FOSS ® LEVERS AND PULLEYS
TEACHER PREPARATION VIDEO TRANSCRIPT

<Larry Lowery Introduction to FOSS Program>

Lowery: Hello. Welcome to the Full Option Science System. This program was funded by the National Science Foundation. Its goal was to develop materials that would involve youngsters with both the processes and the content of science.

The program is developed at the Lawrence Hall of Science, with scientists, science educators and teachers working together as a team to develop the materials. The materials are tested in the hands of teachers and children in classrooms. It takes about two years to turn out a module.

Each module begins with firsthand experiences. This is done because it has been found that firsthand experiences are the best way for youngsters to learn about the concepts of science. As the module progresses, children are introduced to abstractions and reading materials. The sequence from firsthand experiences through reading materials is deliberate because it has been found that youngsters, when they have some experience before they read, learn and understand more from the reading. Authors of reading materials can then take youngsters to greater abstractions.

Trust the materials that you are getting acquainted with. They have been well-tested. We found that they work extremely well in the hands of all teachers and are effective for youngsters in learning about science.

<Larry Lowery Introduction to Levers and Pulleys>

Levers and pulleys are two of the labor saving devices called simple machines. All simple machines have one thing in common. They provide their users with some form of mechanical advantage. This module is divided into two parts.

In the first part students investigate levers and their mechanical advantages. They see how levers have been converted into common tools such as brooms, wheelbarrows and bottle openers. In the last part of the module, students assemble and investigate pulley systems. They learn that pulleys provide an advantage in lifting heavy objects.

<Larry Malone Introduction to Module>

Larry Malone/Narrator: Hi. I'm Larry Malone. And I'm here to help you get started with the Levers and Pulleys module. This module has four investigations that deal with simple machines. We'll deal with two of those simple machines: The lever and the pulley.

Students will be working on some of the fundamental ideas in mechanics. The big idea in this module is force. The students will be amplifying force with their simple machines to find out how to make work easier. Most of the equipment you need to teach this module comes in the kit. Everything you see here comes in this one box. There's enough permanent equipment in the kit for a class of 32 students and enough consumable materials for at least two classes. You will need to check the inventory sheet in the Materials folio to see which materials are consumable and which are permanent.

Here are the materials you'll need to supply. They are mostly tools and kitchen utensils. We'll discuss where each one enters the investigation as we get to them.

Before you launch into teaching this module, be sure to spend time going through the entire Teacher Guide. There's lots of information and detail here that won't be covered in the video. The first thing you will find in the Teacher Guide is the Overview folio which points out the national standards addressed in this module as well as information about how to best use the Teacher Guide. It also includes valuable background information specially written for teachers who do not have extensive science background. The suggested teaching schedule in the Overview will be particularly helpful as you plan.

Next you'll find the Materials folio. If you are the first teacher using a new kit, you'll want to turn to the section that describes first-time prep. If the kit has been used before, check the section called Preparing Your Kit For Your Classroom. Both of these sections will give you helpful hints that will save you lots of preparation time later.

The next four folios are the investigation folios. These are the heart of the program. Each takes one or two weeks to complete. The first page provides overview information. The At A Glance chart summarizes the investigations and helps you plan for assessment and extension activities.

Next you'll find the background information specific to this investigation. There is a section called Teaching Children About which gives you some insight into the research about how children think and learn.

Each investigation has several parts. For each part of the investigation you will find a Materials list, Getting Ready section and step-by-step instructions for how to proceed through the investigation. At the end of the folio, you'll find Interdisciplinary Extensions. You can do some of these extensions with the class or save them for students to use as projects at the end of the module.

Next are the investigation duplication masters. Each master is labeled with a number so it will be easy to find when you need it. Shortly before beginning this module, duplicate the Letter To Parents and send it home with students. This letter tells parents about the module and suggests some activities that they can do at home with their children.

It's important to read the Assessment folio before you begin teaching. It describes a system for assessing students throughout the investigations and also gives you ideas for end-of-module testing and portfolio assembly. The folio contains scoring guides for each of the assessments suggested.

Next are the assessment duplication masters. Here you'll find all the masters for the assessment charts and end-of-module assessments. As part of the kit there are Science Stories for the students to read. The Science Stories folio gives you background information, recommends when to read the stories and suggested follow-up activities. You may want to read the Science Stories during a reading period rather than during science time, especially if you only teach science a couple of times a week.

In the Resource folio, you will find lists of trade books, videos, computer software and other resources that you can use to enrich the program. The final tab is the FOSS website folio. At www.fossweb.com you'll find activities and resources for both students and educators. Each module for Grades 3 through 6 has interactive simulations, movies, Internet links, career information and opportunities to find out what other classes are doing with FOSS. In addition, teachers will find sections on tips and tricks, standards correlations, teacher exchange and implementation information.

Now we're ready to begin.

<Investigation 1, Part 1>
Narrator: In this first investigation, students are introduced to levers. In Part 1, they'll discover how to use the lever to lift loads and to overcome resistance. In each part you'll want to set up a Materials Station to make the distribution of equipment easy.

Here is what you'll need for this part: Materials you'll get from the kit are half meter sticks, wooden dowels, rubber bands, 240 gram masses used as loads, duct tape, binder clips, pyramid erasers, overhead transparency used to introduce students how to use the spring scale and the spring scales.

You'll need to provide one inch masking tape, a permanent marker and lined paper. And to demonstrate real world levers to start the investigation off, you'll want to have either a can and screwdriver to demonstrate how to pry a lid or better yet, a large piece of lumber, perhaps a 2 by 6 and a 4 by 4 or 4 by 6 to demonstrate a very large lever.

Duplicate the student sheet called Levers and Pulleys Journal and make a copies of the Assessment Chart for Investigation 1. Assessment opportunities are embedded throughout the module. You should check the Getting Ready section on assessment and also go to the appropriate page in the Assessment folio to make the best choices for you and your students.

I'm going to make the lever arms now that the students will be using in the first activity. I need masking tape, permanent marking pen and the half meter stick. I'm going to flip it over to these alien units on this side and start by covering them with masking tape.

Now what I want to do is bring in a second half meter stick. Line it up exactly with my first one and mark the center of the tape stick. Just a line about halfway up. I'm then going to mark every 5 centimeters in both directions from the center. Let me label this one 0. And I'm going to continue out all the way to the end.

