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Simply Amazing

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Introduction

Work smarter not harder! This idiom articulates the benefit of the basic engineering principles behind the simple machines that make our lives easier. All around us, day in and day out, we use simple machines to help us work smarter and more efficiently. But first we must ask, "What is considered work?" It does seem that there are a variety of possible answers, depending on your personal perspective. From the scientist's perspective, work is defined as using force to move an object (when the force and object are moving in the same direction). The idea of working smarter is the foundation of this six–week curriculum unit designed for students in sixth grade as they use inquiry and experimentation to discover the work advantage gained through the use of simple machines. We will focus on the lever, wheel and axle, pulley, inclined plane, wedge, and screw.

I am a sixth-grade teacher in a self-contained classroom at Edgewood Magnet School in New Haven. The neighborhood/ magnet setting is a rewarding environment, with students coming to school each day from a variety of home circumstances and with differences in academic levels. As a result of these variables, the children have differing levels of background knowledge and life experiences. The classroom is a mixture of varied ethnicities, economic strata and social and emotional strengths and weaknesses. The use of scientific inquiry allows all students at all levels to learn in an inherently differentiated environment. This unit will provide that foundation and approach.

Objectives

The New Haven Public School Science Curriculum includes a focus on simple machines in sixth grade. This unit is designed to support that curriculum. Reading the book *Castle Under Siege!: Simple Machines* by Andrew Solway introduces the unit and the content to be explored and experienced. The text leads students through the construction of a castle, the workings of the drawbridge, the execution of a siege and how the inhabitants would protect the castle from attack, methods the invaders might use, and what would happen afterward to repair the damage. Students are introduced to the simple machines used during this period of time: the stonemason's wedge, the inclined plane of the castle road, the levers used in the drawbridge, the screw of the crossbow, the axles in the moving siege towers, the fulcrum in the catapult.

Students will develop thinking skills through hands on scientific inquiry, observations, data gathering, discussions, journal entries, note taking, research, and literature. These higher order-thinking skills will allow students to gain insight into how force, motion, and simple machines affect everyday life. Students will demonstrate an understanding of the importance of force, motion, and simple machines through drawing, writing, oral presentations, and creative projects.

Students will define "work" and how to make it easier, and demonstrate through experimentation how simple machines make our work easier. In addition, students will build and use their own simple machines using a variety of materials and operate their machines for and with their classmates. A trip to the Eli Whitney Museum will provide the students an opportunity to build a complex machine, a collection of simple machines in operation.

Rationale

The young students in elementary and secondary school as well are our future scientists and engineers, thinkers and designers, problem solvers and inventors. As teachers, it is critical that we provide opportunities for our 21st century students to explore and to become inspired to reach for these goals. Central to this mission is that we create an educational environment that allows students to build their interest, knowledge, and motivation in science, technology, engineering, and math. Fundamental knowledge and experience builds confidence and a desire to learn more. To encourage students in this direction, it seems clear that beginning an early course of understanding of engineering will help steer them more comfortably in that direction.

Background Information

What is engineering? A question certainly to ask if we are to inspire our students to become engineers! Simply defined, engineering is the practical application of science and math to solve problems. Prior to the Renaissance, "engineering" or design, was centered on religious beliefs, superstitions, or hunches, with out any true math and science applied to support decisions. The forerunners of engineers, practical artists and craftsmen, worked mainly by trial and error and with imagination produced many amazing structures and devices. The respect is embodied in the name "engineer" itself. It originated in the eleventh century from the Latin ingeniator, meaning one with ingenium, the ingenious one. The name, used for builders of ingenious fortifications or makers of ingenious devices, was closely related to the notion of ingenuity, which was captured in the old meaning of "engine" until the word was taken over by steam engines and its like. Leonardo da Vinci bore the official title of Ingegnere Generale. His notebooks reveal that some Renaissance engineers began to ask systematically what works and why. [1]

