Engineering Ups and Downs

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Lesson Focus
Lesson focuses on the engineering behind elevators. Teams of students explore principles and requirements of vertical travel, then design and construct a working elevator to service a toy car garage using wheels, pulleys, string, cardboard and other materials.

Lesson Synopsis
The Engineering Ups and Downs lesson explores the engineering and principles behind working elevators. Student teams explore the history of elevators, their design, and develop their own working elevator using wheels, pulleys, string, cardboard and other materials. Student teams design their toy car garage elevator first on paper, then execute their plan, and evaluate the strategies employed all student teams.

Age Levels
11-18.

Objectives

- Learn about engineering design.
- Learn about elevator operations.
- Learn about teamwork and working in groups.

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

- mechanical engineering and design
- problem solving
- teamwork

Lesson Activities

Students learn how elevators meet human needs, explore how they work, and then work in teams to develop a design for their own elevator to service a toy car garage. Teams plan their system, using materials provided, draw their design, build it, troubleshoot as needed, evaluate their own work and that of other students, and then present their observations to the class.

Resources/Materials
- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Otis Worldwide (www.otisworldwide.com)
- Online History of Otis Elevators (www.otisworldwide.com/d31-timeline.html)
- The Elevator Museum (www.theelevatormuseum.org)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Recommended Reading

- Up, Down, Across: Elevators, Escalators, and Moving Sidewalks (ISBN: 1858942136)
- Vertical Transportation 3E (ISBN: 0471162914)

Optional Writing Activity

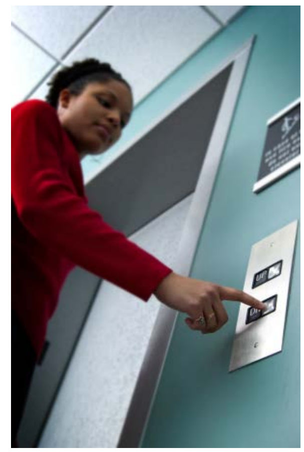
- The invention of elevators has had a huge impact on civil engineering and urban planning. Write an essay or a paragraph about how you think the invention of the elevator has impacted the skyline of the town or city in which you live.

Engineering Ups and Downs

For Teachers:
Teacher Resource

◆ **Lesson Goal**

The Engineering Ups and Downs lesson explores the engineering and principles behind working elevators. Students explore the history of elevators, their design, and develop their own working elevator for a toy car garage using wheels, pulleys, string, cardboard and other materials. Student teams design their elevator first on paper, then execute their plan, and evaluate the strategies employed all student teams.



◆ **Lesson Objectives**

- Learn about engineering design.
- Learn about elevator operations.
- Learn about teamwork and working in groups.

◆ **Materials**

- Student Resource Sheet
- Student Worksheets
- One set of materials for each group of students:
  - Glue, string, paperclips, paper, pencils, cardboard, cardboard tubes (such as from paper towel or toilet paper rolls), markers, pulleys or thread spools (3), thin rope, string or fishing line, cardboard box to serve as elevator room (shoe box, large milk carton), small toy cars.

◆ **Procedure**

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework. Divide students into groups of 2-3 students, providing a set of materials per group.
2. Explain that students are now an "engineering" team that must develop a hand powered elevator to deliver toy cars to a three story parking garage. (you may wish to require a certain weight for each load, or determine that each car is a similar weight). The elevators must be able to securely stop at each floor and lift a toy car of a set weight.
3. Students meet and develop a plan for their elevator system. They agree on materials they will need (out of those you have provided), write or draw their plan, and then present their plan to the class.
4. Student groups next execute their plans. They may need to rethink their plan, add materials, or start over.
5. Each student group evaluates the results, completes an evaluation/reflection worksheet, and presents their findings to the class.