And this is important. I'm also going to mark 2 and a half centimeters right here. Now my finished stick will look like this. 0 in the center, 2 and a half, 5, 10, 15, 20, 25.

This is the scale students will use to measure the effort that they apply to their levers. Here is the load that they will use. And both of these have to be suspended from their lever arm. To do that, we'll attach a rubber band to the hook by passing one end of the rubber band through the other in a typical fashion, and tightening it up, okay?

And I'm going to attach a second rubber band in the same fashion to the top of the balance -- excuse me -- scale. Now I'm going to attach them both to my lever arm by sliding the rubber band over. The advantage of the rubber band particularly for the load is that it can fall to a considerable angle and the load won't slip off and drop on the students' toes. So this is the way the two will look on the scale. The effort will be applied by pulling down on the hook.

There are three things the students need to keep in mind when they use the scale. One is that it's always used upright, never upside down. So that's why we have the rubber band here for some applications. And the second thing is that the indicator needs to be right at the 0 mark before starting the investigations. If it's not, the students can use this little tang sticking out at the top to push this scale up or down relative to the indicator to get it just right.

The third thing is they have to be able to read newtons in tenths of a newton. The little marks on here are two tenths each so they will have to interpolate between the lines.

Now this is a difficult thing to teach the students. So in order to make it easier for you to demonstrate how to read the scale to the students, we've provided this overhead transparency in the kit. The first thing you have to do is cut out the two parts, the scale and the little indicator strip. You have to use a single edged razor blade or mat knife or something to cut a slit across at the 100 and 400 gram or 1 and 4 newton level on those lines. And then we're going to slip the indicator right through those slits like this.

And now what we've got is an oversized emulation of that scale so that we can set different scale readings and ask the students to interpret them. Right here I have .6 newtons. I can set it now at 2 newtons. So this is a visual aid to help the students learn to read the scale accurately.

Your students will be doing some simple work with decimals. They will be adding .5 newton to each of their scale readings throughout the module. If your students are not familiar with decimals or need a little refresher, there's a math extension activity called Introducing Decimals that you might want to use with them.

At fifth and sixth grade it's a good idea for students to keep a journal where they can keep notes of all of their investigations. Take about ten sheets of lined paper. Cover them with the Levers and Pulleys Journal cover that you've duplicated for each student. Square them up and staple them either once in the corner or along the side.

Make a Projects Folder. This is where you can put the students' ideas and questions throughout the module. At the end of the module, the students will be selecting a topic for a project, an independent study. This will be a resource for them. Prepare Word Bank and Content/Inquiry charts using large sheets of paper or a flip chart.

A nice way to start this session is by challenging your students to lift you right off the floor.

Teacher: Are you up for a challenge? Because I would like to challenge you to pick me up with one hand or with one foot. Anyone want to try this morning?
Vince?
Can he do it?
Go ahead. One hand or one foot. Lift me up.

(Laughter)

Teacher: Want to try again?

Student: No.

Teacher: No? Anybody else want to try?
Come on, Deandre.

Deandre is going to try to lift me with either one hand or one foot. Let's see how strong he is this morning.
Did you eat your Wheaties this morning? Let's see how strong you are.
Oh, my goodness he is strong. He moved me a little bit.

(Laughter)

Teacher: I have something that might help this morning. This is a device that we're going to use. And with this device someone will be able to lift me. What do we have down here this morning?
Mason? What do we have down here? So what do you think I should do? How are you going to lift me up?

Student: Go over there.

Teacher: Stand over there? Right here?

Student: On the board.

Teacher: You want me to stand on the board?

(Laughter)

Teacher: Too many donuts this morning. Okay. He was able to lift me up with the board, wasn't he? Is there anything that we can change about the boards so that no one has to jump on the end of it? Mrs. Lawvey doesn't have to fly off the end of the board? Janelle?

Student: Put the board that's the -- the other board that's under more under you.

Teacher: Come show us. Where should we put the board?

Student: This one --

Narrator: This student figures out how to increase the advantage with this lever.

Teacher: Would you like to try it? I'll stand on my end.

Student: Stand with two feet.

Teacher: Both feet on your end. Oops.

Teacher: There are tools that we use to make our work easier. And the tool that we used this morning is called a lever.

Narrator: The teacher explains that these are tools that people use to make work easier. They are called levers. Levers are used to lift weight or to overcome resistance. Levers give us an advantage by making work easier.

Teacher: In your journal writing this morning I have two vocabulary words for you to use. And I did put them on the board. One is fulcrum and one is your lever arm. Now the lever arm is going to be free to pivot. And the fulcrum, which we're going to use this today, will be the point at which it will pivot.

And let me show you how this will work. This is going to be your lever arm today. And each of you -- each group will get a clip. And you see how the numbers are marked in blank ink. We're going to put this clip right over the 0. Just like this. And when your group has your clip on, you're going to flip this part up.

This is now your fulcrum. This is now your lever arm. This rod is going to be used to balance. And we're going to put an eraser at the very end so it will not slide off.

The next thing we do is put it through this way. Put it through the fulcrum. This is your arm. This is your fulcrum. And we're going to tape the lever about three inches away from the end of your desk. And then we'll tape it down.

Narrator: The teacher tells the students to tape the dowel so it sticks out 5 centimeters. They will need to check the way the students do their setup. Some may not know how to use the binder clip. They should all have their rulers right side up and balanced.

After the teacher describes the challenge for today, the getters go to the Materials Station to get the materials for two setups. Each pair will have their own lever to work with. These students have done a good job of setting up their lever. But they do need to balance the lever arm by moving the binder clip a little bit.

Student: This way.

Student: No, this way.

Student: Now -- but it has to be on the 0.

Student: No, it doesn't have to. See.

Narrator: When the arms are level, the students place their load at 15 centimeters and move their fingers, the effort, to different locations to see if that creates a difference in the effort needed to lift the load. The teacher reminds the students to be very careful with the load. It is heavier than it looks and should not be dropped.

Student: See, it's heavy.

Narrator: After several minutes of investigation, the teacher asks the students what they've discovered. The students report that it is easier to lift the load when the effort is applied further from the fulcrum.

Student: You could feel it getting heavier as you put your hand closer to the middle.

Teacher: Okay. Closer to the fulcrum or closer to the end?

Student: Closer to the fulcrum.

Teacher: Good.

