

FOSS ® MODELS AND DESIGNS
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 Models and Designs>

Lowery: Conceptual models are tentative schemes. They help scientists organize ideas around things that cannot be directly seen. Design models help engineers to create machinery, products and other items for particular purposes.

The Black Box Investigation presents a conceptual model problem. Without opening the box, the students must determine what the inside looks like. This experience is analogous to the work of scientists who have never seen an atom or the whole universe, yet they have developed conceptual models of what these phenomena are and how they behave.

Student: I think this looks too big.

Lowery: The Go Carts Investigations present design model problems. They require knowledge and inventiveness on the part of students to construct them. This

investigation is analogous to product development of all types.

<Larry Malone Introduction to Module>

Larry Malone/Narrator: Hi. I'm Larry Malone. I'm here to help you get started with the FOSS Models and Designs module. The module comes in four investigations designed to introduce your students to the important idea of a scientific model and to introduce them to some of the principles that guide design and engineering.

Most of the equipment you need for teaching this module comes in the kit. The materials you see on the table in front of me came out of these two boxes. There's enough permanent equipment in the kit for a class of 32 students and enough consumable equipment 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.

These are the items that you'll have to get from the FOSS Measurement Kit. And these are the items that you'll have to provide yourself.

Before you start teaching the module, be sure to spend some time with the Teacher Guide. This is the heart and soul of the program. There's lots of information in there that will not be covered in detail in this 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 make the best use of the Teacher Guide. It also includes valuable background information specially written for teachers who have not had extensive science background.

Next you'll find the Materials folio. If you are the first teacher using a new kit, you will 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 lots of time and preparation 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 background information specific to this investigation. There's a section called Teaching Children About which gives you some insight into research about how children think and learn. Each investigation has several parts. For each part of the investigation, you'll find a Materials list, Getting Ready section and step-by-step instructions for how to proceed through the investigations.

At the end of the folio you'll find Interdisciplinary Extensions. You can do some of the 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 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-the-module testing or 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-the-module assessments. Included with the module you will find Science Stories for students to read. The Science Stories folio gives you background information, recommends when to read the stories and suggests follow-up activities. You may want to read the stories during a reading period rather than during science time, especially if you only teach science a couple of times a week.

In the Resources 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 that we've had a brief look at the student equipment and turned the pages in the Teacher Guide, it's time to go systematically through the parts of each investigation. And along the way we'll be visiting the classroom to see how the students engage in the investigations, as well.

<Investigation 1, Part 1>

Narrator: This investigation gets rolling when you introduce students to the black box and challenge them to figure out what's inside. For each part you'll want to set up a Materials Station. Here are the materials that you'll need for this part: You need black boxes, As, Bs, Cs and Ds. These come from the kit. And you supply lined paper for student journals.

In addition, you'll want to duplicate the student sheet called Models and Designs Journal

for each student and make a copy of the sheet Black Box Schematics for yourself. Make a copy of the Assessment Chart for Investigation 1, as well.

Assessment opportunities are embedded in the investigations throughout the module. You can prepare yourself by going to two places in the folio. First go through the Getting Ready section and look for the notes on assessment. And second go to the Assessment folio and read the appropriate section.

If you're the first teacher to use the kit, you'll need to make the 16 black boxes, four As, four Bs, four Cs and four Ds following the black box schematic sheet here. So I've got one box here that I'll use as a demonstration for that.

In addition to the 16 black boxes, I've got the roll of masking tape, the roll of black electricians tape, marbles, and the cardboard shapes that will actually form the barriers inside the boxes. I've got the rectangles and triangles here. As I finish, I'm going to want to put a label on a blue dot with a marking pen. And to cut the tape along the way, I'll use scissors.

So here is the procedure. I'm going to make a Box A. So I'm going to open the box. Take one of these shapes. In this case a triangle. Put it in the corner. Get it positioned. I'm going to take the tape here. Pull off, oh, maybe eight centimeters and form a loop about this size right here. I'm going to stick it on the back of the piece. Nothing fancy. Put it in the corner. Press it down securely. Drop in a marble. Close the box. Done.

Now, to close it, I'm going to use the electricians tape. I'm going to start the tape right here just inside the hinge. Stick it on here like this. Come around the box. First tape. I'm going to repeat with another strip here. And then I'm going to put one across like this. When I'm finished, I've got this, labeled A up here at the top by the hinges. And it's ready to go.

Now I'm going to repeat the process. Three more As, four Cs, four Bs, four Ds. Two of these to form the barrier here. One here. And then the other triangle here for this one.

It's recommended by FOSS that once the boxes are made, they remain permanently closed and become permanent equipment in the kit. If you're in agreement with this philosophy, you can make them doubly secure by closing them securely with additional tape. You can eliminate the temptation of peeking in the corners here like this or sticking things into this crack here.

So what I like to use is this packing tape that's transparent. And by just making a couple of nice tight wraps around the box in this direction and then right over the identifying letter, that's pretty secure. Now, if you're really into security, you can go the other

direction. That should do it.

At the fifth and sixth grade level it's a good idea to teach students to make accurate notes in a journal. The process of making student journals is really very simple. Take one cover. A stack of about, oh, maybe ten sheets of lined paper. Bunch them up. Put a staple in the corner. There's a journal. Another alternative is if you're using three ringed binders with your students, three-hole punch this. Put this at the head of the section. Call it the Student Journal.

Prepare Word Bank and Content/Inquiry charts using large sheets of paper or a flip chart. Make a Project Folder. As students come up with interesting questions or ideas during the course of the investigations, have them write them down on paper and put them in the folder. This will be a good resource for students when it comes time to select projects towards the end of the module.

The session starts when you distribute journals to the students and explain that just like scientists, they will be keeping notes throughout their investigation.

Teacher: There's something inside the black box. But we don't know what it is because we can't look inside. What I would like you to do is you're going to be in a group of two. And I'm going to give you a black box to investigate. And I want you to think about -- try to figure out what might be inside.

Narrator: The teacher tells the class the rules. The boxes remain closed. No drawing on the boxes. Not even with erasers. No violent shaking or hard pressing. The boxes might break.

Teacher: The third rule is that you may not open them. And you can use your journals to write down any kind of ideas you might come up with.

Narrator: This teacher is passing out the boxes to each pair. You can assign a box to each pair by letter and have them go to the Materials Station to get them or you can put Box As and Bs at one location and Cs and Ds at another. The getters then pick up one box from each location. The important thing is that the two teams in a group should not be working with the same letter box.

Student: It kind of like gets stuck or something like that. Like when you shake it a certain way, it like gets stuck with some kind of sponge or something.

Student: There's something else. Let me see.

Narrator: After three or four minutes the teacher asks what they have discovered.

Teacher: Tell me.

Class: Marbles.

Teacher: Marbles, yes. There is, indeed, a marble inside.

Narrator: He encourages the students to concentrate on location and shapes of things in the boxes, not the materials of which they are made. He suggests that they use their journal to draw pictures or diagrams of their ideas.

Teacher: The shape of things that are on the inside. I want you concentrating on locations and shapes.

Student: It's like a line going down here or is it like the shape here, too?

