Force & Motion K-1: Mech-a-Blocks

Physical Science Comes Alive: Exploring Things that Go
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Introduction

Overview

This unit introduces mechanical concepts to young children. They learn about inputs, outputs, mechanisms, levers, direction and amount of motion through their own designs of mechanical devices. "Mech-a-Blocks" are reconfigurable mechanical building blocks. Unlike ordinary blocks (which are designed for making structures), children can use Mech-a-Blocks to create mechanisms as well as structures.

Table of Contents

Guide to the Lessons

This unit is subdivided into 10 lessons, each intended for at least one class period. Each lesson is organized into most or all of the following sections:

- **Overview** provides a brief statement of the purpose of the lesson.
- **Materials** lists the supplies needed for the lesson.
- **Procedure** offers a basic lesson plan, including worksheets, focusing questions and prompts for writing entries in the Science Notebooks.
- **Outcomes** states the basic conclusions developed through the lesson.
- **Assessment** suggests methods for determining how well students have attained the outcomes.
- **Troubleshooting** offers help to the teacher, pointing out common pitfalls in the activities, and how to address them.
- **Technical Background** provides teachers with relevant science and math content.
- **Glossary** provides definitions of key terms used in the Lesson. This section is for teachers only, and should not be used as vocabulary for students.

Materials

The materials needed for the Mech-a-Blocks curriculum consist of:

- **A classroom set of Mech-a-Blocks**, including pegboard and cardstock shapes and brass paper fasteners (brads) – See Figure 1 & Table 1, below.
- **Templates** for making cut-out figures (see Table 2).
- **Some manufactured mechanisms.** These could include salad tongs, nut crackers, pliers, scissors, etc. The materials kit includes two large mechanisms: a pair of **fireplace tongs**, and a set of **expandable wooden coat hooks (Table 2)**
- Ordinary **school supplies**. These include:
    - scissors
    - Pencils
    - Markers and crayons
    - Post-Its ™
    - tape
    - chart paper
- **Science notebooks**

Pegboard Mech-a-Blocks	**Color**	**Big**		**Small**		**Used in these Lessons:**
		size	quantity	size	quantity	
Square	orange	4″x 4″	30	2″x 2″	60	1-10
Triangle	green	4″ on each side	30	2″ on each side	60	1-10
Rhombus	blue	4″ on each side	30	2″ on each side	30	1-10
Hexagon	yellow	4″ on each side	30	2″ on each side	30	1-10
Trapezoid	red	½ of large hexagon	30	½ of small hexagon	30	1-10
Base	white	8″ x 12″	30	--	--	1-10
Strip	white	1″ x 12″	100	1″ x 6	100	1-10
Cardstock Mech-a-Blocks	Same shapes, quantities & approximate sizes as Pegboard Mech-a-Blocks					5, 6 &10

Table 2: Mech-a-Blocks classroom set

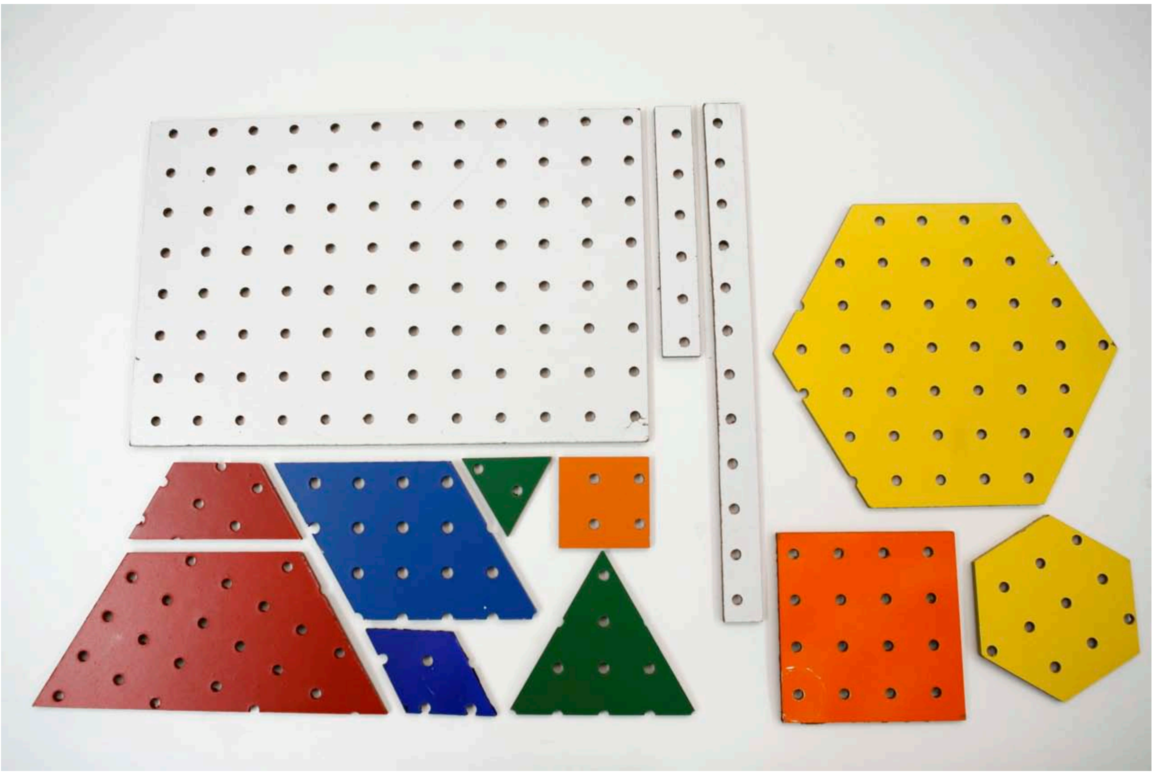


Figure 1: Classroom set of pegboard Mech-a-Blocks. Clockwise from top left: base; large & small strips, hexagons, squares, triangles, rhombuses and trapezoids

Type	Description	Quantity	Used in these Lessons:
Templates for making cut-out figures	cat (6/ sheet)	5 sheets	8
	Mouse (6/ sheet)	5 sheets	8
	Butterfly (6/ sheet)	5 sheets	9
	Net (2/ sheet)	15 sheets	9
Butterfly-net MechAnimation		1	3, 9
Brass paper fasteners	2″ (box of 100)	5 boxes	1-10
	1″ (box of 100)	2 boxes	5, 6 &10
Manufactured mechanisms	Fireplace tongs	1	1, 6
	Coat hooks	1	1, 6

Table 2: Other materials supplied for K-1 Mech-a-Blocks Curriculum

Lesson 1: What can you make?

Overview

In this introductory lesson, children become acquainted with Mech-a-blocks, try to make things from them, and develop their thinking about how to use these materials.

Materials

- ✁ Classroom set of pegboard Mech-a-Blocks
- ