Sparking Discovery in the Classroom

TRAVELING
SCIENCE
WORKSHOPS

DISCOVERY MUSEUM

Simple Machines

Teacher Resource Guide

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Acknowledgements
The Discovery Museum's Simple Machines curriculum is the result of a Teachers' Curriculum Collaborative, organized by the Discovery Museum and funded by the Ramsey McClusky Family Foundation and Dewing Foundation. Eight teachers, including two science curriculum directors, engaged in workshops, group brainstorming sessions, and exchanges about classroom practices to tease out the best of simple machines classroom study. This draft curriculum featuring "The Lever," incorporates the collaborative research, testing, and evaluation of those activities and methods. The goal was to create a curriculum that supports open-ended, discovery learning methods any classroom teacher can easily manage. For those who would like additional support or would like to see the curriculum in action, The Discovery Museum offers this program as a 60-minute Traveling Science Levers Workshop.

Introduction
The Discovery Museum, located in Acton, Massachusetts, are two separate, is a hands-on museum filled with interactive exhibits that invite exploration and discovery of science, nature and play. Guided by the proven approach that "learning by doing" makes the greatest impact on children, the Discovery Museum designs all exhibits and programs to be interactive, open ended, multi-sensory, developmentally appropriate, and conceptually accurate. We develop children's imaginations and skills by showing them that learning about our world is *fun*. Science, art, and technology all come together in play, inspiring children to think critically about underlying scientific principles in everyday experiences.

In 1990, the Discovery Museum began to take its expertise in the physical sciences and reputation for high-quality programs into the classroom. The Traveling Science Workshops help meet each school's specific needs and the Massachusetts State Curriculum Framework. Studies underscore the importance of the museum's methods, indicating that, by the end of middle school, many children have already begun to turn away from the sciences. As the scientific principles taught in schools become more complex and abstract, students often fail to see any relevance to their daily lives. The Discovery Museum has a proven track record for developing experiential learning programs that demonstrate clearly how scientific principles explain everyday occurrences. Our instructors know that children are naturally curious and also that children's retention of learning is best when their natural curiosity acts as a spring board, leading them down a pathway of their own choosing. By addressing science questions through self-directed, interactive activities, TSW instructors help students develop an understanding of basic scientific principles.

Using this Guide
One of the hallmarks of the Discovery Museum's Traveling Science Workshops is the simplicity of the program and the materials. The focus is on presenting one, maybe two, key concepts that give a solid base to grow understanding. The emphasis is on providing concrete experiences that prompt student questions, not on supplying a lot of facts that will soon be forgotten. The Teachers' Curriculum Collaborative has created a curriculum that supports the objectives of the museum and marries them with the practical needs of the classroom teacher.

Using a combination of whole-class and small-group challenges and open-ended investigations, this guide provides introductory experiences that build curiosity and establish a base of understanding that leads to a richer, more in-depth, and broad-based study of the topic. The TCC chose to focus, in this first draft, exclusively on the lever, providing multiple investigations wherein children are empowered to define what a lever is, how and where it is used, and how mechanical advantage can be gained. Once students understand mechanical advantage as it applies to levers, they can easily transfer this knowledge to the study of other simple machines. The design of the program builds in opportunities for children to expand their awareness of the prolific use of levers in their everyday life, indirectly giving a purpose to the study. The fun approach taken in the curriculum builds enthusiasm and leads to self-motivated learners. In short, students will be primed for the next level of study into other simple machines.

The guide includes five featured activities and many additional ideas for further study. Each activity could stand alone or be pulled out to compliment some piece of an existing curriculum, however the intention was that these activities be presented as a whole, in the order given. Each activity has a title, a suggested minimum time requirement, an overview, purpose, background, material requirements, plans for running and processing the experience, and ideas for going further.

