared the formula in her kitchen using a hand mixer, and poured the mixture into little bottles. In 1980, the Liquid Paper Corporation, which Bette Graham built, was sold for over $47 million.

Failure: Seeds of Innovation

Student Worksheet:
The Hurdles to Achievement

◆ **Instruction Phase**
Read the materials provided to you by your teacher.

◆ **Focus and Selection**
As a team, decide product, materials, or process you would like to research. In the box below indicate what your team selected and the reason for your selection.

◆ **Research Phase**
As a team research the following questions (and others you come up with) as related to the product, material, or process your team selected. Bear in mind that you'll be making a presentation to your class -- and if this is done electronically you might want to gather your research in word processing or other file formats.

1. What impact has your product, material, or process had on the world? Why is this a significant contribution to the world?

2. How long did this product, material, or process take to achieve -- from the initial seed of a concept to actual use?

3. What people, companies, or organizations were involved in the development of the product, material, or process? Did these change over time?

4. What significant hurdles did those involved have to overcome in order to develop this innovation? (note, this can include errors along the way, material limitation, costs, availability of manpower, computing restrictions, or other challenges)

5. What mistakes were made along the way? What happened when mistakes were made? How did the mistakes impact the final product, material, or process?

6. Was there a point along the way where the product, material, or process was considered a failure, and was abandoned for a period of time? If so, what reignited the interest in developing the innovation?

7. Who benefits financially from this product, material, or process? Did the original team of innovators gain financially? Did they receive any other recognition for their work?

8. What would the world be like without this product, materials, or process?

9. What other products, materials, or processes depend upon this innovation?

Student Worksheet:

◆ Reflection

Complete the reflection questions below:

1. Describe three aspects of the development of the product, material, or process you selected that really surprised you.

2. Which product, material, or process researched by another student team was the most interesting to you? Why?

3. How do you think this activity will impact how you respond to the next mistake or challenge you face?

4. Do you think there is a point where an engineer should just give up after facing a series of setbacks or failures? What factors would make quitting be the right decision?

5. Did you think that working as a team made this project easier or harder? Why?

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understanding about science and technology
- Abilities to distinguish between natural objects and objects made by humans

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Risks and benefits
- Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor
- Nature of science
- History of science

For Teachers: Alignment to Curriculum Frameworks (cont.)

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 2: Students will develop an understanding of the core concepts of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.

For Teachers:
Alignment to Curriculum Frameworks (cont.)

◆Standards for Technological Literacy - All Ages

Design

- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 13: Students will develop abilities to assess the impact of products and systems.