The Basics of Simple Machines

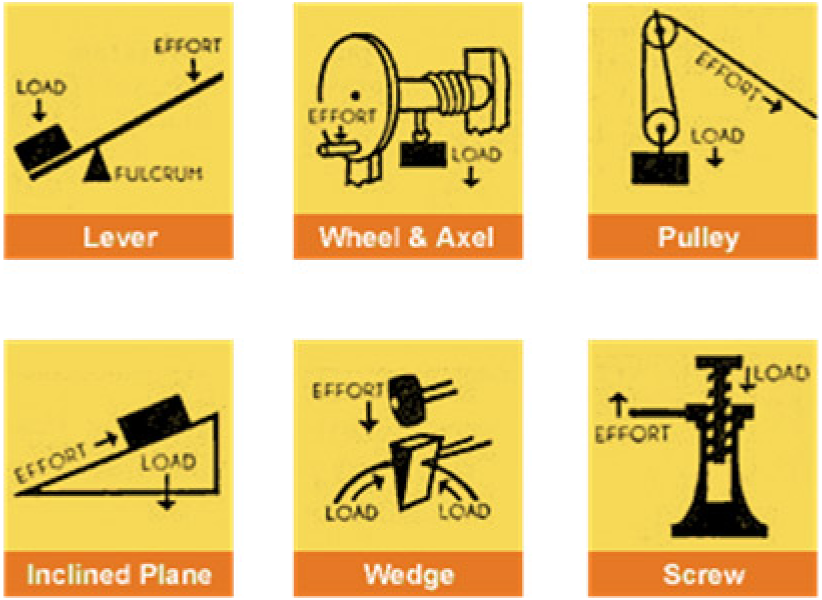
Simple machines are resourceful tools that make work easier and, more importantly, represent basic design elements. There are six simple machines, most of which have few, if any, working parts. They are the inclined plane, wedge, screw, lever, wheel and axle, and pulley. When used in combination, these simple machines become the components of more complex machines that simplify otherwise quite impossible tasks.

Machines are designed to help us with work. In scientific terms, the word work refers to the application of force (a push or a pull) on an object to move it across a distance or to rotate the object (which is case the force is really a torque). So we might say that machines are devices with moving parts that make that work easier. Although machines cannot reduce the total amount of work, they help us do work by changing the amount or direction of force applied.

The world we live in is constantly exerting different forces on itself and on the beings that inhabit it. Forces make objects move; forces make objects change their direction; forces make object rotate; and forces make objects stop. These forces appear to be more important when they are acting on us as individuals, or when we want to use these forces to change our environment to suit our needs. Over long periods of time humans have learned how these forces work, and to some degree we have learned how to control some of these forces. Throughout history, humans have shown that we have been able to use these forces to accomplish many things.

For example, humans have changed their environment in many ways, by building structures for shelter, by clearing land and obtaining and conserving water to grow food on a relatively dependable cycle. This has been accomplished by sawing and lifting large trees, driving nails through hard wood, removing large rocks and pulling out large stumps. All of the changes have come about as humans have learned to control these forces as "pushes or "pulls. When we accomplish a change, such as raising a heavy rock or chopping down a tree, we accomplish work. Work produces change — and change is the result of work. [2]

Humans could not have accomplished many of these changes by using only the energy our relatively small and weak bodies can exert. Humans, however, have used their brains to design devices that have helped in bringing about these changes. A machine is but one example of how human intelligence has helped in making our lives on earth easier. A machine is, in a very general sense, a combination of parts we use to overcome a resistance (which is also a force, like a large rock that needs to be removed) by transferring or transforming energy, usually that exerted by a human being. There are two major forces that machines help us overcome—friction and gravity. Consequently, if we want to move matter, or a mass, which is expressed as weight, we need to exert force on that matter to overcome inertia as well as friction and/or gravity. Usually, the forces we want to overcome we call the "resistance". The forces we use to overcome the resistance we call the "effort". When we do work, we use energy. Energy changes in form, but it does not disappear. In using simple machines for human work, energy transfers from one object to another, or it changes in form as sound, heat or light energy. Understanding how simple machines function is a big step in understanding how much of the world around us functions even in modern times, because the nature of matter and energy has not changed — only our understanding of it has. [3]



Examples of the six simple machines identifying load and effort. [4]

Inclined plane

An inclined plane is a plane surface set at an angle to another surface. This results in doing the same amount of work by applying the force over a longer distance. The most basic inclined plane is a ramp; it requires less force to move up a ramp to a higher elevation than to climb to that height vertically. The wedge is often considered a specific type of inclined plane.