The Lever
4th – 5th Grade

Overview
Through a series of challenges, including both guided and open-ended activities, children work together in teams to learn about the lever, what it is, and how it is used. Through their experiences with the lever, children begin to develop an appreciation for and understanding of mechanical advantage. These introductory experiences with the lever can lay the groundwork for further study of all simple machines.

Background
Levers are used frequently in everyday life, from the handle used to open a door, to the light switch that turns on the light, to the screwdriver used to pry the lid off a paint can, to the golf club that swings through the air and strikes a ball. A lever, in its most crude form, is a board or rod that pivots around a point called a fulcrum and is used to move or lift something. There are four parts to any lever system. The load is the object that needs to be moved, the effort is the force being applied to the lever, the lever (or lever arm) is the tool itself, and the fulcrum is the point at which the lever turns or pivots.

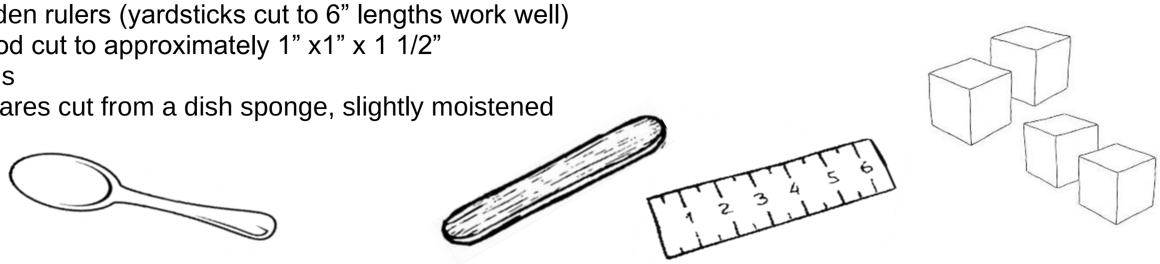
Levers are one of five simple machines that offer mechanical advantage. This means that they make accomplishing work easier by trading off the amount of effort required with the distance over which that effort must be applied. Mathematically speaking, work = force x distance. When working with simple machines, remember that the work will always stay the same, but the amount of force or distance required to complete the work may change according to the equation. If force is increased, distance to accomplish the work will decrease. If force decreases, the distance required to accomplish the same work will increase.

Activity 1: Bull's-Eye Challenge
(10 minutes)

Overview
Students engage in a challenge exercise that draws upon their skills as scientists and allows them to utilize the process of scientific method in a very natural, instinctual way. Using prior knowledge, observations, questioning, trial and error, and communication, students find a variety of possible solutions. Many of the solutions they discover can be described as levers. In this way, the students discover practical advantages and uses of the lever before ever being told its name, the many ways it can be used, or the scientific definition.

Procedure
Children (in groups of five) gather around a central bull's eye. Each group is given slightly damp, pre-cut, 1"x1" squares of a dish sponge and a variety of everyday materials such as tongue depressors and plastic spoons. The students are given the five-minute challenge of coming up with as many ways as possible to use the materials to move the sponge across the floor/table or through the air to reach the bull's eye. Students may use the materials in whatever way they like, but they may not kick or throw the sponges. Additionally they are cautioned that only the sponges may be sent through the air or across the table. Students most often arrive at solutions that incorporate a lever, such as a catapult, hockey stick, or pair of chopsticks. Students sometimes devise non-levers such as slides or bridges.

Materials (for each group of five students)
1 bull's-eye target, measuring at least 6" in diameter (color varying shades of concentric circles on a sheet of paper)
1 small container or basket containing:
- 4 tongue depressors
- 3 six-inch wooden rulers (yardsticks cut to 6" lengths work well)
- 5 pieces of wood cut to approximately 1" x1" x 1 1/2"
- 3 plastic spoons
- 5 one-inch squares cut from a dish sponge, slightly moistened



Purpose

1. To create an environment that allows students to apply prior knowledge, encouraging skills of observation, reasoning, and risk taking.
2. To provide an opportunity for the use of a simple machine to emerge naturally from the materials provided and the work required.