Narrator: After the discussion, the teacher asks the students to record their observations in their journals.

Teacher: Okay, boys and girls. This is a spring scale. And we're going to be using this today to measure the effort.

Narrator: The teacher demonstrates how to use the scale right side up by hanging it on the demonstration lever using the rubber band.

Teacher: And you're going to have the weight on the other side.

Narrator: She shows them how to pull down on the hook to lift the load. She explains the amount of effort is measured in newtons and the newton is read directly from the scale under the word newton. The teacher helps the students zero their scales and review the rules.

Always zero the scale before starting. Always use the scale right side up. Pull until the lever arm is level and read the effort. And never let the scale go past the 10 newton limit.

The teacher gives the students several minutes of free exploration with their new tool. The students use the spring scales to find out if the load is easier to lift when the effort is applied close to or far from the fulcrum. They record their data in their journals.

Teacher: Can somebody raise their hand and tell me what they found out? What

happened today?
Amber?

Narrator: In a class discussion the students describe the relationship of the load and effort. The greater the distance from the fulcrum to the effort, the less effort is required. The teacher starts a list of key vocabulary that relates to levers.

Student: Load.

Teacher: Rosemary, do you know what load is?

Narrator: After the words are written on the chart, the teacher asks questions to help students formulate concept statements.

Student: Something heavy.

Narrator: Some questions the teacher asks: What are the parts of the lever system? In what ways can the lever provide an advantage? How does the position of the lever affect the amount of effort?

Teacher: Okay. Depending on where you put your spring scale?

Student: Yes.

Narrator: In this part, students have learned that a lever is a simple machine that people use to gain a mechanical advantage such as making work a little easier. And that in a lever system, the further from the fulcrum the effort is applied, the greater the advantage. Be sure to check the Science Stories folio to plan a time when students can read the stories.

<Investigation 1, Part 2>
Narrator: In Part 2, students do a lever experiment. They place the load at a predetermined spot and move the effort around to see how much effort is required to lift the load. Here is what you'll need for this part: From the kit: Half meter sticks, modified, dowels, binder clips, erasers and duct tape, loads with rubber bands attached and scales with rubber bands attached.

And you provide the Levers and Pulleys Journals which the students started in the first part. Duplicate the student sheet called Lever Experiment A. You may want to make an overhead transparency at the same time. Duplicate the student sheet called Response Sheet - Levers, which you can use for assessment. Have the Assessment Chart for Investigation 1 available so you can make notes as you work with the students. Consult the Assessment folio for details.

Start this session by reviewing the parts of a lever system and remind the students how to use and read the scales. The teacher asks the students to find out how much effort it takes to lift the load without the aid of a lever. The students hang the load on the spring scale and read how many newtons of force it takes to lift it. They find it takes 2.4 newtons.

After the students have set up their lever systems, the teacher gives them a few minutes for free exploration. The teacher introduces the student sheet and the challenge. The students position the load at 10 centimeters. They apply the effort at various distances from the fulcrum guided by the chart. They record each reading and add .5 newtons to the effort to account for the weight of the scale itself and the force with which it pulls down. When the students have finished their test, the teacher asks questions leading students to realize that the further the effort is applied from the fulcrum, the easier the load is to lift. And the closer the effort gets to the fulcrum the harder it is to lift.

Teacher: And my graph is a little bit smaller than yours. And that's okay.

Narrator: The teacher made a transparency of the grid to demonstrate how to use the two coordinate graphs.

Teacher: Here is 2.5. So here is the 1. Here is the 2 line. And right in the middle of the 2 and the 3 is 2.5.

Narrator: Once the graphs are completed, the students can more easily describe relationships. The load is easier to lift as the effort is applied further from the fulcrum. With this visual aid, students can predict how much effort it would take to lift the load at 10 centimeters if the load were placed at 22 centimeters or 13 centimeters or 30 centimeters. They can even tell where the effort is applied if the load was at 10 centimeters and a force of 4 newtons is required.

In this part, the students should learn or reinforce the idea that the further the effort is applied to the fulcrum, the easier it is to lift the load. This is a good time to introduce the Project Folder. At the end of the module students will be selecting a subject for a project and undertaking it on their own. As students come up with questions or good ideas during the course of the investigation, have them write them down on a piece of paper and put them into the folder. This will be a resource for the students at that time.

<Investigation 1, Part 3>

Narrator: In Part 3, students conduct another lever experiment. But this time instead of placing the load at 10 centimeters, they are going to position the effort at 10 centimeters and move the load from place to place. Here is what we'll need: From the kit: Half meter sticks, modified, dowels, binder clips, erasers and duct tape, loads with rubber bands attached and scales with rubber bands attached. And you'll provide the Levers and Pulleys Journals.

Duplicate the student sheet called Lever Experiment B. Have Assessment Chart for Investigation 1 available so you can make notes as you work with the students. Consult the Assessment folio for details.

Begin this part by recounting Experiment A and reviewing the position of the load and the effort and the results of the experiment.

Student: Okay. So if we pull this down --

Narrator: Today the teacher proposes a change in the experiment. The students will keep the spring scale at the same location on the lever arm and move the load. After making some predictions, they begin to investigate. The students record their results on the student sheet. The teacher reminds them to add .5 newtons to each reading.

Teacher: Okay. Now pull on that until it evens off and read the scale at 5.5. Do you guys find it? Okay.
Now read the scale, Nicole.

Narrator: The teacher expects to find some discrepancies because the students may not have balanced the lever arms precisely. They may not have their scales exactly zeroed. And some may not read the scale accurately. When all of the data have been recorded, the teacher reviews the two coordinate graphs and the students plot their results.

The students compare their results to Experiment A. They use the graph to make predictions and go back to their lever to test their predictions. In a whole class discussion, the teacher will ask the students to figure out the relationship between the location of the load on the lever system and the effort it takes to lift it. He also asks the students to predict how much effort it would take to lift the load if it were placed at 22 centimeters or 13 centimeters or 30 centimeters. He also asks them to think about where the load would be positioned if four newtons were required to lift it.

Teacher: What if you did the distance between both dots each time you go up five, would that tell you anything? What would that tell you?

Student: It would tell you that every single time you go up in the math, you go that same distance up on the chart.

Teacher: Oh, so you're telling me every time you change five, you might go the same distance each time?

Student: Yeah.