Student: Let's see if it -- no. I feel --

Student: Put your hand right here. See, watch. See, it's not touching.

Student: Make it stick and then like this and then see if it --

Student: It gets sort of stuck.

Student: Yeah.

Student: The other side goes through. See. But on that side it doesn't. See.

Student: Yeah.

Student: It might be like a flap that only goes one way so when the marble comes that way, it can go through. But when the marble comes that way, it gets stuck.

Student: It has something right here. But if you go over it, it gets stuck. You can't go over it because it gets stuck right here. You can try it.

Student: See, it's not going.

Student: Right here.

Student: See; see. There's something stuck right there.

Narrator: While the students worked on the boxes, the teacher drew 16 box outlines on the board, four under each letter. After about 15 minutes he asks each pair to send one person to the board to draw up what their box looks like. When the drawings are complete, expect to see different designs under each letter.

The teacher introduces the concept of model. He explains that scientists make models of things that are very big, like planets, things that are very small, like atoms, and things that are impossible to see, like black boxes. A model is a representation or explanation of a system that cannot be observed directly.

Teacher: And we're studying black boxes today as a way to see how scientists use models to find out about things that they can't look into.

When I look at the models that you've drawn here, this person's model shows a rectangular shape here in the lower left corner. This person's model shows sort of a stair step shape that's inside down on the bottom part of the box. When scientists come across a problem like this, they get together to try and share information. They collaborate on the problem.

Narrator: The teacher explains that when scientists are working on difficult problems, they often publish articles in scientific journals for other scientists to read. When scientists go to conferences, those working on similar problems get together and share their information in an attempt to solve problems together. This is called collaboration.

Teacher: -- all of the As together to collaborate on what they think the A box might look like. And I'm getting all of the Bs together and all the Cs together and all the D scientists together. And in that larger group, I would like you together to try to come to consensus, try to come to agreement, on what you think the inside of the box looks like. Again, concentrate on location and shape.

Student: Look, it's stuck right there. And now I hit the bottom.

Student: Oh.

Student: If you go over here -- see, look.

Student: See, you can go all the way over.

Student: See, it's going down like that.

Student: I know. But it's stuck by the wall.

Student: I know. That's what I'm saying.

Student: We're saying it's kind of like a ramp. If you look at it a certain way, if it's coming down this way, it's kind of coming down like a ramp, see.

Student: But it's not going up and down. It goes up and it goes like this.

Student: See, we made it when it goes up, it can make it over. But it can roll back, too.

Student: It goes like this.

Student: It's right there.

Student: I think you guys are making this flat because it seems -- because when we listened, it seemed like it went through one way but couldn't go through the other way as well. But if it's a ramp, it means it can only go one way, depending on how the ramp is positioned.

Student: I know the ramp starts here. That's why the marble is stuck. And when you get over here, it goes like that.

Student: It's a ramp, but it just keeps going up.

Student: All right. We all agree it's a ramp but it goes straight up.

Student: Okay. Yeah.

Narrator: While the students work on their models, the teacher draws four large outlines on chart paper and labels them A, B, C, D. As each group comes to consensus, they select one member to draw their model on the chart paper.

Teacher: First I want to congratulate you for as a group discovering what was inside the box. And I want to talk to you about black boxes in real life. Because in real life when you're talking about a solar system or atoms that are too small to bring in a laboratory -- you can't go in those things. You can't look inside. Those are real life black boxes. And what scientists do is gather more information, and they keep making a new model. And as they get new information, they revise that model and make it better.

So you have an idea of what's inside your black box right now. What could you do to find out more information so that you could revise your model? What kinds of things could you do with your black box or to your black box to help you get more information without opening it?

Sara?

Student: Well, if you had another black box, you could test your theory. Like if your theory was there was a ramp, you could like put another ramp in another black box and put a marble in there and shake it and see if it sounds the same.

Teacher: And compare the two.

Student: Uh-huh.

Teacher: Use another black box that's identical and one you could open.

Student: Uh-huh.

Student: You could probably X-ray it or use a strong light.

Teacher: So you could use some technology and X-ray machine to see what might be on the inside.

Narrator: After the getters return the black boxes to the Materials Station, the teacher asks the students what new words they used in this lesson.

Student: Working together on a problem.

Narrator: They discuss what the words mean as he adds them to the word bank. Next the teacher asks some questions to help students put concept statements together to be listed on the Content/Inquiry chart. As students come up with statements and questions not yet answered, the teacher will add their questions to the chart, also.

In this part, students learn that a model is an explanation of a representation of a system that is not possible to observe directly. Be sure to check the Science Stories folio and plan some time for the students to read the stories.

<Investigation 1, Part 2>

Narrator: In Part 2, students use materials to build physical models of black boxes and compare them to the black boxes that they used in Part 1. Here are the materials you will need. From the kit: the 16 prepared black boxes, 16 empty black boxes, the two rolls of masking tape, the marbles, the bag of rectangles and the bag of triangles.

Duplicate the student sheet called Response Sheet - Black Boxes, which you can use for assessment. Have Assessment Chart for Investigation 1 available so you can make notes as you work with students. Consult the Assessment folio for details.

Begin this session by telling students that you have some black boxes, cardboard shapes and marbles for them to use to try and build a box that behaves like the one they studied. Reorganize the students into teams of two and let them start building their box. Students may not have a good strategy for how to stick the shapes into the boxes. It might be profitable to show them how to take a piece of tape and make a loop with the sticky side out. And use that on one side of the drywall piece to make an adhesive surface.

Students strive to create a black box that behaves like the one they investigated. Once they are satisfied with their model, they reform into their conference groups and compare models. When everyone agrees, if they would like, they can change their consensus model on the chart.

Before ending this session, have students complete the response sheet called Response Sheet - Black Boxes. This will help you assess how well they understand the concept of black boxes. In this part, students learn that models can be refined and revised. One way to do that is by comparing the unknown to the known as they refine their model.

<Investigation 1, Part 3>

Narrator: In Part 3, students are introduced to a provocative device called the Drought Stopper. When you pour 100 milliliters of water at the top, 500 milliliters will come out at the about the bottom. Students are invited to draw pictures of how they think the Drought Stopper works. Here are the materials you'll need for this part: From the kit: The cardboard box -- it's flat right now -- the one liter container with the hole in it, two pieces of plastic tubing -- long and short -- a little plastic funnel and a roll of masking tape.

From the Measurement Kit you'll want to get two basins, a thousand milliliter beaker, a hundred milliliter beaker and you'll need to supply water and the student Models and Designs Journals. Have Assessment Chart for Investigation 1 available.

Check your kit to see if there's a Drought Stopper already assembled. If not, it's quite easy to construct. Okay. There are two constructions here. One is the box. We'll get to that second. And the other is the Drought Stopper itself. The funnel and short piece of tubing just need to be put together. This is what's going to guide water into the system. So that's all there is to that.

This other part here is a little trickier. I need to run this plastic tube through this hole. And the hole is considerably smaller than the diameter of the tube so it's going to be a very tight fit. In order to make it a little easier to run that through, I'm going to cut this on a very slight angle like this. Now I'm going to force that through this hole here. It may take a little twisting and turning but it's going to go in there.