Procedure

Place the bull's eyes on tables or floor around the room. Allow enough space around each bull's eye to accommodate up to five students sitting in a circle about three feet from the bull's eye. Have the baskets of materials ready to distribute to each group.

Explain to the students that you have a challenge for them. Divide the students up into groups of five and ask them to arrange themselves around the bull's eyes. Tell the students that each group will receive a basket of materials and each student a miniature sponge. Their challenge is, in five minutes, to design as many ways as possible to move a sponge across the floor/table surface or through the air to the bull's-eye target using the materials in the basket. Make it clear to the class that only the sponges may be sent through the air and that they are not allowed to throw or kick the sponges.

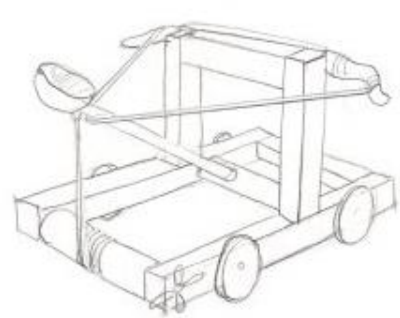
After five minutes, ask the students to collect the materials and place them back in the baskets and set the baskets on the bull's eye.

Processing the Experience

Arrange the students for a discussion about how different individuals or groups solved the problem. Keep the baskets of materials nearby so that individuals or groups can demonstrate how they used the materials. Call on students to share their "designs" while the class listens and observes. Ask each speaker to hold up the material(s) he/she used and to demonstrate their design in action. Encourage discussion about the different and similar ways each person/group found solutions. Also, help them to reflect back on what steps they took to solve the problem. For example, they looked at the materials they were given (observed), they had ideas about what they thought might work (using prior knowledge, asking questions, and reasoning skills), they tested out their ideas (testing), they observed what happened and may have modified the first idea as they learned more about it from direct experience. They shared with each other by observing what someone else did or talking with each other about ideas they had. This is a great opportunity to point out to students that they were behaving as scientists, using elements of a process called the scientific method. It is also a terrific time to suggest that many people naturally used one of the 5 simple machines to solve this problem – the Lever.

Going Further

Catapults emerge naturally in this activity and students are usually very enthusiastic about them. This is a prime opportunity for a student-directed inquiry. Discuss with students what they already know, think they know, or would like to know about catapults. Ask them to consider how they might go about learning more. Perhaps someone would be interested in finding images of catapults on the internet or at the library to share with the class. Perhaps others would like to try constructing a freestanding catapult from their own imagination or prior knowledge. Whether they review images or not, encourage the students to mess around with the materials you have already given them to see if they have some idea how they might construct a simple catapult that they could experiment with. What other easily accessible materials might they use? Where the class takes it from here will be determined by your students' interest, the time allotted for this exploration, and your own gentle guidance and encouragement. The study of catapults can lead your class to explore engineering, history, art, literature, biology…the world.



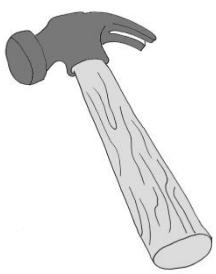
Activity 2: What is a Lever?
(10 minutes)

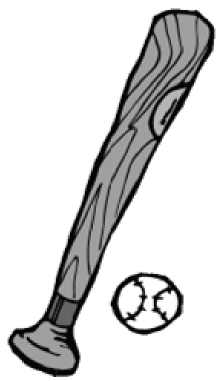
Overview
This activity involves a discussion and review of levers, what they are, where we find them, and how they are used.

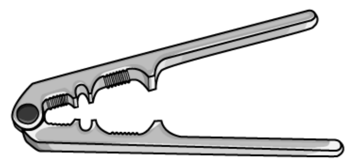
What the students do
Students review what the levers in the previous activity looked like and how they were used. From this experience, they begin to consider which of the things around them might be considered levers and why. From this discussion, they will develop and challenge a definition of the word lever.