Narrator: Part 3 provided students with more experiences with the core idea of mechanics. They should have learned that the effort needed to lift the load decreases as the load gets closer to the fulcrum and the effort increases as the load gets further from the fulcrum.

This brings us to the end of Investigation 1. Be sure to review the interdisciplinary activities and have the students do the math problem of the week before moving on.

<Investigation 2, Part 1>
Narrator: In the first investigation, students investigated levers that had the fulcrum in the middle between the load and the effort. In the first part of this investigation, students will be invited to discover the many different ways that the fulcrum, load and effort can be arranged. Let's see what we need for this part of the activity.

From the kit: The half meter sticks, modified, the dowels, the binder clips, the pyramid erasers, duct tape, loads with rubber bands attached, spring scales with rubber bands attached and the three Lever Diagram Posters: Class 1, Class 2 and Class 3. And you will provide the Levers and Pulleys Journals and the masking tape. Make a copy of the Assessment Chart for Investigation 2, which you can use to record your observations as the students work.

Begin this session by reviewing what students have learned about lever systems.

Teacher: What's this? Who can tell me what this is called?
Eddie, what's this?

Narrator: The teacher reviews the parts of the lever, the force of the load and how the advantage changes with the placement of the load and effort.

Teacher: Next who can tell me what this is right here? What's that? What's that?

Student: That's called a lever.

Teacher: Class, when a load is pulling on something, it's called a force.

Narrator: The teacher demonstrates that the load they are using pulls with a force of 2.4 newtons. The teacher asks the students if the effort needed to lift the load will be more, less or the same as the pull of the load. They find out the effort required will be about 4.8

newtons, which is twice the force of the load pulling down.

Teacher: All right. It's level. What do you have there?

Student: 4.4.

Teacher: It's actually more effort, huh?

Student: Yeah.

Teacher: Uh-huh.

Narrator: The teacher explains to the students that the fulcrum is not always in the middle of the lever arm. He asks them to explore the advantages of moving the fulcrum to new locations along the lever arm.

Student: There you go.

Narrator: After the students have had some time to work with their levers, ask them to report their findings. They should report that the closer the fulcrum moves to the load, the easier it is to lift the load.

Here is a way to diagram the lever that the students have been working with, which is a Class 1 lever. Our convention is that a square with an L is the load. A circle with an E is the effort. And a triangle with the F is the fulcrum.

After this has been diagrammed, you can challenge students to come up with other ways to rearrange the load, fulcrum and effort to come up with other lever designs. As they come up with ideas, you can diagram those, as well. Here is the fulcrum at one end, the load in the middle, effort at the other end. This is a Class 2 lever. And finally they'll come up with fulcrum, effort, load, which is a Class 3 lever.

This is a good time to introduce a pneumonic device to the students so that they can remember the characteristics of Class 1, Class 2 and Class 3 levers. You can use the Lever Diagram Posters to do that. The pneumonic is FLE 1, 2, 3. FLE. 1, 2, 3. And the FLE refers to that part of the lever system that is between the other two.

For instance, a Class 1 lever always has the fulcrum between the load and the effort. A Class 2 lever always has the load between the effort and fulcrum. And a Class 3 lever always has the effort between the fulcrum and the load. FLE. 1, 2, 3.

In this part, the students have learned the three classes of levers and the pneumonic for remembering which is which. The Class 1 lever has the fulcrum in the middle and load and effort at the two ends. The Class 2 lever has the load in the middle. And the Class 3 lever has the effort applied in the middle. Be sure to check the Science Stories folio and plan some time during the investigation for the students to read the stories.

<Investigation 2, Part 2>
Narrator: In this part, the students investigate the advantage that can be derived from each class of lever. Let's see what we'll need.

From the kit: The half meter sticks modified, the dowels, the binder clips, the pyramid erasers, duct tape, loads with rubber bands attached, spring scales with rubber bands attached and the three Lever Diagram Posters: Class 1, Class 2 and Class 3. And you will provide the Levers and Pulleys Journals and the masking tape.

Duplicate the student sheet called Lever Diagrams and the student sheet called Response Sheet - More Leverage, which you can use for assessment. Make a copy of the Assessment Chart for Investigation 2, which you can use to record your observations as the students work.

In this session, the students are introduced to a method for recording the results of their lever experimentations: The Lever Diagram. Explain the conventions that the students will use as they diagram their levers from this point on in the module. The circuit with an E is the effort. A square with an L is the load. And a triangle with an F is the fulcrum. In addition, they can draw arrows from the E and the L indicating the direction that the force is acting. In this case, I would draw an arrow pointing down for the effort. And for the load.

Student: Down here on 15 it's even heavier.

Student: Let me try.

Student: Come around here first.

Student: 15.

Student: Ow. You have to hold it or else it's going to fall.

Student: It's at 15.

Student: Hold it at 15.

Student: It’s slipping. See, it's heavy. Okay. So let's write that one down.

Narrator: The students record their investigations on the student sheet. When the students finish their explorations and diagrams, the teacher allows a few teams to share one of their lever systems with the rest of the students. They demonstrate the lever, identify its class and draw its diagram on the board. Before ending the session, the teacher has the students complete the response sheet that will help him assess how much the students understand about lever systems.

Student: Now we're going -- where should we put the load?

Student: If this is over here --

Student: That's over there.

Student: Where is the eraser?

Student: 20.

Student: We should put the load at 20?

Student: 10. Let's try 10.

Student: Or 15.

Student: Now where is the effort? The effort is at 2.5 going -- it can't be at 2.5.

Student: Yes, it can.

Student: Yes, it can.

Student: Yes, it can. It's just really hard.

Narrator: In this part, students learn that a diagram is a system of symbols and conventions used to communicate information about lever designs. Remember to encourage students to add their ideas and questions to the Project Folder.

<Investigation 2, Part 3>

Narrator: In this part, students analyze kitchen utensils and tools to see if they can figure out what class of lever they are. Let's see what we'll need from the kit. The half meter sticks, modified, and the loads with rubber bands -- these you'll make available for students who would like them to use them while they are modeling their real world levers -- the Lever Diagram Posters that were used earlier and some new posters: The Crowbar, wheelbarrow and Broom as examples of real world levers. And you'll need to provide an array of real world levers. In this case I've got a hammer here, a broom, a screwdriver that can be used as a lever. Here is a garlic press, can opener, couple pairs of pliers, tweezers, nut cracker, scissors. You'll also need to supply the Levers and Pulleys Journals and some masking tape. Have Assessment Chart for Investigation 2 available.

