Biomimicry in Engineering

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on the concept of Biomimicry and students learn how engineers have incorporated structures and methods from the living world in products and solutions for all industries. Students then work in teams to develop a structure or system based on an example in nature that would help people living on the moon. They design their structure on paper, learn about patents, and share their designs with the class.

Lesson Synopsis

The "Biomimicry in Engineering" lesson explores how nature provides inspiration to engineers, both in terms of aesthetics and practical solutions to challenges. Students review current applications and then work as a team to develop a structure or system that would help support people living on the moon. They sketch their plans, consider patent rights, and present to their class.

Year Levels

Year 5 – 10 Science Inquiry Skills and Science as a Human Endeavour

Objectives

- Learn about biomimicry.
- Learn about engineering design and redesign.
- Learn about patents.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- biomimicry
- engineering design
- patents
- teamwork

Lesson Activities

Students explore how engineers have incorporated systems, materials, and methods from nature into manmade products, materials, and methods found in all industries. Students look to natural examples to create on paper a structure or system that would support people living on the moon. They consider patenting options and present their ideas to the class.

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)
- Biometrics Architecture (http://biomimetic-architecture.com)
- The Centre for Biomimetics at the University of Reading, UK (www.reading.ac.uk/biomimetics)
- Ask Nature (www.asknature.org)
- esp@cenet - European Patent Office Search (www.espacenet.com/access/)
- U.S. Patent and Trademark Office (www.uspto.gov/patents)
- Curriculum Links (www.acara.edu.au)

Recommended Reading

- Biomimicry: Innovation Inspired by Nature (ISBN: 978-0060533229)
- Biomimetics: Biologically Inspired Technologies (ISBN: 978-0849331633)
- The Gecko's Foot: Bio- Inspiration: Engineering New Materials from Nature (ISBN: 978-0393337976)
- Biomimicry for Optimization, Control, and Automation (ISBN: 978-1852338046)
- How to Make Patent Drawings (ISBN: 978-1413306538)

Optional Writing Activity

- Write an essay or a paragraph about one example of how engineers have looked to nature to help find solutions to societal challenges.

Biomimicry in Engineering

For Teachers:
Teacher Resources

◆ Lesson Goal
The "Biomimicry in Engineering" lesson explores how nature provides inspiration to engineers, both in terms of aesthetics and practical solutions to challenges. Students review current applications and then work as a team to develop a structure or system that would help support people living on the moon. They sketch their plans, consider patent rights, and present to their class.

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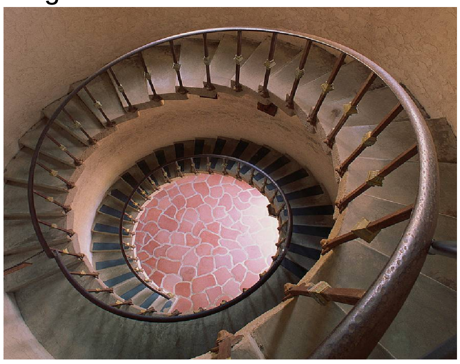


◆ Materials
- Student Resource Sheets
- Student Worksheets
- Student Team Materials: paper, pen, pencil; access to the internet is optional though helpful.

◆ 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 how nature engineers a product -- like a leaf. Ask them to think about the functionality of shapes such as a conch shell or palm leaf, and how they support the structure. Another point might be to look at how a lotus leaf beads up water…and consider that it is the tiny "hairs" on the surface of the leaf that suspend water beads.
3. Teams will consider their challenge, conduct research into other examples of biomimicry and decide whether they are going to design a building, a system, or some other product for use on the moon that incorporates biomimicry.
4. Teams next develop a detailed drawing showing their product or system from at least two perspectives and including a written description of how the design works.
5. Teams present their ideas to the class and complete a reflection sheet.

◆ Time Needed
One to two 45 minute sessions.

Biomimicry in Engineering

Student Resource: All About Patents

◆ What Is a Patent?