Purpose
In the previous activity, students completed a challenge where they used several different types of levers to move an object (a piece of sponge) across a table/floor or through the air. At the end of this experience the teacher shared with the students that many of the solutions the students came up with involved using a lever. The students may or may not be familiar with this word, its definition, or how a lever is used. This activity asks students to consider what a lever is and to begin to identify some of the many levers that they use everyday, in order to arrive at a definition of the word.

Materials
pictures and photographs of everyday levers (such as a car door handle, a construction crane, a wheelbarrow, a baseball player swinging a bat)
dimensional objects that are levers (such as fingernail clippers, broom, fishing pole, hammer, nutcracker, pliers, bottle opener)







Procedure
Ask students to describe what the levers from the target activity look like and how they work. Can they think of other levers they use everyday that work in similar ways? Share 2-D and 3-D examples of some common everyday levers and act out the motion behind each one – removing the lid from a paint can, prying a driven nail from a board using a hammer, swinging a baseball bat, lifting a heavy load using a hand-truck. With each example, ask the students, “How can I open, remove, move this…” and encourage them to name the solution “using a lever.” As they share ideas, talk about how the object they have named works and whether or not everyone agrees it is a lever. What do all the levers mentioned have in common? Use this discussion to formulate a definition for a lever. For example, “A lever is a board or rod that pivots around a single point, called a fulcrum, and is used to move something.”

Going Further I
Students might go on a treasure hunt of their classroom, school, or home to find any and all levers. They can make a list of what they identify or if it is available they might take a digital camera around to photograph examples. Either way, the list or photos can be shared between students in small groups and discussed as to whether or not the object is a lever.

Going Further II
Set up a table of levers and lever-like objects and ask students to discuss which of these objects are levers and which are not. You might even encourage students to add their own objects to this table and/or to hold a debate about a particular object’s authenticity as a lever.

Activity 3: Lift the Teacher
(5 to 10 minutes)

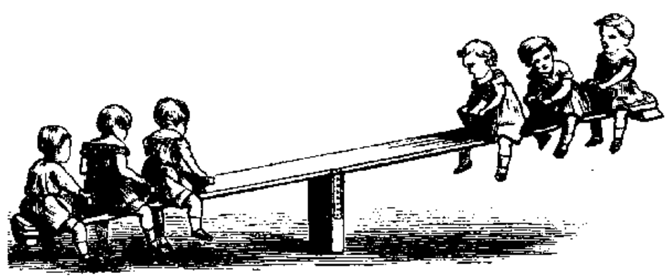
Overview
Students continue to firm up their ideas of what a lever is by working together to build and use a lever. They also begin to appreciate why a lever might be used and for which types of jobs it might be appropriate.

What the students do
The students are given a wooden board and a fulcrum and asked to figure out how to use it to lift a heavy load, the teacher, approximately 6 inches into the air using the smallest effort, in this case one of the smallest kids in the class.

Purpose
To understand what a lever is, how to make one, and how and why it is used.

Materials
6” x 8’ board
something solid to serve as a fulcrum such a block of wood or cement
if floor is uncarpeted, a rug to lay the set-up on to provide a source of friction and avoid materials slipping
1-2 adults to help spot the student and teacher

Procedure
Gather the students around the wooden board and fulcrum. First, ask them to consider whether the board is a lever. Let them discuss this with their classmates. If no one comes up with an affirmative response, ask them to consider what their definition for a lever is. Help them to see the different ways the board might be used as a lever. Swinging through the air it could hit and move something. Set on the block of wood, it resembles a seesaw and can be used to raise and lower someone or something. Challenge the class to use the set-up before them to raise the heaviest load in the class, the teacher, using the least amount of effort in the room, the weight of the smallest child. Students will have all kinds of ideas about how to do this, but eventually they will discover that if they move the fulcrum close to the heaviest load, the smallest effort can succeed in lifting the load. They will observe that moving the fulcrum away from the load makes lifting more difficult. Commandeer the help of at least one other adult to help spot the child. Introduce the vocabulary: fulcrum, load, and effort as you guide this activity and help students to identify and label the lever system.



