What would your students say if you told them they could lift you off the ground using a block and a board? Using a simple machine, they’ll find out they can, and they’ll learn about work, energy, and motion in the process! By the end of this fourth-grade lesson, students will be able to describe the way a lever should be built in order to lift a heavy object. They will be able to use a force meter in order to measure the strength of an applied force and compare the measurement to their perceived effort. Students will also be able to compare the amount of force needed to lift the same load when the position of the fulcrum is changed. Our integrated lesson on levers gives students the opportunity to investigate variables while practicing measurement skills, using technology, and communicating their ideas. We chose first-class levers because they are one of the most basic simple machines and form the foundation for understanding other simple machines. Read “How a Lever Works,” on the next page, before conducting the activities with your students.
How a Lever Works

Levers are often used to pry things up or lift heavy objects. A very simple lever can be made from a long board propped over a pivot point, with one end of the board under the object that needs to be lifted. Specific terms are used to discuss the parts of a lever and the way they work. In Figure 1, the large orange ball is the object that needs to be lifted. It is often called the load or the resistance. The long board that is under the load is called the lever arm. The lever arm is propped over an object so that the lever arm will pivot; that pivot point is called the fulcrum. Effort is the term used to describe the force, or push, which is applied to the lever.

The position of the load, fulcrum, and effort can be changed and moved around in any order on the lever. As long as the fulcrum stays between the effort force and the load, but not necessarily in the middle, the lever is considered a first-class lever. Moving the fulcrum away from the midpoint on the lever arm changes the amount of effort required to lift the load.

Why use a lever to lift a load? Notice in Figure 2 that when the effort force is applied in the downward direction, the load is lifted up. This first-class lever changes the direction of the force applied, one advantage to using a lever. As long as the fulcrum is in the middle of the lever arm, and the load and effort are on opposite ends, the amount of force needed to push down will be equal to the weight of the load. The distance between where the effort force is applied and the pivot point is equal to the distance between the pivot point and the load. This means that the distance the effort force moves down is equal to the distance the load moves upward. These properties of a lever are labeled in Figure 2.

What if you couldn’t push down on a lever with the same amount of force as the weight of the load? You could use an easier push if you moved the fulcrum closer to the load.

How does this work? When you move the fulcrum closer to the load, you make the effort arm longer. Compare Figures 2 and 3. Notice that the effort arm in Figure 3 is longer than it was before, but also that it is now longer than the load arm. By lengthening the effort arm, the distance the effort force will move has gotten bigger. You don’t need to push as hard to lift the load.
though the load will still lift, it won’t go as high as it did in Figure 2. This is one of the trade-offs of using a machine: It can decrease the amount of force you need, but it sacrifices the distance that the load will move.

What if you could push down on the lever with a force equal to or greater than the weight of the load? What if you wanted to lift the load as high as possible? In that case, you could move the fulcrum close to the point where the effort force is applied. The closer the fulcrum gets to the effort, the bigger the effort will need to be. Luckily, this also means that the closer the fulcrum gets to the effort force, the higher the load is lifted. This is shown in Figure 4. Notice how short the effort arm has become and how long the load arm is. This is another type of trade-off with a machine: It can increase the distance the load will move, but it requires more effort than if you lifted the load yourself.

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A Lever Lesson: Lift the Teacher?

This lesson begins with a demonstration inspired by the AIMS activity “Lightening With Levers” (Youngs 2002). The purpose of this demonstration is to show students a dramatic example of a lever, interest them in further investigations in small groups, and provide them with a shared experience to guide their writing before subsequent investigations begin.

This lesson is appropriate to use with all students, regardless of their previous experiences with the science content or using measurement tools. Students will need experience with working together to solve a problem and have basic skills in using a computer in order to use the materials as described below.

Begin the lesson by asking students to complete the first of four steps in a KLEW chart (Hershberger, Zembal-Saul, and Starr 2006). This is a revamped version of a KWL chart (What do we Know? What do we Want to Learn? What did we Learn?) modified to include “What is our Evidence?” (see Figure 5).