And once I get it through, then I'm going to pull most of the length of the hose through so that it's inside the container. I'm going to leave about three centimeters sticking out. Now here is the critical part: This end of it I'm going to form a loop so that the end of the hose is right on the bottom of the container in here. And I want to kind of twist it so that flat beveled edge is flat against the bottom. Now we're all set.

You can probably see through the container a little bit that I've got an arch of that tubing there. The hose comes through the side of the wall, comes up and it goes back down to the bottom. Okay.

Let's put the housing together. For this, this is just making a cardboard box, folding the sides like this. Right here is a die cut hole. That's where this will insert. Let me just tape this -- let me turn it over now before I tape anything. Let me fold the sides in here. Now I'm going to tape the box just using a little bit of our masking tape. All righty.

Notice a hole down here at the bottom. Now the trick is to install this in the box so that this little hose -- I'm going to pull it out a little bit more so that this little hose sticks out this hole. See how that goes. If you find you can't get the tube through the hole easily, you might want to enlarge the hole a little bit by reaming it out with a pencil or perhaps a pair of scissors so that the hose sticks out through the hole in the box and angles down a little bit.

Now we've got the box up against the wall there. That's why this hole is on this side. Then I close the box up and insert this hose through the hole. It's going to direct water right into the container.

So this is the Drought Stopper right here. Any water that I put into the funnel here will end up going into the container. Place a basin in position underneath the outflow to catch any water that spills and give a few practice runs to get a feel for how the Drought Stopper works.

Now that the Drought Stopper is all assembled, I'm going to prime it for use in the classroom. What I will do now is take about 400 milliliters of water, maybe a little bit more, and pour it into the liter container inside the box. And then I'm going to look closely to see just how high the water level has come.

If the water level is still substantially below the top of the loop of the hose inside the container, I'm going to pour some more. I want to bring the water level up just below the top of the loop. Then what I will do once I've got it in prime position is close the box up, use some tape to close it to hold it shut and then I would carefully carry it for the demonstration.

But what I would like to do for you is to remove the guts of the Drought Stopper so we can observe it out in the open here to see what priming looks like. I'm going to put a container underneath the outflow just in case things start happening a little more quickly than I expect. I've got my 100 milliliter beaker ready. Now I'm going to pour the water into the container. You can see right now that I'm going to need a little bit more to bring it up to prime level. Prime.

Now I need 100 milliliters of water to actually complete the demonstration. So I'm going to pour this in. And let's see what happens. Now, this -- normally it would be going through the funnel. But I'm just going to pour it in.

This 100 milliliters of water is going in the loop, is completely submerged and water starts flowing. I can catch the water here. And I'm sure to the amazement of all, there's the 100 milliliters I've put in and it's still coming. There is another hundred. And it's still coming.

All of the water that was in the container is going to flow out much to the amazement of all of your students. Oh, yes. And you may have noticed I was pretty sloppy here. But that's one of the reasons for the basin. I can now round up every last drop and demonstrate to the students that, in fact, for a modest investment of 100 milliliters, we got back nearly 600 milliliters of water.

When you're ready to conduct a demonstration and the Drought Stopper is primed and tucked into its cardboard box, carefully carry it to your demonstration location. Pour in the last 100 milliliters of water. The Drought Stopper siphon will start automatically and have the 1,000 milliliter beaker handy to measure the water that comes out of the Drought Stopper.

The teacher asks the student to read the volume of water in the beaker. It runs 500 milliliters. How could that be? The students do the experiment a few times more with the same result. They are not allowed to pick up, push, tip or manipulate the system in any way.

Teacher: I only had 100 milliliters of water.

Student: Do it again.

Teacher: Okay. In your groups now work together on one drawing of what you think the inside of my Drought Stopper invention looks like.

Student: There had to be tubes going in and out.

Student: I thought they put water in there before.

Student: I think it's the tube.

Student: That's what I think.

Student: I think they put water in it before. They could have done that.

Student: You see, what I think is if you pushed it like there was a hole in it like this and there was a little thing that covered up the hole but then it would push down on it like this. The extra water and the hole would be uncovered. The water would all run out that hole and go out the tube that sticks out.

Student: I agree.

Student: I agree, too.

Narrator: Let the Drought Stopper remain a mystery until the end of the module. If it remains a mystery, some students might like to take it on as their project at the end of the module and try to build a Drought Stopper of their own.

In this part, students have had another opportunity to develop another conceptual model. A conceptual model might be a drawing, computer program or mathematical description of something. And the full form of what a conceptual model means will be developing as the students work through the rest of the module.

This brings us to the end of Investigation 1. Be sure to look over the interdisciplinary activities to see if some of those meet with your other curriculum goals and challenge the students with the math problem of the week.

<Investigation 2, Part 1>

Narrator: In the first part of this investigation, students are introduced to a whimsical device called the Hum Dinger. When you pull its string, it hums. When you release the string, it dings. Here are the materials you'll need for this part: From the kit you'll get the construction boards and the bases to support them. Here are the cells and cell holders. Motors, binder clips, bells, sticks of three sizes -- long, medium, short -- wooden hubs, and clothes pins, string, rubber bands, masking tape, copper wire, jumbo paper clips and plastic bags that the students will keep their inventory in.

You'll need to provide a pair of pliers, student scissors, a large pair of scissors, a large shopping bag and the student journals. Duplicate the student sheet called Hum Dinger

Parts Inventory. Make a copy of the Hum Dinger Construction sheet. Make a copy of the Assessment Chart for Investigation 2, which you should keep with you so you can make notes about how your students are working.

To prepare for this part of the activity, duplicate the Hum Dinger Inventory sheets. Cut them in half. Use the numbers written on the inventory sheet to guide the assembly of sets of these construction materials for each collaborative group, one set per collaborative group.

After you've assembled all of the items in the quantities called for, put an inventory sheet into each bag and the job is done. Now, some teachers choose to have the students make the inventories. They provide the bags and the inventory sheets and then invite the getters to come up to the Materials Station, pick up an inventory sheet and fill out the sets according to the numbers here.

Some of your students may have used this equipment before but it's still worth reviewing for the sake of those students who haven't encountered it before. The cell clips right into the cell holder like this. And then the fond stock clip has this little lever sticking up. By pressing down on that, it reveals a little arch in the center of the clip. You can pass a wire underneath the arch and then when you release the little flipper on top, it will grip the wire securely.

Here is how to build your Hum Dinger: Find a quiet place where you won't be disturbed for about 20 minutes or half an hour. Collect yourself and collect these materials and set to it. You'll need to have one construction base and support. You'll need to have tape and a pair of scissors is good and a length of string, one of the little bells, three rubber bands, a long stick, four short ones, a small binder clip, one large paper clip, the motor and the cell and cell holder. That's what you'll need to build your Hum Dinger.

Here is how I recommend you do that task: First thing we want to do is attach the cell holder to the base. Now, notice that the holes are distributed symmetrically. But the whole set of them is shifted towards this end of the board. That's important. So make sure that this hole which I'm going to call No. 10 -- 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 -- no. 10 is closer to the edge than No. 1.