A patent for an invention is the grant of a property right to the inventor, issued by a country's Patent and Trademark Office. The procedure for granting patents, the requirements placed on the patentee, and the extent of the exclusive rights vary widely between countries according to national laws and international agreements. In Australia, the term of a new patent is 20 years from the date on which the application for the patent was filed or, in special cases, from the date an earlier related application was filed, subject to the payment of maintenance fees. *Standard patents* gives long term protection and control over an invention. The invention claimed in a standard patent must be new, involve an inventive step and be able to made and used in an industry. *Innovation patents* lasts for 8 years and is designed to protect inventions that do not meet the inventive threshold required for standard patents. The innovative patent requires an innovation step rather than an inventive step, to protect an incremental advance on existing technology rather than a groundbreaking invention. *Plant breeder rights* are legally enforceable and gives the breeder exclusive rights to commercially use, sell and direct the production, sale and distribution of the plants. Hybrid tea roses, Silver Queen corn, and Better Boy tomatoes are all types of plant patents.

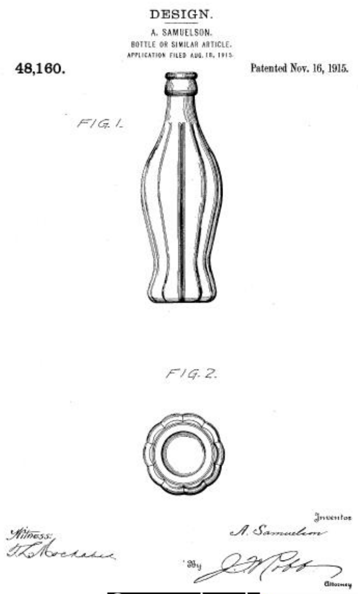
◆ Famous Patents

Safety Pin: The patent for the "safety pin" was issued on April 10, 1849 to Walter Hunt, of New York. Hunt's pin was made from one piece of wire, which was coiled into a spring at one end and a separate clasp and point at the other end, allowing the point of the wire to be forced by the spring into the clasp.

Dishwasher: A patent for the first practical dish washing machine was issued December 28, 1886 to Josephine Garis Cochran of Shelbyville, Illinois. She was wealthy, entertained often, and wanted a machine that could wash dishes quickly, and without breaking them. When she couldn't find one, she built it herself.

◆ How to Register a Patent

Each country, or sometimes a region has its own patent procedures. For example, in Australia you apply to the government to patent a new product. Wherever you are, you have to design your product on paper or on a computer and specifically show why your design is different from others. On the left is one of the first drawings of the Coca Cola bottle, and on the right, is a copy of the patent design. You also need to check to see if someone else has already invented what you think you did! Try searching for a patent at http://www.ipaustralia.gov.au/ .

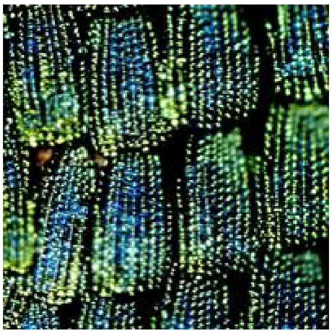


Student Worksheet: What is Biomimicry?

People have always been inspired by nature -- and engineers are no exception! Throughout history, structures, systems, and materials developed by engineers have had roots in natural structures, systems, and materials. For example, the echolocation used by bats in the dark have helped lead to improvements in cane technology for blind people. Others have looked to the methods beetles use to draw water from fog, or how the structure of a lotus leaf can help keep moisture away from the surface -- this has led to changing the surface of fabrics at the nanoscale so they too repel water. And, gecko tape mimics the feed of a gecko lizard by including nanoscopic hairs. Other engineers have looked to the way tower building termites have structures designed to maintain a constant temperature in climates with wide temperature swings. The Eastgate building in Harare, Zimbabwe has passive, self-cooling systems modeled on termite mounds. The building, a mixture of offices, shops and car parking, uses an average of 90 per cent less energy than a comparable structure saving more than $3.5 million since opening in the 1990s.

◆ **How butterflies' wings could cut bank fraud**

University of Cambridge scientists and engineers recently discovered a way of mimicking the stunningly bright and beautiful colours found on the wings of tropical butterflies. The findings could have important applications in the security printing industry, helping to make bank notes and credit cards harder to forge. Mimicking nature's most colourful, eye-catching surfaces has proved elusive. This is partly because rather than relying on pigments, these colours are produced by light bouncing off microscopic structures on the insects' wings. Mathias Kolle, working with Professor Ullrich Steiner and Professor Jeremy Baumberg of the University of Cambridge, studied the Indonesian Peacock or Swallowtail butterfly (*Papilio blumei*) (Image at right is courtesy: University of Cambridge), whose wing scales are composed of intricate, microscopic structures that resemble the inside of an egg carton. Because of their shape and the fact that they are made up of alternate layers of cuticle and air, these structures produce intense colours. Using a combination of nanofabrication procedures - including self-assembly and atomic layer deposition - Kolle and his colleagues made structurally identical copies of the butterfly scales, and these copies produced the same vivid colours as the butterflies' wings. As well as helping scientists gain a deeper understanding of the physics behind these butterflies' colours, being able to mimic them has promising applications in security printing.