Focus students’ “What do we think we Know” on what they know about forces and ways to lift heavy objects. To help the students get started, ask them to describe something they have done to move an object, and ask, “What do you do if you want to move something that is heavy?” Encourage students to write down all their initial ideas. This process helps you formatively assess their knowledge and should serve as a guide for the design of further instruction. For example, a student might respond that in order to move a heavy object, they have placed the object on a skateboard and pushed it to the place they needed it to go. Based on this feedback, you can infer that students understand that placing something on wheels makes it easier to move. Even if students don’t explain the reason why this works, this comment does give you an opener to explain that this lesson will help them understand other ways they can move heavy objects.

To prepare for the demonstration, you’ll need to build the lever. A diagram of the setup is provided in Figure 6. The lever can be assembled with a 2” × 6” board, at least 8’ long, which can be purchased at most lumberyards. The longer the board, the easier it will be for the students to lift you! You will also need a 2” × 4” × 12” block to use as a fulcrum. Place the block on the floor. Perpendicular to and over the block, place the 2” × 6” board. Leave about 8” of the board hanging over the edge of the block. (This is the short load arm and the side you will stand on.) Invite students, one at a time, to come and press down on the other end to lift you. Students tend to be very enthusiastic about getting a chance to lift the teacher. At no time should their fingers be placed under the board or anywhere near the fulcrum. Depending on the
students’ strength, they should be able to lift you by gently pushing on the lever with one hand. If they are unable to push with one hand, allow them to use two. Encourage the students to push slowly. For your own safety, gently rest your hand on the table for balance. Students often comment in surprise about how easy it is to lift you. They are eager to find the minimum number of fingers they can use to lift you off the floor and want to experiment. Some students will ask what the “trick” behind it is. For this reason, it is important that you build the simple machine in front of them so that they can see it is made of simple materials.

Next, have students complete the second part of the chart, “What are we Learning?” Ask them to think about “how hard” they needed to push on the lever. How many fingers or hands did they need? What happened when they changed the number of fingers or hands they used? Students should respond that as they reduced the number of fingers or hands they used to push on the lever, the harder the push they needed to provide.

Help students focus the “Learning” part of the chart with the associated “Evidence” they witnessed during the demonstration. For example, students might notice that the lever changes their force. As evidence to support this claim, they could say that this is because they push down on the lever, but the teacher is lifted up (see Figure 5 for more examples of potential answers). To encourage the students’ thought processes, you can ask the students to write down what they can conclude from the activity (this is the “What are we Learning”) and match those ideas by asking them to provide reasons why they think this claim is true (this is the “Evidence”). At this point in the lesson, students should be comfortable with the idea that levers can be

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**Figure 5.**

KLEW chart.

<table>
<thead>
<tr>
<th>What do we think we Know?</th>
<th>What are we Learning?</th>
<th>What is our Evidence?</th>
<th>What are we Wondering?</th>
</tr>
</thead>
<tbody>
<tr>
<td>To get an object to move, I push or pull on it.</td>
<td>The strength of the push depends on our contact with the lever.</td>
<td>The more fingers and hands used to push down on the lever, the easier it felt.</td>
<td>What happens if we change the position of the pivot point? How hard will we need to push to lift the teacher?</td>
</tr>
<tr>
<td>The heavier an object is, the harder we have to push to get it to move.</td>
<td>Using a lever makes it easier to lift a heavy object.</td>
<td>I can’t lift the teacher off the floor without the lever, but I can lift her when I use the lever.</td>
<td>Can we raise the teacher higher off the floor?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>What other types of objects can be lifted with a lever?</td>
</tr>
</tbody>
</table>

---

**Figure 6.**

Setup for lifting the teacher.
used to lift heavy objects and should have a sense that if the lever is long enough, they can lift an object with very little force.

Next, ask the students to complete the fourth and final part of the KLEW chart—“What they are Wondering” now.

**Use the Dual Force**

Students’ wonderings can next form the basis for small-group investigations focused on the central question: *How does the effort force change when the position of the fulcrum changes?* The previous demonstration is extended using a student dual force meter and LoggerLite software from Vernier (see Internet Resources). The dual force meter works like a traditional spring scale. It can measure both pushes and pulls up to 50 newtons (N). The meter can be connected to a laptop computer via a “Go!Link” adaptor and a DIN-BTA adaptor. LoggerLite software is free from Vernier with the purchase of one of the Go!Link cables. Together, these three pieces would cost $173. Both adaptor cables are $64, so consider contacting a local middle or high school to see if you can borrow a dual force meter to keep costs down. The three components are shown in Figure 7. On the left is the dual force meter. The DIN-BTA adaptor is in the middle, and the Go!Link cable is on the right. In order to use the sensor, connect the adaptors. Plug the end of the Go!Link cable into the computer. This step is shown in Figure 8.