Activity 4: Building a Lever
(15 minutes)

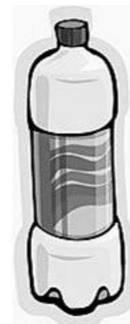
Overview
There are a few rules that apply to how levers work. When given a chance to experiment with levers, students can begin to directly experience and articulate these rules.

Background
There are three classes of levers: first, second, and third class. The different classes of levers are determined by the placement of the fulcrum, the load, and the effort to one another. A first-class lever has the fulcrum positioned between the load and the effort. The closer the load is to the fulcrum and the longer the distance between the fulcrum and effort (the longer the lever arm), the less effort is required to lift the load. An example of a first-class lever is a seesaw. A second-class lever has the fulcrum positioned at one end, the effort at the opposite end, and the load in the middle. An example of a second-class lever is a wheelbarrow. A third-class lever has the fulcrum at one end, the load at the opposite end, and the effort in the middle. A fishing rod is an example of a third-class lever.

What the students do
Students work in groups of three to build a lever that can lift a two-liter bottle of water (the load), using a half-liter of water (the effort). Students must experiment with the placement of the fulcrum, the load, and the effort in order to solve the challenge. When they succeed, they draw a picture of the set-up and label the different parts as the lever arm, fulcrum, load, and effort.

Next, the students "feel" the effort required to lift the two-liter bottle when the fulcrum is set at different distances from the load. The effort this time is applied by the student's pinky finger, making the mechanical advantage quite obvious.

Purpose
1. Give more direct experience with setting up and using a lever to raise a heavy load.
2. Establish, from direct experience with the materials, the rule of a first-class lever.

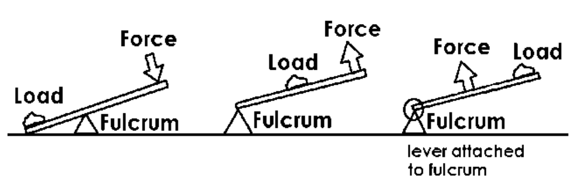


Materials (for each group of 3 students)
3" x 4' piece of wood
plastic coffee mug with handle, turned on its side
two-liter bottle of water
half-liter bottle of water
large sheets of white paper
colored markers

Procedure
Place the students into groups of three. Give each group a board (lever arm), a coffee mug laid on its side (fulcrum), a two-liter bottle of water (the load) and a half-liter bottle of water (the effort). Demonstrate for the students how they can lay the board over the mug (the fulcrum) to create a lever. Ask the students to set up the lever to raise the two-liter bottle of water using just the weight of the half-liter bottle as the effort. (The process is similar to what they did when they lifted the teacher.)

Students should accomplish this task within two to five minutes. Ask them to draw the lever as they arranged it, labeling the fulcrum, load, and effort. Post all of the drawings at the front of the room and ask the students to identify what is the same among all of the pictures. Ask them to establish a rule about how to use a lever to lift a heavier load with a lighter weight as the effort. The rule will state something to the effect that if the load is placed close to the fulcrum and the effort is placed further from the fulcrum on the opposite side, it is possible to lift a heavier load with a lighter effort.
Now, ask the students to experiment, using their pinky finger to lift the load instead of using the half-liter bottle. Have them begin with the fulcrum in the center of the board and the load on one end. Using just their pinky finger, ask the students to push down on the opposite end of the board in an effort to lift the load. Ask them to slide the fulcrum towards the load in small increments and compare how much effort is needed to lift the load with each movement of the fulcrum closer to the load. After everyone has experienced this, ask the class if their findings support the rule just established.