Begin this session by reviewing the different classes of levers. The teacher reviews the three classes of levers and asks the students in which direction the effort moves in each of the classes.

Teacher: For the first class lever, the load is on one side, the fulcrum is in the center and the effort is on the other side. Now, which way would the effort go on that one, up or down?
Laquita?

Student: It would be going down.

Teacher: Yeah, exactly. The second class lever the effort is on this side, the fulcrum is on this side and the load is in the center. On this one which way would the effort be going?
Nat?

Student: It would be going up higher.

Teacher: That's right. The effort would be going up. Class 3 lever the fulcrum is on the left side. The effort is in the center. And the load is on the right. On that one, which one which way would the effort be going?

Student: The effort would be going up.

Teacher: Actually a Class 1 lever is a crowbar.

Narrator: The teacher gives the students some real world examples of levers using the posters of the crowbar, wheelbarrow and broom.

Teacher: So the crowbar is actually a Class 1 lever. A Class 2 lever is a wheelbarrow because the load is in the middle like the wheelbarrow forcing down. The effort, you pull it up. And the fulcrum is what? The wheel. That's the Class 2 lever.

And a Class 3 lever, the fulcrum is at the very end. That would be a broom. And the fulcrum is at the very end. The effort is in the center when you sweep. And then the load is actually the main part of the broom on the bottom. That would be a Class 3 lever.

Narrator: Next you can demonstrate how to use a real world lever in action. Students know how to pry a lid off of a putty can with a screwdriver. So ask them to think about where is the load, where is the fulcrum, where is the effort. After the students identify the resistance of the can lid as the load, the effort as the pressure out on the handle of the screw diver and the fulcrum is the edge of the can right here, then show them how to diagram this lever.

Here is a diagram of the lever. The screwdriver, used to lift the lid off the can. The load, the resistance of the lid. The fulcrum, the edge of the can. And the effort to push on the screwdriver handle. The students use the sheet called Levers At Work and the tools to determine where the load, effort and fulcrum are located on each tool.

Student: That's the effort, right?

Student: Yeah, right up here.

Student: I think the load is down here because this is where the nut would go.

Student: Yeah.

Student: And then the effort is right up here because you have to squeeze it.

Student: Where would the fulcrum be?

Student: How about right down here because this is what makes the nut crack?

Student: That's the effort, right?

Narrator: The students will record the class of the levers and draw their diagrams.

Student: Here is where the effort is because you open it here. And the fulcrum is right here because that's what allows it to open.

Teacher: Oh, okay. Now where is the load?

Student: And the load is at the end because that's what does all the work and it's heavy.

Teacher: Thinking of that -- thinking of all of those things together, what class is that now?

Student: It's a 1 because the fulcrum is in the middle, the load is on this side and the effort is on the other side.

Teacher: You can teach the class today. You're right. That's neat.

Student: The load is right here -- no, that's the Class 1. Because the load is right there and the effort is right there but the fulcrum is in the middle. So that's a Class 1.

Student: That's exactly a Class 1, yeah.

Student: The load is here where you would use it. And then you've got the effort here where you would go like that. And then you've got the fulcrum here. It would be a 3, Class 3.

Student: This would be the fulcrum because it's going like that because you're pulling a nail out. And this would be where the load is because that's where the nail is going to be. And this is where the effort is because that's where you're moving it. And it would be a Class 2.

Student: The bottle opener has the load on one end, effort on one end and the fulcrum right around the -- where the load is. Just like a crowbar. So you apply it up, pushing down the load on this side. So it would be a Class 1 lever.

Narrator: In this part, students have the opportunity to consider many common implements as levers: Scissors, pliers, bottle openers, hammers and so forth. And the students continue to reinforce the idea that the effort is reduced as the load is moved closer to the fulcrum.

<Investigation 2, Part 4>

Narrator: In this final part of the investigation, students analyze and diagram pictures of common tools. Let's see what we'll need. From the kit: The Lever Diagram Posters and the Lever Picture Posters. And you provide masking tape and the Levers and Pulleys Journals.

Begin this session by reviewing the diagrams the students made of the tools in the previous session. You may want to have those tools available. Make copies of Lever Pictures 1 and Lever Pictures 2 for each student. You can use them as group or individual exercises during school time or they can be used for homework.

This brings our lever investigations to a close. Be sure to check the interdisciplinary activities and have the students do the math problem of the week.

<Investigation 3, Part 1>

Narrator: Now it's time to move on to pulleys. In this first part of the investigation students are challenged to set up pulley systems with one pulley. And they'll discover that they can set up a single fixed pulley or a single moveable pulley system. Let's see what we'll need.

From the kit the half meter sticks, the scales -- the rubber bands have been removed -- paper clips, binder clips, pulleys, loads -- again, rubber bands have been removed -- duct tape and some cord. And you need to provide heavy books, scissors, masking tape and the student journals. Duplicate the student sheet called Pulley Diagrams and make one copy of Assessment Chart for Investigation 3.

You'll need to prepare a rope for each pair of students. Each finished rope should be 75 centimeters long. So I'm going to measure 85 centimeters. There's 50. Plus 35. I'm going to cut it right there.

I'm going to fold back the end 5 centimeters. Tape that loop in place with a short piece of masking tape. Do the same thing on this end. Fold it back 5 centimeters. Tape it securely. We have a finished string now, and you should check this. The finished cord will be exactly 75 centimeters long from the top of the loop to the top of the loop.

Students will need to attach a paper clip hook to the loop of their scale so they can attach it to the rope. Open the paper clip just a little bit, rotate it around like this. And there you have it.

I've got the parts of a pulley setup here. And I'm going to show the standard way of assembling them so the students can do their pulley investigations. I'm going to put the binder clip on the end of the half meter stick, fold the bottom clip back under and set the thing right on the edge of my table here. A piece of duct tape to hold it in place and my heavy book here at the back to keep the backend from flipping up. Now I can hang my pulley right from the upper handle of the binder clip.

For a standard fixed pulley system, I can pass the rope through the pulley. I can attach the load right to the loop. And there is my single fixed pulley setup.

For a moveable pulley setup, I can remove the pulley here. I attach the end of the rope over the top of the clip, attach to the load to the pulley. And there's my moveable pulley system. This is a standard setup that the students will use throughout the rest of the module.