◆ **Tips**

To speed up the construction process, you may wish to create the three level "garage" first, and then simply have each team move their elevator to the garage for testing. This will eliminate the need for each team to make the garage themselves. Garages can be three shoeboxes taped together, or some other simple structure. Also, if students glue any part of their elevator system, it may require an overnight drying period.

◆ **Time Needed**

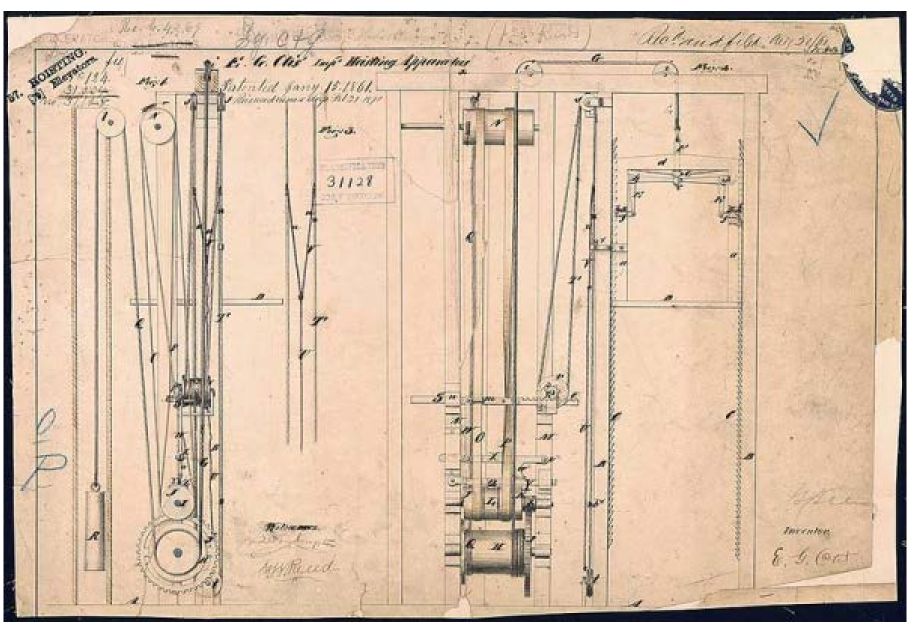
Two to four 45 minute sessions

◆ Elevator History

An elevator or lift is a transport device used to move goods or people vertically. The first reference about the elevator is located in the works of the Roman architect Vitruvius, who reported that Archimedes built his first lift or elevator, probably, in 236 B.C. In some literary sources of later historical period lifts were mentioned as cabs, on the hemp rope and powered by hand or by animal's force. In 1853, Elisha Otis introduced the safety elevator, which prevented the fall of the cab if the cable broke. The design of the OTIS safety is somewhat similar to one type still used today. The safety elevator used a special mechanism to lock the elevator car in place should the hoisting ropes fail. Otis made skyscrapers possible by providing safe mechanical transport to upper floors.

◆ Otis and Other Manufacturers

On March 23, 1857 the first Otis elevator was installed at 488 Broadway in New York City. The first elevator shaft preceded the first elevator by four years. Construction for Peter Cooper's Cooper Union building in New York began in 1853. An elevator shaft was included in the design for Cooper Union, because Cooper was utterly confident a safe passenger elevator would soon be invented; the shaft however was circular because Cooper felt it was the most efficient design. Later Otis designed a special elevator for the school. Today the Otis Elevator Company, now a subsidiary of United Technologies Corporation, is the world's largest manufacturer of vertical transport systems, followed by Schindler, Thyssen-Krupp, Kone, and Fujitec. According to United Technologies, Otis elevators carry the equivalent of the world's population every nine days. The following is Elisha Otis's Elevator Patent Drawing, 01/15/1861.