So over here by hole No. 1, I'm going to position the cell holder. So I'm going to take it out of here. I'm going to flush it with the base and with the side. And I'm going to stick it on with masking tape. Now I'm going to take the four short sticks and I'm going to put them into Holes No. 2, 4, 7 and 10. Make sure that they are in there nice and tight.

Now I'm going to take the paper clip and I'm going to bend it into a new shape. And this is important. I'm going to take the inside wire that is now pointing down. And I'm going

to bend it out to the side like this so it points straight out to the side. And then I'm going to open it up another way. I'm going to take and open it up like this. Okay? So now I've transformed it into a new shape. Kind of three sides of a rectangle curled back here.

Now I'm going to grab this bottom part and I'm going to twist it so that it now is rotated 90 degrees to where it was originally. That's the shape that we want. This is going to become part of our switch for the hum of our Hum Dinger. And where I'm going to position this now is right up here on my cell holder.

So what I'm going to do is push down on the fond stock clip and slide the end of the paper clip through the fond stock clip so that this is attached up here at the top. I'm going to go ahead and put the cell in right now. Okay. And now I'm going to install it in the base like this.

Next I'm going to make a switch that's going to reside right in this area here and pivot on this stick right here. To do that I'm going to clip the binder clip onto the long stick and slide it over the stick like this. It's a little tight. It's hitting the side of the cell holder. So I can move it back a little bit. That's looking pretty good now.

Now, what I want to have happen is I'm going to connect the motor to one end of the cell and the other end of the motor is going to make contact here. So I'm going to take this switch, lay this wire right along the bottom of the stick so that the stripped end of the wire is just extending over the end of the wooden stick a little bit. That's a good position right there. Now with a little tape, I'm going to secure that in place. I don't want to cover the exposed part of the wire. It's looking pretty good. There's that wire.

Now when I reinstall this, that wire is going to go right into this yoke and go up and down inside this paper clip yoke that I made. Let's put that together and see how things are aligning. Pretty good here. Okay. Good.

Now let me connect the bottom wire of my motor to the bottom of my cell here. Now, by adjusting this wire yoke so that it makes contact with the end of this wire only, when I pull down, I'll have the switch that I need for my Hum Dinger. So I'm going to have to work with this. Looking good. Okay.

Now, let's put a rubber band around here so that when I work my switch, it's going to bounce back by itself. Here is how I'll do that. I'm going to put a rubber band around this stick. I'm going to take it behind this stick here and bring it back up around and here. Okay. Good.

Now it's time -- we've got the hum going. Now it's time for the ding. I'm going to suspend the bell right in here with two rubber bands. I'm going to put two rubber bands

through the handle of the bell. One of them I'm going to bring over to this stick, both ends of it. Both ends of the other rubber band I'm going to bring over to this stick. And now the rubber band -- the two rubber bands are holding the bell suspended right over the other end of my lever stick. Looking good.

Now to operate the thing with a string, I need to run a string through this hole and tie it around my switch. Okay. Let's see how we're doing here. Great.

Now, the final thing I want to do is make the hum a little bit louder. So I'm going to take a small piece of tape and attach it like a flag to the shaft extending out from the motor. I'm just going to pinch it right around there. It seems a little bit big. I'm going to trim a little of that off. That seems pretty good. Yeah, now it's making a good racket.

To hold the motor down here against the base, here is what I want to do: I'm going to pull the whole business out of the base. I'm going to put two rubber bands around the base like this. I'm going to reinstall -- look those rubber bands are positioned to hold the motor into place. So I'll just put those little guys right in there.

Now a little fine tuning of the switch. This is the trickiest part, the switch here. If all goes well, I've got a hum and a ding, which is going to be reliable, trustworthy and durable.

You may be wondering why pliers are suggested as part of the materials for this activity. Occasionally the students will be so enthusiastic in their effort to make a Hum Dinger or go-cart that they'll get things jammed in so tightly that the dowels can't be removed with hand power. You'll need to have a pair of pliers to grip the dowel and twist it out of a hub or out of a construction board.

Begin this session by introducing and demonstrating the Hum Dinger.

Teacher: And this particular invention does just what it's called. It hums and it dings. Hum. Ding. Okay? Your task today is going to be to work together in your collaborative groups to try and create a model of a Hum Dinger.

Narrator: The teacher explains to the students that there are two types of models. When words, drawings or mathematics are used to describe how something is built, it's called a conceptual model. In this activity they'll create a physical model, a real model. Instead of a drawing, it can be tested and compared to a real Hum Dinger.

Teacher: You may send one person from your collaborative group to come up and test this Hum Dinger. But there are some rules about that. When you come up to test it, you must place your hand up at the top here and hold it. Then you take your other hand and

you can pull with the string as long as you like and let go. You may not try to peek inside the bag or tear the bag apart or open it in any way. You may not move the Hum Dinger from where it is.

Okay. Before you get started, I want to remind you of what it's like to work in a collaborative group. Make sure that you're allowing everybody in your group to have a turn to work with the materials, share the time with the materials. Make sure that you're all using each other's ideas.

There are no ideas that are stupid or wrong. Try out anything that comes up. And whoever is going to start first, make sure you're thinking about fairness and how you can make sure that everybody in your group is going to get a turn with the materials.

Narrator: The getters come to the Materials Station for their equipment. The starters check the inventory of materials.

Student: We've got a D cell battery, a D cell battery holder, a motor, short sticks, medium sticks, and long sticks.

Narrator: When they begin, students seem to tinker aimlessly. Relax and offer encouragement. Let them work on their own for most of the period. Students usually identify the motor as the source of the hum and the bell as the source of the ding right away but don't immediately come up with ways to coordinate them to make a Hum Dinger. After a while they begin to put parts together.

Student: Let go.

Student: We have to tape it down somehow.

Student: Look, we have masking tape on it.

Student: It makes it a loud hum.

Teacher: It makes it a loud hum. Boy, you can really hear that.

Student: I think this is cracking.

Teacher: What are the paper clips doing?

Student: Oh, the metal makes it higher.

Teacher: So it will raise it up.

Narrator: The teacher reminds the students that scientists often go to conventions to meet with other scientists to share ideas that might help them solve problems.

Teacher: And that's what we're going to do now. We're going to hold a mini convention. And a convention is when people get together to talk over their ideas.

Brigitta?

Student: Our group decided that maybe we could -- to make it ding, we could wrap that around like that. And then when you pull up, it will hum. But when you drop, it will ding.

Student: You tie a string to the motor -- to the motor's wires and we put -- what are these called?

Teacher: The clips on the end?

Student: Yeah, the clips. We put one in like this through here so whenever that -- we pulled the string, it would start humming. And then when we let go, it would stop.

Student: We put the paper clips and tape and rubber band on it and we put some masking tape on this. And -- because at first we put it on the battery and it made a lot of noise. Then we put it like this.

Teacher: So you're discovering that putting the masking tape on the top of the motor when it spins, it makes a louder noise, you can really hear that hum.

Student: And we would tie the string to it. Because when we touched -- if we would touch the bottom, it would still make it on the bottom. We would put it right here and we would pull the string.

