Critical Load

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on issues civil engineers face, including critical load and how to reinforce the design of a structure to hold more weight.

Lesson Synopsis

The Critical Load activity explores the concepts of structural engineering and how to measure the critical load, or the maximum weight a structure can bear. Students learn about basic structures, how to reinforce, materials selection, and working as a team, design and build a prototype structure to hold increasingly greater weights.

Year Levels

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

Objectives

- Learn about civil engineering and the testing of building structure.
- Learn about efficiency ratings and critical load.
- Learn about teamwork and the engineering problem solving.

Anticipated Learner Outcomes

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

- efficiency ratings and critical load
- structural design and testing
- engineering problem solving
- measurement and reporting
- teamwork

Lesson Activities

Students learn about how to test structures for maximum load by designing prototypes of buildings out of cards. Topics examined include problem solving, teamwork, and the engineering design process. Students work first individually to build a structure, then combine materials in student teams to design the strongest structure, evaluate the load capacity and critical load, and discuss why the strongest design worked best. Students also learn about famous failed and successful building structures.

Resources / Materials

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

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Bryan Burg Cardstacker (www.cardstacker.com/index2.html)
- Great Structures of the World (http://greatstructures.info)
- Curriculum links (www.acara.edu.au)

Recommended Reading

- Stacking the Deck : Secrets of the World's Master Card Architect by Bryan Berg (ISBN: 0743232879)
- Why Buildings Stand Up: The Strength of Architecture by Mario Salvadori (ISBN: 0393306763)
- Why Buildings Fall Down: How Structures Fail Architecture by Mario Salvadori (ISBN: 039331152X)

Optional Writing Activities

- Write an essay or a paragraph describing a recognizable building in your town. Include the history, interesting challenges to the building's engineering, and challenges that the engineers faced in design and construction.

Critical Load

For Teachers:
Teacher Resources

◆ Lesson Goal
Explores the concepts of structural engineering and how to measure the critical load, or the weight at which a structure will fail. Students learn about basic structures, how to reinforce, materials selection, and working as a team, design and build a prototype structure to hold the greatest weight.

◆ Lesson Objectives
- Students learn about civil engineering and the testing of building structures.
- Students learn about critical load.
- Students learn about teamwork and engineering problem solving.

◆ Materials

- Student Resource Sheets
- Student Worksheets
- One set of materials for each student team:
    - twelve unused playing cards
    - one roll of scotch tape
    - 4 coins
- Testing materials:
    - Base of empty square based two litre cardboard juice container
    - Objects to build weight of base from 2 – 4.5 kg (coins, marbles, sand)

◆ Procedure
1. Show students the student reference sheet. These may be read in class or provided as reading material for the prior night's homework.
2. Provide each student team with materials and ask them to devise a structure that will hold the most weight. They are to plan out their structure, and build a prototype for testing. Allow 10 minutes for planning and execution.
3. Instructor places weights on each team's prototype increasing the weight until the structure fails. Students chart the maximum load each prototype successfully held (the amount just prior to failure)
4. Each student group presents their vision for their design, and explains why they think their design did well or failed. Ask students how would they adjust the design if they could do it again?

◆ Time Needed
One to two 45 minute sessions.

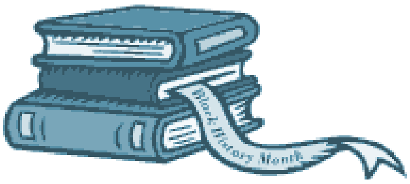
Critical Load

Student Resource: Civil Engineering Challenges

◆ What Civil Engineers Do

Civil engineers are problem solvers, meeting the challenges of pollution, traffic congestion, drinking water and energy needs, urban redevelopment, and community planning. This activity focuses on the work of structural engineers who face the challenge of designing structures that support their own weight and the loads they carry, and that resist wind, temperature, earthquake, and many other forces.

◆ Famous Building Failures



The John Hancock Tower in Boston, Massachusetts is said to have been "known more for its early engineering flaws than for its architectural achievement." Wind-induced swaying was so large, it was said to cause motion sickness for people on the upper-floors. This problem was solved by adding a pair of 300-ton dampers on the 58th floor. Another unrelated but serious problem was that 65 of its 10,344 floor-to-ceiling plate-glass windowpanes fell out of the building to the ground during construction -- luckily no injuries resulted to either workers or passersby! Another example is a library built at Syracuse University in the late 1970's was built without having taken into consideration the weight of the books!

◆ Famous Structures

- The Stratosphere Tower in Las Vegas, Nevada, is the tallest free-standing tower (350 metres) in the United States, rising taller than Paris' Eiffel Tower, and the Tokyo Tower.
- The world's tallest bridge is in France and spans the Tarn valley. It is 2460m long and is supported by seven piers ranging from 77m to 244m in height.
- The Petronas Twin Towers in Kuala Lumpur, Malaysia, are the tallest office buildings in the world. They soar 451.9 metres from street level.
- The CN Tower in Toronto, Ontario, Canada has the title of "World's Tallest Building and Free-Standing Structure." It is 553.33m tall.
- Canada also has the world's largest shopping and entertainment complex -- the West Edmonton Mall in Edmonton, Alberta. It spans 49 hectares (121 acres) an houses over 800 stores!

◆ Efficiency Ratings and Critical Load

The efficiency rating measures the weight that will cause a structure to fail divided by the weight of the structure itself. The most efficient structures are strong and lightweight - a difficult combination to achieve. For example, roofers in areas which experience heavy snows must factor in the weight of a massive snowstorm into designing the strength of the roof. The weight at which a building or structure fails is called the "critical load."

Critical Load

Student Worksheet:
Measuring Critical Load - Page One

Step One:
You have been provided with four playing cards, some sticky tape, and scissors. As a team, and without altering (cutting for example) the cards, devise a structure that you think will hold up a 2.0L container without collapsing.

Question:
1. What is your team's strategy or plan for construction?

Prediction:
1. Predict the "critical load" of your structure as you have designed it.

Step Two:
As a team, build your structure (prototype) for testing.

Step Three:
Your instructor will test your structure, and determine at what weight your team's structure will fail by adding measurable weights (coins, sand, other materials) until it collapses. This is your structure's "critical load."

Questions:

1. What was your structure's "critical load?"

2. How close were you to your prediction from Step One?

Critical Load

Student Worksheet:
Measuring Critical Load - Page Two

3. What aspects of your design do you think helped its ability to hold more weight?

4. What aspects of your design do you think hindered its ability to hold more weight?

5. What was the highest critical load in your classroom?

6. What was the difference in the winner's design and yours? Or…if your team had the winning structure, what do you think set your structure apart from the rest?

7. If you could do your design all over….what would you change, and why?

8. What human factors do you think a civil/structural engineer needs to take into consideration when planning an office building? (examples are the weight of people and furnishings, need for water, fresh air, escape routes)

Critical Load

For Teachers:
Alignment to Curriculum Frameworks

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**)

In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task **(ACSIS126)**

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**)

In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task **(ACSIS141)**

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 • Data analysis skills (graphs) • 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.