More specifically, an inclined plane is any slope or ramp, like a wheelchair ramp or a slide, which makes it easier to lift something heavy, like a rock. Instead of lifting the rock straight up, you can push it a greater distance, but with less force. The amount of work remains the same. Work is force times distance, so if you increase the distance the rock moves, you can decrease the amount of force you need. If you make the ramp steeper, you'll have a shorter distance, but it will be harder to push the rock (you'll need more force). If you make the ramp less steep, it will have to be longer, but it will be easier to push the rock. Either way, it's the same amount of work in the end, but you have the choice of doing easier work for a longer time, or harder work for a shorter time.

We call it an "inclined plane" because it is a plane – a flat surface – and it is inclined – sloped, not level. All kinds of animals use inclined planes when they choose their path up a steep hill, and people have used them since there first were people, about 200,000 years ago. In Egypt, about 2500 BC, people were building their own earth ramps to move heavy stones for the Pyramids. The first staircases (a kind of inclined plane, because stairs make it easier to go up than if you had to jump) also go back to the Bronze Age.

Lever

A lever is a simple machine that consists of a rigid object (often a bar of some kind) and a fulcrum (or pivot). Applying a force to one end of the rigid object causes it to pivot about the fulcrum, causing a magnification of the force at another point along the rigid object. There are three classes of levers, depending on where the input force, output force, and fulcrum are in relation to each other. Baseball bats, seesaws, wheelbarrows, and crowbars are types of levers.

Class 1: Fulcrum in the middle: the effort is applied on one side of the fulcrum and the resistance on the other side, for example, a crowbar or a pair of scissors or a seesaw.

Class 2: Resistance in the middle: the effort is applied on one side of the resistance and the fulcrum is located on the other side, for example, a wheelbarrow or a nutcracker or a bottle opener.

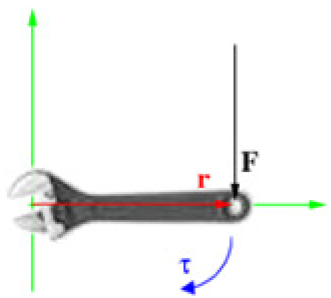
Class 3: Effort in the middle: the resistance is on one side of the effort and the fulcrum is located on the other side, for example, a pair of tweezers or the human mandible.

These cases are described by the mnemonic "fre 123" where the fulcrum is in the middle for the 1st class lever, the resistance is in the middle for the 2nd class lever, and the effort is in the middle for the 3rd class lever.

Wheel and Axle

A wheel is a circular device that is attached to a rigid bar in its center. A force applied to the wheel causes the axle to rotate, which can be used to magnify the force (by, for example, having a rope wind around the axle). Alternately, a force applied to provide rotation on the axle translates into rotation of the wheel. It can be viewed as a type of lever that rotates around a center fulcrum. This force is known as torque.

The most basic definition of torque in physics is a turning or twisting force. If a force is used to begin to spin an object, or to stop an object from spinning, a torque is made. The force applied to a lever, multiplied by the distance from the lever's fulcrum is described as torque. Fulcrum is the axis of rotation or point of support on which a lever turns in raising or moving something. Ferris wheels, tires, and rolling pins are examples of wheels & axles.



Wedge

A wedge is a double-inclined plane (both sides are inclined) that moves to exert a force along the lengths of the sides. The force is perpendicular to the inclined surfaces, so it pushes two objects (or portions of a single object) apart. Axes, knives, and chisels are all wedges. The common "door wedge" uses the force on the surfaces to provide friction, rather than separate things, but it's still fundamentally a wedge.