Teacher: So you're thinking about ways to make sure that when the wire comes back, it's going to hit something that's going to make it hum no matter where it goes.

Student: Yeah.

Student: Our group thought that when we would -- we would attach this to the hummer and since that -- it would spin, we would attach the string to this. So when it was pulled up, it was out of this thing's reach. When it would drop, then it would hit it.

Student: Our idea was to take the motor and put a string on one of the wires. And we had a clip with one of them attached to the battery. And we put it like under -- we had it

next to the clip. So that when we pulled the string, it goes up and hits the clip and makes the noise.

Teacher: Oh, a way to get it to hum so the string would be pulling one of the wires into something that was connected to the battery.

Student: Yeah. And the other part was already connected.

Teacher: The other part was connected to the battery so you only need to get that one touch. Great.

Some of you have been successful making your hummer hum. But let's make sure that everybody has that idea before we move on.

Narrator: The teacher suggests that students connect the wires from the motor directly to the battery and introduces the word circuit to help them focus on how to get the hum. Another helper concept that the teacher introduces is the idea of a switch. That for a switch to work you have to be able to close the circuit and open the circuit. The teacher will use his fingers in order to demonstrate this for the students.

Student: I know how to make a switch. Put that down here.

Student: What if you can hold it.

Student: Look. It's connected and now it's not.

Student: All you have to do is touch that wire.

Student: It will have to be touched to the one like that.

Teacher: So in your way it looks like we're using it sort of to turn going up and down, up and down.

Student: You tape it right here. When you pull this up, watch what happens. This goes up. And when the wires are here, when you touch it --

Narrator: The teacher asks the students to record their ideas in their journals so next time they can pick up where they left off. He asks them to write their names on the inventory sheets, dismantle the partial models, inventory the parts and return them all to their zip bags. Students may protest when asked to disassemble their hard work. But there are definite advantages to a fresh start next time. In the future it won't be necessary to disassemble the Hum Dingers at the end of the session.

Students should remember that a physical model is a three-dimensional construction designed to represent how something works. And that a circuit is a pathway through which electricity can flow. And a switch is a device for controlling the flow of electricity by opening and closing a circuit.

Check the Science Stories folio so you can plan the reading activities that you would like to have the students do during this investigation.

<Investigation 2, Part 2>

Narrator: Over the next several sessions students will be designing, redesigning, testing and designing again until they get a device that hums and dings to their satisfaction. Here are the materials that you'll need from the kit construction: Boards and bases, copper wire, string, jumbo paper clips and masking tape. You'll need to provide the bags of construction materials, student scissors, large scissors, pliers, the student journals and your Hum Dinger. Duplicate the student sheet called Response Heat -- Hum Dingers which you can use for assessment. Have Assessment Chart for Investigation 2 available.

Begin this investigation by reintroducing the Hum Dinger and reviewing the progress that the students made in the first session.

Teacher: Before you get started today, I do want to show you this one part on this Hum Dinger. How many of you noticed that when you pull on the string, you really have to pull it? You can't -- you have to really put some effort into that.

You might want to think about what kind of materials you have in your bag that will make it so that when you pull on the string, you really have to give it a good tug. It doesn't come so easily. You really have to pull it. There are things inside your bag that will help you with that resistance.

Student: Then pull it. It goes like this --

Student: Then what's this it -- if we let go?

Student: Yeah, that will go down and go ping like that.

Student: But then it won't work again. Or it will stop.

Narrator: Many of the ideas that the students come up with do not work but each student gets to try to his or her ideas and the enthusiasm doesn't seem to wane. The teacher visits are very important to keep the momentum going.

Teacher: Oh, so the problem you're having is the paper clip isn't hitting the end of the battery. That's a pretty -- wait. Before you start, wait, hold on a second. That's a pretty small spot to hit this small spot. Is there a way to make it bigger so it could hit?

Student: Run it through that loop and then try it.

Student: Pull it up.

Student: Pull up.

Student: Pull it up a little bit.

Student: Now try it.

Student: Oh.

Student: We need these two right like this.

Student: You guys have got it probably all wrong. You're only needing one loop.

Narrator: When the students seem to reach a frustration point, the teacher calls a mini conference to give hints and to ask groups to share ideas with each other.

Teacher: Did you have a breakthrough that you came up with that was helping you? A problem that you were encountering that you don't know what to do about yet?

Student: We figured out that you can even put the wire touching the bell. And put both wires, the bell will get electricity and put it through the other wire.

Student: We found out that if we pull on this string, it will make it hum. Because -- but if we pull on this string, it hums. And then --

Teacher: So you're able to pull it forward. And what problem are you having right now?

Student: We're having a problem that these two get tangled by the rope and they stay and when you let go, it still keeps on going.

Student: We found out that if we put this little piece of tape on it, then it will make the sound vibrate more and it makes it louder.

Student: Our group had found out that if we could tie two sticks like this and put another one with rubber bands and then pull it, it would make like a lever. And then that would

have like little wires on it to activate the motor. And then when you let it go, it would come down and hit the bell.

Teacher: So you're using that lever idea so when you pull on the string, it makes it go up making the hum. And when you let go, it will come down and smash on the bell.

Student: Yeah.

Student: The problem we're having is because when we lift it up, then we just drop it, it might not fall in the hole.

Teacher: I've noticed the other groups having a similar kind of problem. That they get it to hum and then when they let go, they can't get it to stop or the other way around. That's a good problem.

So you've heard from a lot of different groups now about what they were able to do so far and what kind of problems they are having. Please, while you're working in this next session, feel free to visit each other's work. Scientists when they collaborate often get great ideas by watching how someone else is solving that problem. You're all working on a similar problem. You should help each other with each other's ideas.

If someone comes to your table, please allow them to look at what you're doing. And if you have questions, feel free to ask people what they are doing. And you might be able to apply it to what you're doing, as well.

Student: You go under.

Student: Pull it hard.

Student: No.

Student: Yes!

Student: Okay.

Student: Yes! Got it.

Student: It works; it works; it works; it works.

Student: We got it; we got it.

Teacher: So will you explain to me how it works?

Student: We had the bell and I tied it onto there.

Student: This wire right here, it's touching. So when you pull, it will get closer and it will touch the point.

Teacher: So wait. You're telling me when you pull on the rope, the wire touches the end of the battery. And what does that do?

Student: Which is connected to a paper clip. Which that paper clip is connected to this. And that part is already connected to here.

Teacher: So that completes the circuit and makes it hum.

Student: Yeah. And when you let go --

Student: This rubber keeps it from going unless you pull on it.

Teacher: What makes it snap back?

Student: The rubber band right here.

Teacher: So you have the rope connected to the rubber band there. Can I try?

Student: Yeah, go ahead.

Teacher: What happens if you pull up?

Student: We never tried it. You can only pull it diagonally.

Student: The wire goes up.

Teacher: Can you pull down?

Student: That works.

Teacher: That works. Okay. How about to the left or right? All right. You definitely have a Hum Dinger. There is a Hum Dinger. It hums when you pull on it, dings when you let go. Very cool. That's a Hum Dinger.