Begin this session by explaining that levers aren't appropriate for all jobs.

Teacher: There's another simple machine that can also make lifting easier. Can anyone think of another machine that maybe you've seen at a construction site that makes --

Narrator: The teacher explains that if construction workers needed to lift the steel girder to the fifth level of a building, the lever would not be very practical. The students have some ideas.

Teacher: Dominique?

Student: A bulldozer.

Teacher: A bulldozer.

Student: A crane.

Teacher: A crane, yes.

Narrator: The teacher introduces the pulley and tells the students they will have the opportunity to work with the pulleys and find out what they can do.

Teacher: We're going to be doing some investigations with pulleys.

Narrator: After the teacher demonstrates how to set them up, each pair of students begins to set up their own pulley system. It may take students a little bit of time to get their systems functional. Allow them to problem solve on their own for a while. They soon have a single fixed pulley system set up and are trying it out with the load.

Teacher: So it looks like everybody was able to create a pulley that made it easier to lift the load. And this pulley has a name. It's called a single fixed pulley. So we know that a pulley is a grooved wheel. Single means one. And we're using one wheel. And fixed means it's attached. It stays in place. And how did we make the pulley stay in place? Frank?

Student: You could hook it into your desk to make it stay up.

Teacher: Good. You hooked it onto your desk using the binder clip to make it fixed or attached to your desk. So single, one wheel. Fixed, attached. And pulley, a grooved wheel.

Now what you're going to do is --

Narrator: The teacher now challenges the students to figure out how to set up a single moveable pulley.

Teacher: So you're still going to use the one grooved wheel. But this time it's not going to be attached. It needs to move. It needs to move. So this one is more challenging. But you still need to be able to lift the load and the wheel needs to move, not be attached.

Student: We got it; we got it.

Narrator: The pulley is moving but that's not quite what the teacher had in mind.

Student: And the wheel moves while we're pulling the weight up and down and while he's moving the paper clip.

Narrator: Here is another interpretation of moveable. Most children struggle with this one. If some teams are stumped the teacher will tell them that a moveable pulley always moves with the load.

Student: Yeah, maybe we can do that and then put the pulley on the end.

Student: I was going to try to put it in here.

Student: Yeah. And then put it there.

Student: Now we've got to use the weight.

Narrator: Success at last. Most of the groups will have theirs going in just a few more minutes.

Student: You can't even feel it.

Student: It's not like even it's attached. It's just hanging from the rope.

Narrator: The teacher asks the students which system gave them more of an advantage in lifting the load. The students can feel that the moveable pulley gave them a greater advantage.

Teacher: Is there any advantage to using one pulley over the other pulley?

Narrator: Next the teacher asks how they can find out for sure which gives the better advantage and how much. They suggest using the spring scale. The teacher reviews how to 0 the scale and how to read the scale. She reminds them to add .5 newtons to the reading whenever pulling down only.

The teacher draws Part 1 of the Pulley Diagram sheet on the board to help students understand what they need to do next. The students find that they need a paper clip hook to attach to the scale to keep it upright. The teacher reminds them to add .5 newtons to their reading.

Student: Take the paper clip and hold it down on the other end of the string.

Student: It's 0.2. Oh.

Student: It’s 2.2.

Narrator: And they measure the force of a moveable pulley.

Student: 2.1. 2 and one tenth. Because we have to add 5.

Narrator: The teacher collects the data from the students and adds .5 newton to the single fixed reading. Looking at the chart shows the students that they changed the direction of the effort but that did not reduce the effort. However, the single moveable pulley reduced the amount of effort needed to lift the load. The students write what they learned about the pulleys on their student sheet.

In this introductory experience with pulleys, the students learn they can set up a single pulley two different ways, either a fixed pulley or a moveable pulley. They go on to discover that the fixed pulley can only change the direction of the effort, not reduce it. This is a directional advantage. At the same time they learn that the single moveable pulley reduces the effort needed to lift the load. And this is a mechanical advantage.

And plan to have the students read the Science Stories during this part of the investigation.

<Investigation 3, Part 2>
Narrator: In this part, two teams will bring their pulleys together so they can investigate two pulley systems. Here is what you'll need. From the kit: Half meter sticks, scales, paper clips and binder clips, pulleys, duct tape, loads, sticky dots and the ropes finished to 75 centimeters with a loop at each end. And you need to provide heavy books, Pulley Diagram sheets started in Part 1 and Levers and Pulleys Journals. Duplicate the student sheet called Pulley Diagrams. Have Assessment Chart for Investigation 3 available.

Begin this part with a discussion of what the students learned about one pulley systems. The teacher asks the students how single fixed pulleys and single moveable pulleys are alike and how they are different. She also asks them how the pulleys are similar to levers. They conclude that all provide an advantage when trying to lift a load.

The teacher explains that some pulley systems contain two or more pulleys. Today the challenge is to set up a pulley system with two pulleys. Students will often set up a pulley system that gives them no advantage. Let them struggle with these non-productive systems. It is through such trial and error investigations that students learn how to assemble useful pulley systems.

Student: We can put one there and one there and it's perfect.

Student: Are you sure?

Student: We need to put the weights on it.

Student: Here is the weight.

Student: I have a better idea.

Student: Turn it around.

Student: Wait. Put the weight on it. Just try it.

Student: Do it the other way then.

Student: The weight is right here.

Student: I have a better idea.

Student: First we have to go through here.

Student: Now put this through here.

Student: Now you push it through --

Student: Push this right here.

Student: Where is the --

Student: Where is the other weight?

Student: You got it on? Okay. Now I'll hold this for you.

Narrator: After three to five minutes, the students are not getting the hang of it so the teacher gives them a hint. She shows them the rope hanging from the bottom hook of a fixed pulley.

Success at last. The students find the direction of the effort changes if they attach the rope to the fixed pulley instead of the moveable pulley.

Student: We just put this -- the string through --

Student: We put this string through.

Student: -- this pulley down and it goes up. It will make a --

Student: A single.

Student: Shanesha helped us putting it right here.

Student: It will make a single fixed and single moveable pulley.

Narrator: The teacher demonstrates how to diagram a single fixed pulley. Each group gets 24 sticky dots to use as pulleys in their diagrams. The students begin to draw. Here we see a diagram of a single fixed pulley. The teacher suggests they put their systems together if they need a little help diagramming.