◆ **China Winter Olympics**

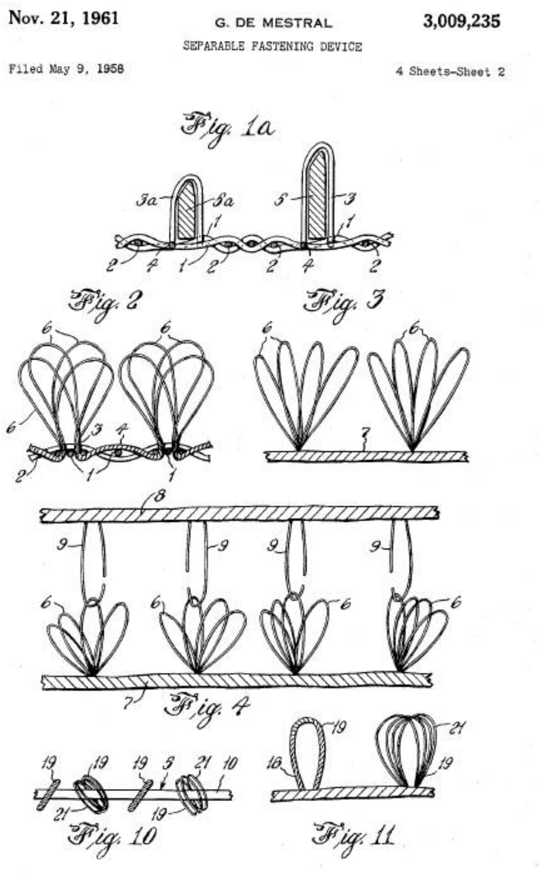
The National Aquatic Center in Beijing, China structure stands on enormous twisted beams around the exterior similar to a nest. The designing team studied some countless natural nests for understanding the weaving pattern of the threads. Some hundreds of models were created for the design.

Biomimicry in Engineering

Student Worksheet:

◆ Engineering Teamwork and Planning

You are part of a team of engineers given the challenge of developing a system or building that would be based on the moon that is based on a product or system found in nature. You'll research ideas online, then work as a team to develop a drawn diagram. You'll also consider patenting your idea, and present your designs to your class.

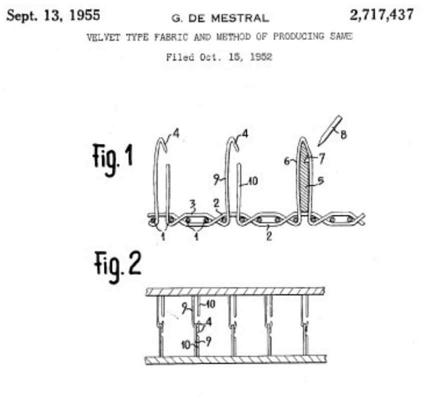


◆ Research Phase

Read the materials provided to you by your teacher. If you have access to the internet, also visit Asknature.org, and take some time to explore the various challenges and solutions nature has to offer. For example, you might search for "store oxygen" or "termites" or anything related to what you are considering working on. Gain ideas by seeing what others are working on.

◆ Planning and Design Phase

Leonardo da Vinci both studied how birds fly and also drew intricate illustrations of his designs in preparation for construction. In the same way, George de Mestral, a Swiss engineer hiking in the Alps found that many burs from a burdock tree were sticking to his clothing….he later invented what is now known as Velcro. But he also had to draw his ideas in order to gain a patent for his invention. You can see one page of his patent to the right. Mechanising the process of weaving the hooks took eight years, and it took another year to create the loom that trimmed the loops after weaving them. It took him about a decade to create a mechanised process that worked. He submitted his idea for patent in Switzerland in 1951 and the patent was granted in 1955.



Now it is your turn! On a separate piece of paper draw a detailed diagram showing several views of your system, similar to what might be required for a patent. Present this plan to your class. Be sure to list the materials you might need and include a paragraph or more describing how your invention works and how it relates to nature….what makes it an example of Biomimicry?

◆ Presentation Phase

Present your ideas, drawings, and connection to Biomimicry to the class, the complete the reflection sheet.