Student: Yea! We made a Hum Dinger.

Narrator: After a lot of hard work, the students record the design of the successful Hum Dingers in the journals as a record of a permanent design. The goal is for it to be clear enough and detailed enough for someone else to replicate it. When the students have their Hum Dingers working, the moment they have been waiting for arrives: The opportunity to show off their Hum Dinger.

Student: Our Hum Dinger, at first it didn't work. But we kept on trying and now it works. When you pull, it connects to that, which is connected to that by the bull clip. And when you let go -- uh-oh.
(Applause)

Student: And when it falls, it will ding like that. (Applause)

Student: This is our Hum Dinger. We decided to put the bell like that and tie this to the wire. Because if you take one end of the wire off, it starts up.

Student: Let go.

Student: And when you let go, the bell rings.
(Applause)

Student: This is our Hum Dinger. And the way it works is the electronics are this paper clip is connected to this part of the wire. And this wire is already connected here, which is connected to the motor and comes over this big ball of wire and stuff. And when it comes up, it hits this paper clip, which connects all the wires to make the full circuit.

Student: And then when you let go --

Student: It cuts off the bell.
(Applause)

Narrator: Although not all the Hum Dingers will perform flawlessly, it's an opportunity for the students to demonstrate what they've learned about problem solving.

Student: Motor.

Student: Okay. Check.

Narrator: If you are not planning to conduct Part 3, show students the demonstration Hum Dinger and have them break down the models, inventory the parts and return them to the Materials Station. If you plan to have students replicate the demonstration Hum Dinger in Part 3, students can complete the breakdown now and inventory the parts or

they can do so at the beginning of Part 3.

In this part, the students experience a diversity of thinking styles and ways of solving problems and in the end they discovered that there are many different models that they can create to explain the same system. Encourage students to add questions and ideas to their Project Folder.

<Investigation 2, Part 3>

Narrator: In this part, the original demonstration Hum Dinger is revealed to the students and they are invited to try and replicate one themselves. This is an optional activity but a valuable one because it does involve technical reading in the context of science.

Here are the materials you'll need: From the kit: Construction boards and bases, copper wire, string, jumbo paper clips and masking tape. You'll need to provide the bags of construction materials, student scissors, large scissors, pliers, the student journals and your Hum Dinger.

If you decide to have the students construct Hum Dingers following the standard model, make copies of the Hum Dinger Construction sheet, one for each group. Have Assessment Chart for Investigation 2 available.

Be sure to test your Hum Dinger before starting this session to make sure it's still working and then kick it off by telling the students that today they get to see inside the Hum Dinger.

Teacher: And the reason that I'm going to show it to you is because I want you to know that there are many ways to solve these problems, that there isn't just one way. And so I'm going to show you one way to have solved the Hum Dinger problem. Now, this model of a Hum Dinger works by pulling up on the lever which makes the wires touch and it completes the electric circuit. And then when you let it go, the bell comes down.

Student: Oh, that's cool.

Teacher: One more time. When you let go, the bell goes. (Applause)

Narrator: At this point the teacher hands out a copy of the Hum Dinger Construction sheet to each group and following this as a technical reading and using the materials at hand, the students build a replica of the demonstration Hum Dinger.

This brings us to the close of Investigation 2. Be sure to check your folio for the interdisciplinary activities and the math problem of the week.

<Investigation 3, Part 1>

Narrator: In this part, students work in pairs to build free rolling carts called go-carts. They will be designing them using the materials they're familiar with.

We've switched away now to a new topic. We're going to be working on design. In design the students know in advance where they are headed with their projects. Before, we were working with models. They were trying to explain the unknown. This is a conceptual change.

For this part we will need the following materials: Items from the kit: Construction boards and bases, bags for the inventory, copper wire, once again sticks of three lengths and the hubs, brass fasteners, string, rubber bands, jumbo paper clips, binder clips, masking tape and clothes pins.

You need to provide student journals, student scissors, large scissors, pliers and sheets of cardboard. Duplicate the student sheet called Go-carts Parts Inventory. Make a copy of Assessment Chart for Investigation 3.

You will need to put together the sets of construction materials for go-carts. Once again, there's an inventory sheet. Duplicate them and follow the numbers next to the items here to fill out the inventories. And when you finish, insert one of the sheets into each collection. As before, if you would like the students to assemble the inventory, you can provide the inventory sheets and the bags and ask the getters to come up and fill out the inventory.

Students use the construction board and base to make a ramp. The easiest way for them to do this is to stand up, put their weight on the board as they press down and there you've got it. Then when the base is put on its side, it makes a nice ramp.

Begin this session by discussing what a cart is. Students will conclude that a cart has to have a minimum of a wheel, probably more, and a body. The teacher explains that people who design things as simple as can openers or as complicated as space shuttles are called engineers. The challenge for each pair of students is to design a go-cart that can roll down a ramp and across the floor a short distance by itself.

Teacher: What it will have to do is it's going to have to go down a ramp. And we have some ramps here. But we're not going to use the ramps right away.

Narrator: After showing the students the ramps, the teacher shows the bag of materials that they have to build their own carts. He tells them these are the same materials that they used to build their Hum Dingers for the most part.

Teacher: Now, there aren't any rules that say that you have to make a certain kind of

model cart, just that you need to make a cart. And it needs to be able to roll down the ramp. You can make anything you want. You can make it look like anything you want.

Now, in addition to the bag full of materials, there's some other pieces of material --

Narrator: The teacher shows the students the extra materials at the Materials Station. He reminds them that the large scissors, tape and pliers stay at the station. On the first trip to the Materials Station, the getters get a bag of materials and a pair of scissors for each pair. The students write their names on the inventory sheet and begin to explore the materials. Expect them to spend several minutes in free exploration.

Student: We need some wire and some cardboard. I have an idea.

Narrator: The teacher circulates among the students offering encouragement. He encourages them to collaborate and share ideas. He allows them plenty of time to explore their own ideas.

Student: Now we need to get a body.

Teacher: One piece of cardboard. Don't take a whole bunch.

Student: I can't open it.

Student: Where is the other long one?

Student: We need something in the middle so it will stay up. So maybe just a thin piece of cardboard right there.

Student: Okay.

Narrator: When the teacher notices that a number of groups are having technical difficulties, he might remind them that scientists collaborate to learn from each other. He asks them to share some problems and some solutions. However, expect some students to consider the scrutiny by other groups as espionage.

Teacher: Josh, what about your group?

Student: We're using the black binder clips. We are putting them in but we put these -- the wooden sticks in so they can tighten it. And it will let it loose and then it can roll.

Student: Can everybody see how she's using paper clips and rubber bands and fasteners and clothes pins? She's using all the different materials to combine together to make her

cart stay together, make it a cart.

Student: It's doing good. But this thing kind of limps.

Teacher: It what?

Student: It limps.

Teacher: It limps? But it rolls.

Student: Yeah.

Teacher: How do you connect it on the bottom? Hold it up so everybody can see. Okay.

Student: Well, we put the --

Student: Black binder.

Student: The black binder through the wheels so it could roll on it for the body.

Teacher: Then you hooked it all together with string.