Next, load and launch the LoggerLite software. Most of the time, the software will recognize the type of sensor you’ve plugged in. However, because of the adaptors, you have to tell the computer you are using a dual force meter. Go to the “Experiment” menu at the top of the screen. Select the “Set Up Sensor” option. Choose the dual range force sensor from the list. A small picture of this sensor will show up in the upper right corner of the window. The green light will light up on the Go!Link cable. You are now ready to collect data.

For data collection, students can push on the lever using the sensor. To do this, place the silver hook against the lever as you would your finger. Push down while holding the body of the sensor. The amount of force will show on the computer screen in the lower left corner. If students would like to see how the amount of force they apply changes during the push, they can hit the green “collect” button at the top of the screen and data will collect continuously for five seconds.

This setup allows the students to compare the amount of force they used to push on the lever compared with the weight of the object lifted. If they measure and record the length of the effort arm, the lever arm, and the force applied, you can guide them through finding patterns in the data when you begin moving the position of the fulcrum. In Figure 6 (p. 25), the effort arm is shown with a long arrow, and the load arm is shown with a short arrow. The black dot is placed right over the pivot point, where the lever arm meets the fulcrum. Students should measure these distances with a metric measuring tape. Students are also likely to wonder what will happen to the amount of force they need to use if they change the position of the fulcrum. Ask the students to predict what will happen to the lengths of the effort and load arms when the fulcrum is moved away from the teacher. Encourage them to predict how the amount of force will change: *Will it get bigger or smaller?*
Students can move the fulcrum closer to them and repeat their measurements. They can move the fulcrum closer to the load and repeat the measurements. They can explore this both by pushing on the lever with their own hands and with the force sensor. Students should compare the way they feel (Are they pushing harder or easier?) to the force measured by the sensor, associating the experience of pushing with the measurement itself. The strength of the effort, as measured by the force sensor, can then be compared to the distance the effort was applied over. These comparisons can be descriptive, or students can make graphs comparing these variables to each other. For example, direct students to the data. As the effort arm gets shorter, the amount of force they will need to use will increase. To help students see this, it is helpful to have them make a series of sketches with the effort arm getting progressively shorter and the force getting progressively larger.

There is a limit to the amount the fulcrum can be moved and still enable students to lift the teacher. In order to fully explore the wide range of fulcrum positions and their effects on the force needed to lift the load, other materials need to be used. Brick Layers is a set of explorations about simple machines (Erikson, Seymour, and Suey 1994). These activities use Legos to build different classes of levers and provide students with the ability to manipulate the positions of the effort, load, and fulcrum.

After the lesson, assign students the task of writing a letter. Tell the students that one of the teachers needs to change her tire and needs to lift the car off the pavement in order to do it. In the letter, students should explain how the teacher should set up a lever to lift the car. The letter should also address how long the effort arm would need to be to lift the car and the amount of a push the teacher would need to give in order to change the tire.

**Not So Simple**

Students who participate in this lesson should be able to explain that when they feel like they are pushing harder to lift an object, they are using more force. This amount of force can be measured. They should also be able to tell you that a lever reduces the amount of force they need to move an object. The longer the effort arm, the less the amount of force is needed in order to lift the object. The letter the students write assesses these outcomes. Are the students able to explain how to lift the car? Do they provide evidence from their investigation to support their explanations?

As with the other simple machines, studying levers provides students with an opportunity to apply their developing mathematical skills to problems with real-world application. This content provides an excellent opportunity for teachers to allow students to explore relationships between variables and design investigations to test their ideas. By making lessons on simple machines a part of their instruction, teachers are able to leverage the learning of their students.

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**References**


**Connecting to the Standards**

This article relates to the following *National Science Education Standards* (NRC 1996):

**Content Standards**

**Grades K–4**

**Standard A: Science as Inquiry**
- Abilities necessary to do scientific inquiry

**Standard B: Physical Science**
- Position and motion of objects