Screw

A screw is a shaft that has an inclined groove along its surface. By rotating the screw (applying a torque), the force is applied perpendicular to the groove, thus translating a rotational force into a linear one. It is frequently used to fasten objects together (as the hardware screw & bolt does), although Babylonians developed a "screw" that could elevate water from a low-lying body to a higher one (which later came to be known as Archimedes' screw).

Pulley

A pulley is a wheel with a groove along its edge, where a rope or cable can be placed. It uses the principle of applying force over a longer distance, and also the tension in the rope or cable, to reduce the magnitude of the necessary force. Complex systems of pulleys can be used to greatly reduce the force that must be applied initially to move an object.

Teaching Strategies

The approaches for this curriculum unit will vary to reflect the learning styles of all students. Included will be:

Experiential Learning: The major strategy for this unit is to engage the students in hands-on learning. I want them to be actively participating as scientists, not observing a demonstration by the teacher or looking at examples in books. The activities will be designed to be exploratory for the students so they are engaged in the enjoyment of the process as well as the product. A wide range and variety of building and art materials will be included in the exploration and design.

Differentiated Instruction: Lessons and activities will be targeted to maximize learning. The students will use a variety of approaches, working sometimes individually and sometimes in small groups, determined by the complexity of the activity. Because these are young children with variance in levels and background, guidance and pacing will need to be closely monitored. Understanding the benefits and functions of simple machines will to be based in concrete experiences the students will experience.

Cooperative Learning: The students will be given opportunities to work as cooperative groups to complete assignments and activities. This strategy will allow students to work collaboratively taking on various roles necessary to complete the work, with a focus on success for all. A culminating activity will include six groups designing and creating a simple machine each and demonstrating its function and advantage to the class.

Oral and written discourse is important. It focuses the attention of students on how they know what they know and how their knowledge connects to larger ideas. In these lessons, students are encouraged to express their ideas in complete sentences rather than single word or short phrases. This practice helps them to express underlying ideas completely and to reinforce their understanding of the concepts.

Small group collaboration is part of scientific inquiry. Throughout the lessons pairs or small groups of students should work together to brainstorm ideas/questions, share data, and engage with their classmates in explaining, clarifying, and justifying what they have learned.

Classroom Activities

Session 1

Background Knowledge: Force is a push or pull. Every machine needs a force to make it work. Simple machines use less force to produce the same amount of work.

Read (literature/real life connection – Dr. DeSoto by William Steig). Students will conduct a class discussion on how work as a dentist was made easier by simple machines.

Comprehension: Students will complete a "Think, Pair, Share" activity about simple machines.

1. Teacher suggests a topic of discussion. (Simple machines)
2. Students "think" and write down what they know or have learned about the topic.
3. After the students have written, they "pair" up with another student to share their ideas.
4. Conclude with a whole class "share" discussion.

Cooperative Activity: Group students into partners for the unit. Give each group a set of index cards and an index file card box. Instruct students to move around the room and investigate. How many simple machines can they find in the classroom? For each simple machine they find, they should identify the object and which simple machine is being used, draw a picture of it, label the picture, and write a description of how it makes our work easier. Students will store their cards in their file box under the categories for the six simple machines. Students can label the dividers appropriately.

Application: Students will illustrate a simple machine that has made their life easier. Class/team product: Design a popscicle stick/straw/pencil sculpture of a simple machine to make an object move more quickly.

Real world connection: Many musical instruments use keys, including almost all the woodwinds and many of the brasses. As with piano keys, the keys on these instruments are levers. Choose an instrument and find out how the keys work the levers. What do the levers do?