Biomimicry in Engineering

Student Worksheet:

◆ **Reflection**
Complete the reflection questions below:

1. What was the most interesting proposed use of biomimicry that was developed in your class presentations? Why?

2. Do you think that your design is patentable? Is it unique enough to be approved?

3. Do you think your product, building, or system would work if manufactured?

4. Do you think that you could raise funds to pay for manufacturing? How would you go about raising funds?

5. Do you think that many engineers explore solutions from nature into their inventions?

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

Alignment to Curriculum Frameworks

Note: All lesson plans in this series are aligned to the Australian Curriculum for both Science.

Science Inquiry Skills

Year 5

With guidance, select appropriate investigation methods to answer questions or solve problems. (**ACSIS086**)

Use equipment and materials safely, identifying potential risks (**ACSIS088**)

Suggest improvements to the methods used to investigate a question or solve a problem (**ACSIS091**)

Year 6

With guidance, select appropriate investigation methods to answer questions or solve problems. (**ACSIS103**)

Use equipment and materials safely, identifying potential risks (**ACSIS105**)

Suggest improvements to the methods used to investigate a question or solve a problem (**ACSIS108**)

Year 7

Collaboratively and individually plan and conduct a range of investigation types including fieldwork and experiments, ensuring safety and ethical guidelines are followed (**ACSIS125**)

Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of data collected, and identify improvements to the method **(ACSIS131)**

Year 8

Collaboratively and individually plan and conduct a range of investigation types including fieldwork and experiments, ensuring safety and ethical guidelines are followed (**ACSIS140**)

Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of data collected, and identify improvements to the method **(ACSIS146)**

Year 9

Plan, select and use appropriate investigation methods, including fieldwork and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods **(ACSIS165)**

Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data **(ACSIS166)**

Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data **(ACSIS171)**

Year 10

Plan, select and use appropriate investigation methods, including fieldwork and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods **(ACSIS199)**

Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data **(ACSIS200)**

Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data **(ACSIS205)**

Science as a Human Endeavour

Year 5

Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena **(ACSHE081)**

Scientific understandings, discoveries and inventions are used to solve problems and directly affect people's lives **(ACSHE083)**

Year 6

Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena **(ACSHE098)**

Scientific understandings, discoveries and inventions are used to solve problems and directly affect people's lives **(ACSHE100)**

Year 7

Science knowledge can develop through collaboration and connecting ideas across the disciplines of science **(ACSHE223)**

People use understanding and skills from across the disciplines of science in their occupations **(ACSHE224)**

Year 8

Science knowledge can develop through collaboration and connecting ideas across the disciplines of science **(ACSHE226)**

People use understanding and skills from across the disciplines of science in their occupations **(ACSHE227)**

Year 9

Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries **(ACSHE158)**

Advances in science and emerging sciences and technologies can significantly affect people's lives, including generating new career opportunities **(ACSHE161)**

Year 10

Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries **(ACSHE192)**

Advances in science and emerging sciences and technologies can significantly affect people's lives, including generating new career opportunities **(ACSHE195)**

Mathematics Links with Science Curriculum (Skills used in this activity)	General Capabilities	Cross-Curriculum Priorities
• Process data using simple tables • Analysis of patterns and trends • Use of metric units	• Literacy • Numeracy • Critical and creative thinking • Personal and social capacity • ICT capability	• Sustainability

Science Achievement Standards

Year 5

By the end of Year 5, students classify substances according to their observable properties and behaviours. They explain everyday phenomena associated with the transfer of light. They describe the key features of our solar system. They analyse how the form of living things enables them to function in their environments. Students discuss how scientific developments have affected people's lives and how science knowledge develops from many people's contributions.

Students follow instructions to pose questions for investigation, predict what might happen when variables are changed, and plan investigation methods. They use equipment in ways that are safe and improve the accuracy of their observations. Students construct tables and graphs to organise and identify patterns. They use patterns in their data to suggest explanations and refer to data when they report their findings. They describe ways to improve the fairness of their methods and communicate their ideas, methods and findings using a range of texts.

Year 6

By the end of Year 6, students compare and classify different types of observable changes in materials. They analyse requirements for the transfer of electricity and describe how energy can be transformed from one form to another to generate electricity. They explain how natural events cause rapid changes to the Earth's surface. They decide and predict the effect of environmental changes on individual living things. Students explain how scientific knowledge is used in decision making and identify contributions to the development of science by people from a range of cultures.