Student: Yes.

Teacher: I think that's the first group I've seen using string. That's good. That's a great idea. It's almost -- it's done pretty much, isn't it?

Student: But we have to get another string around this side so it will stay better.

Teacher: Okay.

Student: That's if it stays.

Student: It stayed.

Narrator: This cart is too wide for the ramp.

Student: The thing is too long.

Narrator: The student found the solution.

Student: There.

Student: Now, one, two, three. Yea!

Student: You're going to make what, doors?

Student: See.

Student: It works.

Narrator: This cart may need its body trimmed or it may be attached too tightly to the axles so the wheels don't turn freely. With some adjustments, we see improved results.

Student: Hey, we're perfect scientists.

Teacher: We used a whole bunch of different things as the bearing. Bearing is the part that connects to the axle to make it spin. So some of you used the fasteners, the black clip fasteners as your bearing. What were some of the other things that you used as bearings?

Joey?

Student: The -- those little gold things, the brass.

Teacher: Jodi?

Student: The string.

Teacher: Leslie?

Student: The wire or the paper clips.

Teacher: Wire and paper clips made good bearings, too. So you could use all different materials as your bearing to hold the axle to the body and make sure that everything spun and that your cart moved.

Narrator: Students inventory their materials and put the inventory and inventory sheet and their card into the zip bag and store them at the Materials Station until the next session. In this part, students are introduced to the idea that the way something is put together is its design. And the people who use design are called engineers. They use scientific knowledge to design things that are useful to people.

Plan a time for the students to read the Science Stories while doing this investigation.

<Investigation 3, Part 2>

Narrator: In this part, students are challenged to bring the design up to a new level. They are challenged to power their carts so that they can go two meters on their own power. For this part you'll need this equipment: From the kit: The rubber bands, masking tape, copper wire and string. And from the Measurement Kit: The meter tapes.

You provide the construction materials in their bags including the half manufactured cars, the models and designs journals, student scissors, big scissors, pliers and cardboard supply. Duplicate the student sheet called Wheel Patterns. Make copies of the student sheet called Response Sheet - Go-Carts, which you can use for assessment. Have Assessment Chart for Investigation 3 available.

You'll need to make an apparatus that demonstrates one way to get power to a wheel and axle system. You'll need three rubber bands, one of the binder clips, two long sticks and a couple of hubs. Start by cutting the three rubber bands to make strips of rubber material and then tie them end to end to make one long continuous piece of rubber strand like this.

Then what you want you to do is catch one end of the rubber band strand in the cut in each end of the stick like this. And then put a hub on each end of the stick. Okay. Now we've got this loop of rubber. Now what I want to do is make a bearing. And I'm going to insert the axle into my bearing here. Reassemble. And then find the center of this loop of rubber band material and slide it into the slice at the end of the stick like this.

This is the demonstration piece. To show students how it can operate, I'm going to mount it into a construction board. Here is the system mounted on a construction board. And at this point you can demonstrate to the students how you can wind the rubber band around the axle by rotating the axle wheel system and the bearing and when you release it, the wheels turn. This should be a starter for the students as they power up their carts.

Begin this part by reviewing the design features of the free wheeling carts that the students made in the last session.

Teacher: So we made carts. And they were all really good carts. I was really impressed. And they would all roll down the ramp. But when they were flat on the ground, what did they do?

Student: Nothing.

Teacher: Nothing. They don't really roll if they don't have any kind of thing to propel them.

Narrator: The teacher challenges the students to modify their carts so they are self

propelled, able to go two meters on level ground without an external push or pull.

Teacher: Now, this isn't going to be easy. In fact, this is going to be really hard. It's going to require you to think very hard about the different ways that you can do this.

Student: Maybe --

Student: Maybe if we --

Student: We can't pull it with string.

Student: I think we should put the rubber bands under there. See, then it would probably go by itself. If you pull it back and let it go, because rubber bands are stretchy.

Narrator: Good idea, but not quite right.

Student: Why can't we use wire?

Student: It doesn't work.

Narrator: After the students have been working for a while without success, the teacher shows them how rubber bands can be used to propel the carts. He suggests that he is demonstrating only one way that might work.

Teacher: Rubber band rolled up on the axle and it goes all by itself. That's a self propelled motor.

Student: So this is one way to try it on.

Student: Wait, this is loose.

Student: It's going to break.

Student: Can you move?

Student: It's going to move towards you because you're doing it the wrong way.

Student: Okay.

Student: It's going to break.

Student: Wow. Doh!

Student: Mr. Shaver.

Student: It went forward and back.

Teacher: What do you think it would make it go a meter? It will only go so far with that rubber band, right?

Student: Why don't we make it more power?

Student: More power; more power.

Student: What the heck.

Student: It just broke.

Student: Oh, no.

Student: Why isn't it working?

Teacher: Some people are still having a little bit of trouble. So what I want to do is I want to go around just like we did yesterday with the convention and share ideas and share problems that some of you might have had in getting your cart to move or not getting your cart to move, however it is.

Student: Our cart was going okay. But when we -- at first one rubber band wasn't long enough.

Student: My car went about four inches and then it stopped. Because when we rolled up the rubber band, it broke.

Student: When we and Ashley started to roll the thing, the cart, it didn't really start to go. It went two inches and stopped. So we decided to take off some tape on the back and the front. And when we took it off, it didn't go at all. So we couldn't figure out what the problem is. And now we're going to fix the cart all up again.

Narrator: Now that the teacher has the problems on the board the class comes up with some solutions to try.

Student: You can put rubber bands on the wheels so it can have a better grip.

Student: If the rubber band wasn't long enough, you can tie some rubber bands together.

Narrator: After the teacher has recorded the students' suggestions on the board, he poses a question.

Teacher: If this wheel went all the way around one full rotation -- okay. So my finger is on the top and it goes all the way around, how far do you think that would be?

Narrator: To help students find out, here is a trick they can do. They can mark the location on the wheel, put it down on paper, and mark the paper at that location. Now we're going to go one rotation of the wheel. And when it comes back down in the same position, we'll mark the paper again.

Now I can see just how far I go with each rotation of my wheels. If I choose, I can actually quantify that metrically and find out it goes just about 14 and a half centimeters. So how many revolutions of this wheel will be required to go the two meters? Nice math problem for the students to work on.

Teacher: So if we have this wheel that's going to go 15 centimeters far in one rotation, how far do you think this wheel would go?

Narrator: Some of the children decide to try the larger wheels to see what will happen.

Teacher: Not quite.

Narrator: The students may need more than one session to perfect their designs.

Student: Okay.

Student: Go; go. Yeah!

Student: Mr. Shaver.

Student: Mr. Shaver, we did it! We did it!

Narrator: Before ending the session, the teacher conducts one more mini conference so the students can help each other with their problems. And he tells them that during the next session, they'll have a chance to demonstrate their carts.

In this session, the students learn some important technical information. They learn that larger wheels go further each time they rotate and that longer rubber bands can store more energy. And remember to add student ideas to the Project Folder.