◆ Types of Elevators

In general, there are three means of moving an elevator:

1. Traction elevators: Geared Traction machines are driven by AC or DC electric motors. Geared machines use worm gears to control mechanically movement of elevator cars by "rolling" steel hoist ropes over a drive sheave which is attached to a gearbox driven by a high speed motor. A brake is mounted between the motor and drive sheave (or gearbox) to hold the elevator stationary at a floor. The grooves in the drive sheave are specially designed to prevent the cables from slipping. "Traction" is provided to the ropes by the grip of the grooves in the sheave, thereby the name. As the ropes age and the traction grooves wear, some traction is lost and the ropes must be replaced and the sheave repaired or replaced.

2. Hydraulic elevators: Conventional Hydraulic elevators were first developed by Dover Elevator (now ThyssenKrupp Elevator). They are quite common for low and medium rise buildings (2-10 floors) and use a hydraulically powered plunger to push the elevator upwards. On some, the hydraulic piston (plunger) consists of telescoping concentric tubes, allowing a shallow tube to contain the mechanism below the lowest floor. On others, the piston requires a deeper hole below the bottom landing, usually with a PVC casing (also known as a caisson) for protection

3. Climbing elevator: A climbing elevator is a self-ascending elevator with its own propulsion. The propulsion can be done by an electric or a combustion engine. Climbing elevators are used in guyed masts or towers, in order to make easy access to parts of these constructions, such as flight safety lamps for maintenance.

◆ Did You Know?

-- The elevator in the new city hall in Hanover, Germany is a technical rarity, and unique in Europe, as the elevator starts straight up but then changes its angle by 15 degrees to follow the contour of the dome of the hall.

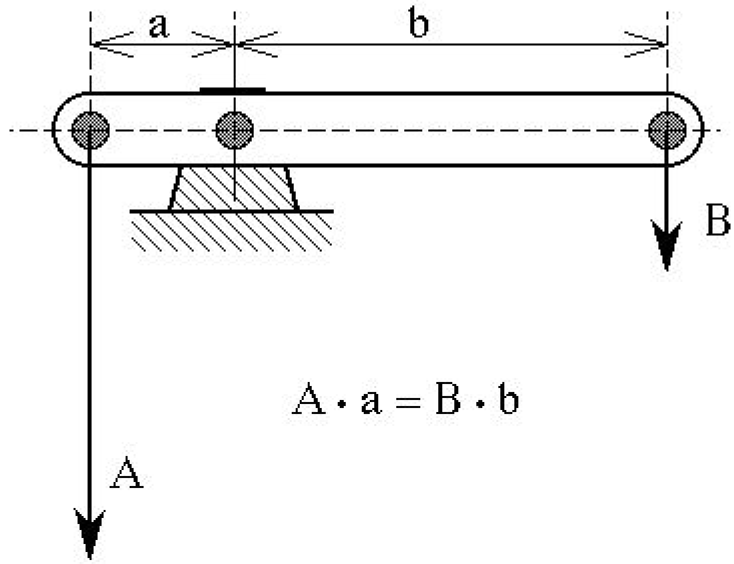
-- A small freight elevator is often called a dumbwaiter, often used for the moving of small items such as dishes in a 2-story kitchen or books in a multi-story rack assembly. Dumbwaiters, especially older ones, may also be hand operated using a roped pulley, and they are often found in Victorian-era houses, offices and other establishments when such devices were at their peak.

Student Resource: Mechanical Advantage

◆ **What is Mechanical Advantage**

In physics and engineering, mechanical advantage (MA) is the factor by which a mechanism multiplies the force put into it. Following are simple machines where the mechanical advantage is calculated.

The beam shown is in static equilibrium around the fulcrum. This is due to the moment created by vector force "A" counterclockwise (moment A*a) being in equilibrium with the moment created by vector force "B" clockwise (moment B*b). The relatively low vector force "B" is translated in a relatively high vector force "A". The force is thus increased in the ratio of the forces A : B, which is equal to the ratio of the distances to the fulcrum b : a. This ratio is called the mechanical advantage. This idealized situation does not take into account friction.