Session 2

Cooperative Activity: Students will need clipboards, data collection sheets, and digital cameras to go on a simple machines scavenger hunt in this activity. Discuss what kinds of simple machines they found in the classroom in the previous activity. Have students work with another group to share what they found, and verify their findings. Take them to a variety of places in your school. At each location, they should find at least one example of each type of simple machine. If you have digital cameras available for student use, students should use them to collect examples, as these photos will come in handy later in the unit. Some good locations (with permission, of course) would be the library, cafeteria, office, gym, art room and playground. Back in the classroom, when pictures are printed, the students can convert their findings into individual index cards to be filed in their file card boxes. Return to this activity at the end of the unit and see if students can identify more simple machines after they have studied them.

Session 3

Higher order thinking skills: Students will discuss all six simple machines.

Class/Team individual product: Create a collage of simple machines from pictures in a magazine, newspaper, computer downloads, personal pictures and generate a list to go with that collage. How are used, helpful, beneficial? What exactly are they doing or designed to do?

Cooperative Activity: Lever Activity

Materials: 24" boards, Spring scales, Rubber bands, Prisms, Textbooks, Buckets, Standard weights

In this activity students will use standard measurement to measure the effort force needed to move a given object using a lever. Hand out materials to students. Instruct them to set up a first class lever using the board, with the prism as the fulcrum. Have them place their science textbook on the load arm, and attach a rubber band to the effort force arm, which should be hanging off the edge of the table. Instruct them to hook the spring scale to the rubber band, hanging off the edge of the table. Attach a bucket to the spring scale and use standard weights to change the effort force in order to move the textbook.

Students should measure the effort force needed to move the book and record it in a table. Students should follow the same procedure to measure the effort with the fulcrum in at least four different positions. Students can use the Lever graph worksheet to record their findings.

Home / School Connection: Discuss simple machines with parents, and find out what simple machines make their lives easier.

Session 4

Knowledge: The students will understand that the more massive an object is, the less effect a given force has. Read (literature connection) Aisha: Industrial Engineering and Making Work Easier by the Engineering is Elementary Team. Students will list some machines that can be used to move masses.

Comprehension: In-groups of two demonstrate understanding by using the Machine Cube Match Game:

Student 1. Create a cube. Draw six machines on the sides of the cube.

Student 2. Create a cube. Draw six objects to be moved on the sides of the cube.

Roll the dice and decide together if the machine is the proper tool to do the job and chart how and why.

Application: News Clip on natural disaster (hurricane, tornado) footage. Students will discuss how machines helped in the cleanup after a disaster. Class/team product: Build a "Multi-medium Mural" to be displayed as a museum exhibit. Materials from newspaper clippings to magazines to clay etc. will be used.

Research famous paintings on the subject of natural disasters. Compare how, through time, the use of machines has helped humans recover from damage/destruction.

Class/team/individual product: Construct a flipbook demonstrating a machine moving objects from place to place. What simple machines are operating?

Cooperative Activity: Wheel and Axle Activity

Materials: Thick cardboard, straight pins or small paperclips, straws, bendable wire, thick paper, pie tins, pencils, scissors, board for a ramp, measuring tool (uninstalled doorknob)

The wheel and axle is a lever that moves in a circle. A wheel and axle is made from a wheel that turns on a center post. Show display of wheels and axles and discuss that the larger the wheel, the more mechanical advantage you gain. Compare roller skate wheels, with bicycle wheels, with automobile wheels. Demonstrate the mechanical advantage by having students try to turn a doorknob without the knob. Is it hard to turn? Try it with the knob attached. Is it easier? Have students create a variety of wheels and axles using cardboard for wheels and a straw and wire for the axle. Record the wheel diameter and the distance each set travels down a ramp. Make sure students are measuring from the bottom of the ramp to the wheel and axle stopping point straight out, not at an angle. Record information in a table, organize from smallest to largest wheel size and then graph data into a line graph

Home/School Connection: Ask family member what machine they remember their parents and grandparents using often.

Activity Bank

These activities can be incorporated as time allows or used as a form of assessment for understanding.

Lever Activity

Students will complete an activity trying to lift a brick upright using only a skewer and pebbles. Pass out materials to each group. Tell students that the brick is an obelisk, a stone pillar that stands upright which usually narrows to a pyramid shape at the top.