<Investigation 3, Part 3>

Narrator: In this part, students demonstrate their go-carts and discuss their successful design features. For this part, you'll need this equipment: From the kit you'll need the masking tape, copper wire, string, and from the Measurement Kit, the meter tapes. You need to supply the construction materials, including partially developed cars, journals, scissors for students, large scissors, pliers and cardboard. Have Assessment Chart for Investigation 3 available.

Before you start this session, decide how you want students to demonstrate their carts. You might choose to have a narrow runway so that the students can go team by team and be in the spotlight for a brief time or if you would like a carnival atmosphere in your classroom, have a wide runway and let all the teams run at the same time. Whatever you choose, make sure that the students understand the rules of the road.

Teacher: Okay. Behind the line now. Oh, about halfway. That was close. Not quite. Nice try.
(Applause)

Teacher: Now, you know, you get three tries. So you know, that's not the only one. Who is next?
Saveriano?

Student: You can do it.

Teacher: Ta da! Yea!
(Applause)

Teacher: Boy, that barely made it. What did you do to make it go so far?

Student: Made the wheels bigger.

Teacher: So the different size of the wheels made a difference on yours.

Narrator: This session concludes with each team checking their inventory and placing their cart and extra parts in the zip bag for storage. They will be used in Investigation 4.

This brings us to the end of Investigation 3. Some teams may not have had a successful two meter run yet. They may need more time in order to perfect their models. However, during this time, other teams, the successful teams, can be working on interdisciplinary activities. They can be reading the Science Stories or perhaps working on the math problem of the week.

<Investigation 4, Part 1>

Narrator: In this investigation, students modify their carts to turn a corner. Here is what you'll need: From the kit: Copper wire, masking tape, string. You supply the student bags of construction materials with carts, student journals, a book or a box, large scissors, student scissors and a supply of cardboard. Duplicate the student sheet called Wheel Patterns from Investigation 3. Copy student sheets called Response Sheet - Cart Tricks, which you can use for assessment. Make a copy of the Assessment Chart for Investigation 4. You might want to check your supply of cardboard because students will be making additional wheels in this session.

Start the session by reviewing the most successful elements of cart design. The teacher proposes a new challenge: Design a go-cart that will turn a corner.

Teacher: -- around a turn. It's going to have to start from this side of the box on the line, go all the way around the box to the other side of the line.

Student: You can turn this part so then maybe it will turn sort of --

Student: It's turning.

Teacher: No. Around the cardboard. Around the outside of it. Maybe that will help. I don't know. It might not. I've never tried it before.

Student: Maybe we should use the barbed -- the brass, because the brass is bendable. So maybe it can bend by itself.

Narrator: This team has a good start but still has a way to go.

Student: Go; go.

Student: Man, it's stopping it.

Narrator: Now that some teams are beginning to make progress, the teacher calls a mini conference. Each team briefly shares one design modification they have tried.

Student: We used the barbed wire so -- to make it turn to make the front of the wheels like slanted so then when we rolled the rubber band, it will turn by itself.

Student: Well, our cart, what we did instead of having the cardboard wheels on all of them, the front ones don't have them and then the two back ones are different sizes and so it turns.

Teacher: Great idea. Two different sized wheels. And how did that make it turn?

Student: Well, it was leaning one way so instead of just going -- since -- since both wheels weren't the same size, it wouldn't go straight, it would slant one way.

Student: Like Martina said, two different sizes of wheels. We had two different sizes. And it turned halfway. But it had a short turn so it ran into the box. And so we tried to -- so we're going to try a bigger wheel and see if it works now.

Student: When our cart wasn't working, they had to -- the big wheels weren't working. We cut them littler and made them work. Now it's working. And then we had a thing you could put it which side you wanted to turn it.

Teacher: There are a whole bunch of different ideas that some of the groups are using. There are other ways to do it, too. So don't let those limit you. If you've got another idea, go for it.

Narrator: The teacher describes the five-phased process engineers use when developing new products: Design, construction, testing, evaluation and redesign. He helps students see which phase they are in and how they can use this process as they continue working. The most amazing thing is how kids keep testing, evaluate, redesigning and retesting confident that they can figure it out.

Student: We made it!

Narrator: We now have a consultant.

Student: Can I shake your hand? Thank you.

Narrator: It may take a couple of sessions before all of the teams successfully construct a cart that can go around the box. But as they learn to collaborate with other teams, they can all be successful. And remember to have the students read the Science Stories as they engage in this investigation.

<Investigation 4, Part 2>

Narrator: In this part of the investigation, students work with their partners to modify their cars to do interesting maneuvers. Here are the materials you'll need: From the kit: The string, motors, cells and cell holders, wire, bells, masking tape. And from the Measurement Kit you'll get the meter tapes. You'll need to supply the construction materials and the carts in the bags, student journals, student scissors, large scissors and cardboard.

Duplicate the student sheet called Design Plan and make copies of the student sheet called Oval Patterns. Have Assessment Chart for Investigation 4 available.

The teacher describes a number of different tricks that go-carts can do with some modifications.

Teacher: Or it can bounce and buck up and down.

Student: Let's try the bucked up and down by like making the oval wheels.

Narrator: The teacher gives the team several minutes to come up with a design. They use the student sheet called Design Plan to record their ideas. These will be added to their journals.

Student: Then the little rubber band.

Student: When we drive it, when it's driving, it can like -- when it hits the bumps, it will keep ringing and ringing.

Student: We're going to tape some -- we're going to put some string around the tape -- I mean, around the string. We're going to put some tape around the string --

Student: Taped to the battery.

Student: And put the stick on the battery.

Student: Uh, in the tape.

Student: In the tape.

Narrator: As the teams complete their plans, the teacher approves them before they begin the construction phase.

Teacher: Have a motor, bell and a motor. Take the tape. Put the tape -- okay. It looks like something that will work. Do you want to go get your bag?

Student: Sure.

Teacher: Start working on it.

Narrator: When most of the teams are ready, the teacher organizes a show and tell.
(Applause)

(Applause)

(Applause)

(Applause)

Narrator: This part is really a test of perseverance. The students change this a little bit, work on that, change the other thing a little bit, test it, see how it runs. In the process they are really grappling with the concept of a variable. A variable is anything you can change in a design that might affect the performance of the product. Students may have come up with some 12th hour questions or statements that you'll want to get into your Project Folder for use in the next session.

<Investigation 4, Part 3>

Narrator: In this last part of the investigation, students will be working on their own projects. This will be an opportunity for you to see how the students have advanced with their understanding of models and advanced with their ability to design things.

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 that they have come 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 about more investigations.

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

FOSS suggests giving three-minute presentations following the Presentation Guidelines sheet. They can also make a poster to help them explain their investigations to the class. You should plan on about two weeks for the students to work on their projects. You can devote some time to the projects at school and the students can work on them at home.

The Assessment folio has suggestions for scoring the student work on the projects. Also in that 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 Models and Design module. Bear in mind that probably some of the most powerful messages that your students will take away from this experience are not the hard contents that they've learned or necessarily the products that they've created but the interactions with other students and the kinds of creative thinking and the problem solving that emerged along the way. And do remember that most of the

information that we've covered here is covered in greater detail in the Teacher Guide.