Student: It went up, down, up, down. But on this one it went up. So we have to have where we have the one and it's pulling it this way.

Student: Go like that. Tell me if you need the stickers to do it.

Student: The load.

Student: Oops.

Student: We can switch to a different pulley. See how it's the upper pulley.

Teacher: Then you're pulling upwards so your effort is going up. Good.

Student: Yeah. To make the downward pulley we have to take it off of that and then --

Teacher: Very good; very good. That's it.

Student: Then you can attach it whenever you want to and then it just goes like that.

Teacher: Excellent.

Student: Here. But Thomas, this is supposed to be a circle.

Narrator: After working with their two pulley systems the, students are introduced to the idea that pulleys are one of six different kinds of simple machines, devices that provide mechanical or other kinds of advantages such as levers as pulleys. Continue to add student ideas to the Project Folder.

<Investigation 3, Part 3>

Narrator: In this part, students play a game setting up pulley systems as fast as they can, Racing The Clock. Let's see what we need for this part. From the kit: Half meter sticks, paper clips, binder clips, pulleys, loads, duct tape and the ropes. And you need to provide heavy books, the student journals. Have Assessment Chart for Investigation 3 available.

This part gives students additional practice with pulley systems and the spatial relationships involved.

Teacher: We're going to play a pulley game. And it's kind of a competition more against the clock than against each other. There's four people in each group. We're going to number the people in each group 1, 2, 3, 4.

Narrator: The teacher will be the timer. The students are numbered 1 through 4 and each student will get his or her turn to be the competitor. The students in the group can give the competitor verbal help and encouragement but they can't touch.

Teacher: -- what kind of pulley No. 1, Person No. 1, has to set up within three minutes. And that person cannot receive any help from any other person in the group.

Student: All right. Now what? Now what? That's it.

Student: We have ours.

Student: Put it through; put it through. Okay; okay. Now put the weight --

Student: Is that ours?

Student: No, that's theirs.

Student: Put one on; put one on.

Student: No, you can't.

Student: Yes, we can.

Student: We can talk to him.

Student: Raise your hand.

Student: Raise your hand.

Student: You're not doing things right.

Teacher: Muy bien, muy bien. Quita todo. All the pulleys have been disassembled? Okay. No. 2: Single fixed, single moveable.

Student: God, I don't know.

Student: One on top, one on bottom. And it goes through.

Student: How do you do that one?

Student: Remember?

Student: One on top, one on bottom. You can't look at that.

Student: Too bad.

Student: I'm so tired.

Student: Look. Look at theirs.

Student: No. You put the string through.

Student: No. Cameron; Cameron. So it's like one and then another. And then you put the string through.

Student: Oh, man.

Student: I can't touch the --

Teacher: Good; good. Disassemble.

Student: And put it off track. Take this and put it off track. No. Yeah, like that. And make it so it can't move.

Student: Make it so it cannot move.

Student: And then put it on the track.

Student: Put it on there.

Student: You know how it's supposed to go, Dominique?

Student: Oh, yeah.

Student: Oh, no.

Student: Come on; come on; come on; come on. No, Ray! You're doing it wrong; you're doing it wrong.

Student: There you go.

Student: You can do it. Let's go, Ray Ray. Let's go. Come on, Ray. You can do this, man. It's two of them. Where is the other one?

Student: Where is the other one?

Student: She took it; she took it; she took it.

Student: No. It's right there.

Student: Yeah.

Student: Yea, we finished!

Student: Move it now. Move it. We got it.

Student: Geez.

Narrator: Single moveable is called next.

Teacher: Single moveable. Very good. Show me it in action. Yes, good; good.

Narrator: This brings us to the end of Investigation 3. Be sure to check over the interdisciplinary activities and have the students do the math problem of the week.

<Investigation 4, Part 1>
Narrator: In this investigation, the students will get into their four different pulley systems in greater depth. Here is what they will need: From the kit: The half meter sticks, the scales, the binder clips, the pulleys, the duct tape, paper clips, loads and ropes.

You'll need to provide heavy books, masking tape, student journals and the completed Pulley Diagrams sheets. Duplicate the student sheet called Pulley Data and one copy of Assessment Chart for Investigation 4.

Start this session by reminding students that pulleys are members of a general category of devices called simple machines.

Teacher: So levers are a kind of simple machine. And when you use a simple machine, it helps you in some way. Can anyone remember the two ways that simple machines help us?
Sam?

Student: By lifting things easily.

Teacher: Right.

Student: To help us.

Teacher: Right. They make the work easier. Can someone think of a second way?
Nick?

Student: They give us an advantage.

Teacher: Good. They give us an advantage. And how are these two pulley systems the same?
Thomas?

Narrator: The students respond that they both use two pulleys and a rope. When asked how they are different, the students respond one has the effort pulling down with two ropes holding up on the load and the other has the effort pulling up with three ropes holding the load.

Teacher: Okay. If we were to use a single system and were going to double the load, how many newtons would it take to lift a double load using the single fixed pulley?

Narrator: The teacher asks the students to predict what would happen if they each used a single pulley system to lift a double load. The predictions of 4.8 newtons for the single fixed and 2.4 newtons for the single moveable.

The teacher distributes the Pulley Data sheets and they discuss the headings of the first six columns. They can fill in some of the columns by looking at their Pulley Diagrams. They will be able to fill in the rest after working with their pulleys again.

The students measure the effort for two loads. The teacher reminds the students that they need to add .5 newtons to their reading when the effort is applied downward. The teacher visits with each group and assesses progress.

Teacher: That's good. You start from a down position and then raise it up and look at the spring scale while you're moving it. That's the way. What's the reading?

Student: 3 and a half. I think it's 3 and a half.

Narrator: When all of the measurements have been recorded, the teacher asks the groups to discuss the data and see if they can see a relationship between the number of ropes and the effort required to lift the load.

Teacher: See if you can come up with some conclusion about the relationship between the number of ropes and the amount of effort that was required.

Student: The one with the one rope has the most effort put into it.

Student: And then the one with three ropes has like less.

Student: The least.

Student: The least.

Student: And then they both have 2.5. So the more the rope, the less you have to --

Teacher: So in your groups what did you find out? What is the relationship between the number of ropes and the effort?
Shanesha?

Student: The more the ropes, the less the effort.