"A great ruler would like it put up outside of his palace. You may not touch the brick with your hands. You will use the bamboo skewers for your lever, and the pebbles for support stones." Give students an opportunity to explore ways that they might lift the brick. Tell groups to record what class of lever they are using, what difficulties they had trying to erect the obelisk, and how they overcame them. At the end of the allotted time, have students measure how far the top of their brick is from the desk.

Brown Bag Identification

Place a variety of objects that incorporate a simple machine into their makeup in brown paper bags. Place these bags at stations around the room. Have groups move through the room to identify the object, its use, and the simple machine involved in its use. Give groups approximately 60 seconds at each station. (Some good items would be a manual can-opener, a corkscrew with arms, a clamp, scissors, picture of a bike, doorknob, mini blinds, tweezers, screw, a corkscrew without arms…)

The Simple Machines Important Book

Read "The Important Book" to students. This is a picture book about what is important in the story character's life. There is a pattern to how each item is written about. In The Simple Machines Important Book, students will write about simple machines in general, and then individually about each. Students design the book as they would like.

Unload a truck

Students are told that there is a big order coming in to the school, and they have been asked to help unload it because the principal has heard they know all about simple machines, and that they can make the work easier. Students will brainstorm and then write a plan for unloading the order from the truck, bringing the order into the school, and delivering the items to their correct location.

Learn about an inventor

Read "Real McCoy: The life of an African-American Inventor" by Wendy Towle to class. Discuss what it means to say "It's the real McCoy!" Give each group a large piece of sandpaper, a matchbox car, and some oil. Have students push the matchbox car across the sandpaper. Instruct them to pour the oil into the center of the sandpaper. Now have them try to push the matchbox car across the sandpaper. Discuss the importance of lubrication and how it reduces friction in machines. Why was it important to have the real McCoy? How did McCoy come up with his invention? Discuss that engineer's jobs are to create things to solve problems they are faced with.

Inventor report

Students will research an inventor and his/her invention(s). Students will utilize the library, and the internet. Students will use the attached Inventor Report form and the Inventor rubric to plan and write report. Students will be required to present their information about both the inventor and the invention. Students will be required to provide some kind of visual.

Toy Expo

Students will work in groups to plan, design and create a simple machine toy. They must market their toy by creating posters, a price, a description of what the toy does, the simple machine included, the name of their company, and an exciting 'catch-phrase'. Persuasive writing will incorporate Language Arts, and economics will incorporate Social Studies and Math into the project. The class will set up a toy expo where other classes and parents can visit. They will be given toy expo dollars to spend at the expo to 'order' the toys they like best. Students will be set up at booths trying to market their toys and take in the most money for 'orders' of their product.

Resources

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Solway, Andrew. *Castle under siege!: Simple Machines.* Chicago, IL: Raintree, 2005.

Websites

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http://www.egfi-k12.org/

http://www.generalpatton.org/

http://nsta.org/

http://www.teachengineering.org/

http://tryengineering.org/

Appendix

An exploration of simple machines introduces and addresses content standards of the National Science Education Standards in many areas: (a) Unifying Concepts and Processes, (b) Science as Inquiry, (c) Physical Science, (e)Science and Technology, and (f) History and Nature of Science. Specific content standards include:

Physical Science: Content Standard B:

Motions and forces:

- The motion of an object can be described by its position, direction of motion, and speed.
- That motion can be measured and represented on a graph
- An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.
- If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude.
- Unbalanced forces will cause changes in the speed or direction of an object's motion.

Transfer of Energy:

· Energy is a property of many substances and is associated with mechanical motion
· Energy is transferred in many ways.

Science and Technology: Content Standard E

Abilities of technological design

Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

Science and technology in society

Endnotes

1. www.britannica.com
2. http://www.creatingtechnology.org
3. John B. Beaver and Barbara R. Sandall, 10.
4. http://www.generalpatton.org