Lead a brief discussion about how this rule applies to this particular arrangement of the lever, with the fulcrum in the middle and the load and effort on opposite ends. This type of lever is called a first-class lever. There are other types of levers and they provide the same mechanical advantage that the students felt, but the arrangement of the fulcrum, load, and effort are different. Ask the students if they can think of a lever that has the fulcrum at one end, the load in the middle, and the effort on the end opposite the fulcrum (a wheelbarrow). You might share with the students that this is called a second-class lever. Then ask them if they can visualize a tool that has the load at one end, the effort in the middle, and the fulcrum at the end (a fishing rod). This would be a third-class lever.



1st Class Lever 2nd Class Lever 3rd Class Lever

Going Further I
Give students a mini first-class lever set-up which includes a strip of peg board about 20” x 2” and a piece of wood that is 1” to 2” wide with sand paper attached to the upper surface to serve as the fulcrum. Give the students two medicine cups. Have the students place a single hex nut into one medicine cup. This will be the load. Place this load on one side of the lever. Ask the students to guess how many paper clips they would need to add to the other cup (the effort) to balance the lever. Encourage them to test their guesses. The students can add more or less until they find the balancing point, but they need to keep track of how many paper clips they use. Once the apparatus balances, ask the students to move the fulcrum a distance of one hole toward the cup with the hex nut (the load) and see how many paper clips are now required to balance the load. Students can continue to test this while moving the fulcrum closer and closer to the load, and tracking how many paper clips are needed. The difference in the number of paper clips required is significant and illustrates the mechanical advantage of a longer lever arm.

Going Further II
Students might like comparing 2-D or 3-D examples of levers and identifying where the fulcrum, load, and effort are on the levers. They might challenge each other to identify and prove whether each example is a first-, second-, or third-class lever.

Activity 5: Toy Banks Exploration
(15 minutes)

Overview
With the rules established, students use their recent experiences and honed science skills of observation, questioning, and reasoning to explore a few mechanical toy banks. The mechanical banks all use levers, which are visible on the outside of the banks, but there are other mechanical parts hidden on the inside of the banks that help to work these levers. The toy banks are welded shut and can’t be opened, so these inner workings can’t be seen. They are “black boxes,” and give a great perspective of what working scientists face everyday, the inability to see directly what is going on with some phenomena. Just as scientists do, the students will have to find ways to understand and prove to themselves what is happening inside these banks and how it relates to what is visible on the outside.

Background
These mechanical banks are welded shut and can’t easily be opened. They will remain black boxes to the students and teachers, an important and valuable lesson for students to experience. Science helps to build understanding about the world, but it doesn’t often provide clear-cut answers. More often it leads to new questions, ideas, and theories. The students will observe directly how some parts of these banks work including the lever mechanisms. The inside parts will have to be imagined. Questions will be raised, and wonderful, healthy debates among students may arise. Some members of the class may even be primed to take on the challenge of trying to build such a bank to test out their ideas.

What the students do
Students experiment in groups of five with two to three different mechanical banks. They observe what they can see, and consider what they can not see, in order to come up with some ideas about how these banks might work. Ask students to sketch their ideas and to share these with one or two other classmates.

Purpose
1. Encourage students to draw on their recent experiences and apply some of the ideas and concepts of levers introduced in the previous lessons.
2. Further strengthen their exposure to and experience with everyday examples of levers.
3. Give students opportunity and encouragement to think mechanically.
4. Use toys as a means to build an interest in finding out what’s inside mechanical devices.