Teacher: Very good.
Nick?

Student: You get a bigger advantage with more rope.

Teacher: Very good. You get a bigger advantage with more ropes.

Narrator: In this part, the students are introduced to the mechanical advantage that they can have by using a pulley. The greater the number of ropes supporting the load, the less the effort needed to lift the load. And furthermore, the effort needed to lift the load can be predicted if you know the weight of the load and the number of ropes supporting the load.

Plan to have the students read the Science Stories while they are doing this investigation.

<Investigation 4, Part 2>

Narrator: In this part of the investigation, the students compare the effort needed to lift the load 5 centimeters and the distance the effort has to be applied. Here are the materials we'll need: From the kit: The half meter sticks, cardboard sheets, pulleys, the duct tape, binder clips, paper clips, loads and ropes.

You'll need to provide heavy books, masking tape, student journals and plain white paper. Duplicate the student sheets called Pulley Data and Starting Line and Response Sheet - Pulleys At Work. Have Assessment Chart for Investigation 4 available.

To assemble a starting line for Part 2, you'll need the Starting Line sheet, some tape, a blank piece of paper and a cardboard sheet. Start by centering the Starting Line sheet on the bottom of the cardboard and taping it in place, top and bottom. Then position the plain piece of paper over the top of the words "starting line" and flush with the top of the sheet. Tape it in place. That's it.

Begin this session by discussing the effort measurements made in Part 1 and the advantage that students were able to gain. The teacher explains that in the natural world, you never get an advantage for free. Now an investigation will be aimed at discovering the cost of reducing the effort needed to lift the load.

Teacher: So we're going to be investigating what we have to pay for in order to get something easier.

Narrator: Now an investigation will be aimed at discovering the cost of reducing the effort needed to lift a load. She goes on to direct the students' attention to Part 2 of the Pulley Data sheet where the students will record their findings. She also discusses the price for reduced effort, which is the greater distance the rope must be pulled.

The students can graph the relationship following the suggestions in the mathematics extensions session. The students attach the cardboard to the top edge of their desk with masking tape and position the half meter stick over the middle of the cardboard. The students set up a single fixed pulley system with a single load.

When they are ready, they stick a pencil through the effort end of the rope with the pencil supporting the load. They draw a little horizontal line. When the top of the load is at 0 centimeters on the Starting Line sheet, keeping the pencil level, they drag the pencil straight down the paper drawing a line as they go.

When the top of the load reaches the 5 centimeter mark, they draw another little horizontal line marking the spot. They measure the line with the half meter stick and record it on their student sheet. They label the line SF for single fixed.

Student: Okay.

Student: Hey, stop.

Student: Make a line.

Narrator: Testing the single moveable pulley.

Student: Okay. Go up.

Student: Wait. All right. Up.

Student: Stop.

Student: 10.

Student: It's 8.

Student: It's 9.

Student: Stop; stop.

Student: I can't see.

Narrator: The students think about what these results mean. You may get some discrepancies in the results. Possible causes are the students don't hold the pencil straight or they don't measure accurately. But the results should be close. You may want to have them do these tests more than once. While waiting for the other groups to complete their investigations, these students are discussing their findings and answering the two questions on the bottom of their student sheet.

Student: You use the -- when you --

Student: No. The more ropes, you use the less effort you use and it moves more -- and it moves the effort more.

Student: Using more ropes gives you the advantage.

Narrator: The teacher asks each group to discuss the advantages and disadvantages of using the pulley system.

Student: You have to like move it 14 centimeters to make it move 5 centimeters on that one.

Student: Oh, but --

Student: But that's -- in order to -- notice the more effort you put into it, the less distance the effort moves.

Student: It is lighter, too.

Student: It is lighter.

Student: So we should put that down for like --

Student: So you have to move it longer with less effort to get it to move the same distance.

Student: Yeah.

Student: So it can be easier.

Narrator: After a few minutes the teacher asks the class to report the advantages and disadvantages of the pulley systems. The teacher emphasizes the relationship between the number of ropes lifting the load and the advantage. She also discusses the price for reduced effort, which is the greater distance the rope must be pulled. The students can graph the relationship following the suggestions in the mathematics extensions section.

Teacher: I would like you to think about what use the largest pulley system in the world would have. How could we apply this and come up with the largest pulley system in the world?

Makayla?

Student: You can lift Abraham Lincoln's statute out of the Lincoln Memorial.

Student: Like a crane like could -- like junk metal like cars, you know, like they are in squares. They can lift it and take it to a junk yard.

Teacher: Uh-huh.

Student: You can lift a very, very big building.

Teacher: Lift a very big building. Very good.

Narrator: In this part, students learn that benefits gained by using simple machines are always balanced by costs. When the benefits outweigh the costs, the machine is a useful tool to assist with the accomplishment of work. This is your last chance to get those student ideas and questions into the Project Folder.

<Investigation 4, Part 3>
Narrator: In the last part of this module, students do their own investigations. While the students are doing their projects, you'll be able to gain some insight into how well they've internalized the ideas of mechanics.

This is the time to bring out the Project Ideas Folder. As much as possible you want students to use their own ideas and investigate the questions they came up with during the module. If you don't have enough ideas in the Project Folder for everyone to investigate, you can use the Project Ideas sheet to help students think of more investigations.

The Project Proposal sheet should be completed by each student or team of students doing a project. You will want to make sure the projects the students propose are realistic and will be of some benefit to the class. This sheet also helps you control materials.

FOSS suggests students give three-minute presentations following the Presentation Guidelines sheet. They can also make a poster to help them explain their investigation to the class.

You should plan about two weeks for the students to complete their projects. You can spend time in class or the students might want to work on their projects at home. The Assessment folio has suggestions for scoring the student work on the projects. Also in the folio you will find information and masters for two kinds of summative assessment: An end-of-module test given in a variety of formats and suggestions for assembling portfolios.

This brings us to the end of the levers and pulleys module and our brief introduction to simple machines. I think you'll agree that they are not really that simple at all. And in fact, during the development of this module, we considered calling it not so simple machines. If your students were paying attention and the ideas resonated well, I think that they'll never again look at a simple kitchen appliance or tool the same way that they did before. They will always see the levers in them.

If your students are still enthusiastic about getting further into these simple machines, I would recommend that you look at the mathematics extensions carefully because this will allow them to take the next step into the mathematical model for simple machines.