Students follow procedures to develop investigable questions and design investigations into simple cause-and-effect relationships. They identify variables to be changed and measured and describe potential safety risks when planning methods. They collect, organise and interpret their data, identifying where improvements to their methods or research could improve the data. They describe and analyse relationships in data using graphic representations and construct multi-modal texts to communicate ideas, methods and findings.

Year 7

By the end of Year 7, students describe techniques to separate pure substances from mixtures. They represent and predict the effects of unbalanced forces, including Earth's gravity, on motion. They explain how the relative positions of the Earth, sun and moon affect phenomena on Earth. They analyse how the sustainable use of resources depends on the way they are formed and cycled through Earth systems. They predict the effect of environmental changes on feeding relationships and classify and organise diverse organisms based on observable differences. Students describe situations where scientific knowledge from different science disciplines has been used to solve a real-world problem. They explain how the solution was viewed by, and impacted on, different groups in society.

Students identify questions that can be investigated scientifically. ***They plan fair experimental methods, identify variables to be changed and measured. They select equipment that improves fairness and accuracy and describe how they considered safety. Students draw on evidence to support their conclusions***. They summarise data from different sources, describe trends and refer to the quality of their data when suggesting improvements to their methods. They communicate their ideas, methods and findings using scientific language and appropriate representations.

Year 8

By the end of Year 8, students compare physical and chemical changes and use the particle model to explain and predict the properties and behaviours of substances. They identify different forms of energy and describe how energy transfers and transformations cause change in simple systems. They compare processes of rock formation, including the time scales involved. They analyse the relationship between structure and function at cell, organ and body system levels. Students examine the different science knowledge used in occupations. They explain how evidence has led to an improved understanding of a scientific idea and describe situations in which scientists collaborate to generate solutions to contemporary problems.

Students identify and construct questions and problems that they can investigate scientifically. ***They consider safety and ethics when planning investigations, including designing field or experimental methods. They identify variables to be changed, measured and controlled***. Students construct representations of their data to reveal and analyse patterns and trends, and use these when justifying their conclusions. ***They explain how modifications to methods could improve the quality of their data and apply their own scientific knowledge and investigation findings to evaluate claims made by others***. They use appropriate language and representations to communicate science ideas, methods and findings in a range of texts types.

Year 9

By the end of Year 9, students explain chemical processes and natural radioactivity in terms of atoms and energy transfers and describe examples of important chemical reactions. They describe models of energy transfer and apply these to explain phenomena. They explain global features and events in terms of geological processes and timescales. They analyse how biological systems function and respond to external changes with reference to interdependencies, energy transfers and flows of matter. They describe social and technological factors that have influenced scientific developments and predict how future applications of science and technology may affect people's lives.

Students design questions that can be investigated using a range of inquiry skills. ***They design methods that include the control and accurate measurement of variables and systematic collection of data and describe how they considered ethics and safety. They analyse trend in data, identify relationships between variables and reveal inconsistencies in results. They analyse their methods and the quality of their data, and explain specific actions to improve the quality of their evidence***. They evaluate others 'methods and explanations from a scientific perspective and use appropriate language and representations when communicating their findings and ideas to specific audiences.

Year 10

By the end of Year 10, students analyse how the periodic table organises elements and use it to make predictions about the properties of elements. They explain how chemical reactions are used to produce particular products and how different factors influence the rate of reactions. They explain the concept of energy conservation and represent energy transfer and transformation within systems. They apply relationships between force, mass and acceleration to predict changes in the motions of objects. Students describe and analyse interactions and cycles within and between Earth's spheres. They evaluate the evidence for scientific theories that explain the origin of the universe and the diversity of life on Earth. They explain the processes that underpin heredity and evolution. Students analyse how the models and theories they use have developed over time and discuss the factors that prompted their view.

Students develop questions and hypotheses and independently design and improve appropriate methods of investigation, including field work and laboratory experimentation. They explain how they have considered reliability, safety, fairness and ethical actions in their methods and identify where digital technologies can be used to enhance the quality of their data. When analysing data, selecting evidence and developing and justifying conclusions, they identify alternative explanations for findings and explain any sources of uncertainty. Students evaluate the validity and reliability of claims made in secondary sources with reference to currently held scientific views, the quality of methodology and the evidence cited. They construct evidence-based arguments and select appropriate representations and text types to communicate science ideas for specific purposes.