Wheel and axle: A wheel is essentially a lever with one arm the distance between the axle and the outer point of the wheel, and the other the radius of the axle. Typically this is a fairly large difference, leading to a proportionately large mechanical advantage. This allows even simple wheels with wooden axles running in wooden blocks to still turn freely, because their friction is overwhelmed by the rotational force of the wheel multiplied by the mechanical advantage.

Pulley: Pulleys change the direction of a tension force on a flexible material, e.g. a rope or cable. In addition, pulleys can be "added together" to create mechanical advantage, by having the flexible material looped over several pulleys in turn. More loops and pulleys increase the mechanical advantage.

Engineering Ups and Downs

Student Worksheet: Build Your Elevator

You are a team of engineers who have been given the challenge of building a small elevator system to deliver cars to a three story toy car garage. Your elevator must be able to securely stop at each floor and lift a toy car of a set weight.

◆ Research/Preparation Phase

1. Review the various Student Reference Sheets.

◆ Planning as a Team

1. Your team has been provided with some "building materials" by your teacher. You have glue, string, paperclips, paper, pencils, cardboard, cardboard tubes (such as from paper towel or toilet paper rolls), markers, pulleys or thread spools (3), thin rope, string or fishing line, cardboard box to serve as elevator room (shoe box, large milk carton), small toy cars and other resources.

2. Start by meeting with your team and devising a plan to build your elevator. Think about how you will incorporate the pulleys and affix materials to the elevator room which could be a small milk carton, pasta box, or other grocery container.

3. Write or draw your plan in the box below, including your projection for the materials you'll require to complete the construction. Present your design to the class, and explain your choice of materials. You may choose to revise your teams' plan after you receive feedback from class.

Materials Needed:

◆ Construction Phase

5. Build your elevator!
6. Evaluate your team's results compared to those of other teams, complete the evaluation worksheet, and present your findings to the class.

◆ Use this worksheet to evaluate your team's results in the Engineering Ups and Downs lesson:

1. Did you succeed in creating an elevator that could deliver cars to three stories of the toy car garage? If not, why did it fail?

2. Did you need to request additional or different materials while building your elevator? If so, what happened between the design (drawing) and the actual construction that changed your material needs?

3. Do you think that engineers have to adapt their original plans during the manufacturing process? Why might they?

4. If you had to do it all over again, how would your planned design change? Why?

5. What designs or methods did you see other teams try that you thought worked well?

6. Did you find that there were many designs in your classroom that met the project goal? What does this tell you about engineering plans?

7. Did you find there was an advantage to working in a team for this project? Explain…

8. Do you think that the expectations of riders have impacted the designs of elevators? For example, how has the design been adjusted to accommodate riders with disabilities?

9. What safety considerations do you think engineers must integrate into new elevator designs? For example, many elevators have telephones on board in case of emergencies. What else can you identify?

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 5-8 (ages 10 - 14)

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of
- Motions and forces
- Transfer of energy

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
- Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of
- History of science

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

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of
- Motions and forces
- Interactions of energy and matter

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop
- Abilities of technological design
- Understandings about science and technology

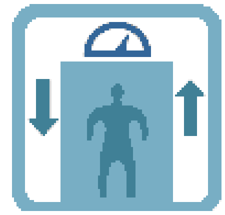
CONTENT STANDARD F: Science in Personal and Social Perspectives

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
- Historical perspectives

For Teachers: Alignment to Curriculum Frameworks (continued)



◆Next Generation Science Standards – Grades 3-5 (Ages 8-11)

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆Next Generation Science Standards – Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆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.

For Teachers:
Alignment to Curriculum Frameworks (continued)

◆Standards for Technological Literacy - All Ages

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 5: Students will develop an understanding of the effects of technology on the environment.
- 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.
- 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 11: Students will develop abilities to apply the design process.
- Standard 13: Students will develop abilities to assess the impact of products and systems.

The Designed World

- Standard 18: Students will develop an understanding of and be able to select and use transportation technologies.