Materials
8 to 10 steel mechanical banks
graph paper
pencils

Procedure

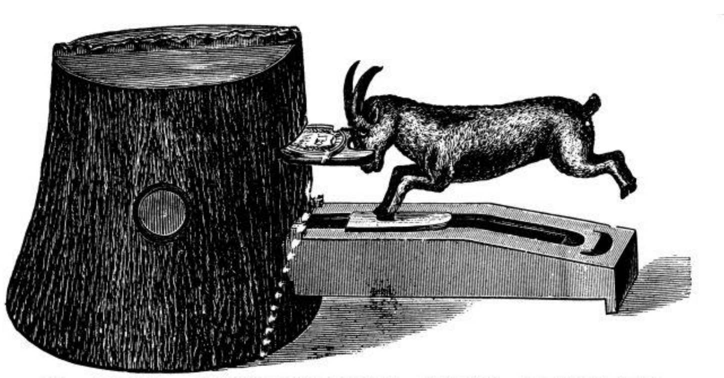
1. Arrange the students into groups of five.
2. Distribute one bank to each group and ask them to take turns playing with it.
3. Encourage students to talk aloud as they take turns with the banks.
4. Move from group to group, asking questions, such as: “What do you notice? What surprises you? What do you wonder about?”
5. After a few minutes rotate the banks and continue to encourage discussion about what they are doing, testing, questioning, etc.
6. If time allows, rotate the banks one more time.
7. If it hasn’t been mentioned, draw students’ attention to the use of levers.
8. What can they see happening?
9. What do they think might be happening on the inside?
10. After all the students have experimented with two or three banks, ask the children to move the banks back to the center of the table and to resist playing with them during this next phase of the activity.
11. Inform the students that these banks will not be opened, but that you think they are capable of imagining some ideas about what might be found inside.
12. Talk about the idea of a “black box” in science.
13. Pass out paper and pencils to each child and ask them to quickly sketch their ideas about what is inside this bank and how it connects with what they can see on the outside.
14. Ask the children to share their ideas and drawings with one or two other students.
15. How do their ideas compare?
16. Are they able to learn anything new from one another’s ideas?
17. Ask the students to consider how they might test out their ideas about what is inside the banks.

Going Further I

Design a mechanical bank. Using a shoebox or other form, ask children to design and possibly build a system to move coins from one part of the box to another. Students must use everyday materials to design their banks and must incorporate at least one lever. This activity allows for student-driven inquiry and can act as an informative assessment piece.

Going Further 2

Toy Exploration. Many mechanical toys use simple machines to function. Encourage students, with their parent’s consent, to take apart old toys, sketch what they see, consider how they think it all works together, identify the simple machines, and share what they learn. Toddler toys often provide some of the best examples. You can also encourage them to take it another step and see if they can put the toys back together or build something else from the parts.



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Resources:

Print Resources

- *Simple Machines: Forces in Action*, Buffy Silverman, Heinemann, 2016
- *Sensational Science Projects with Simple Machines*, Robert Gardner, Enslow Elementary, 2006
- *Explore Simple Machines! With 25 Great Projects*, Anita Yasuda, Nomad Press, 2011
- *The Kids' Book of Simple Machines,* Kelly Doudna, Mighty Media Kids, 2015
- *Smash! Wile E. Coyote Experiments with Simple Machines*, Mark Andrew Weakland, Capstone Press, 2014
- *Simple Machines: Wheels, Levers, and Pulleys*, David A. Adler, Holiday House, 2016
- *The LEGO Technic Idea Book: Simple Machines*, Yoshihito Isogawa, No Starch Press, 2010
- *Simple Machines*, Dana Meachen Rau, Scholastic, 2011
- *Simple Machines*, Steve Way and Gerry Bailey, Gareth Stevens, 2008
- *How Do You Lift a Lion?* Robert E. Wells, Albert Whitman & Company, 1996
- *Lever, Screw, and Inclined Plane,* Gare Thompson, National Geographic Kids, 2006

Online Resources

- Simple Machines interactive information via DK FindOut!
  - https://www.dkfindout.com/uk/science/simple-machines/
- Science Trek: Simple Machines video via PBS
  - https://www.pbs.org/video/science-trek-simple-machines/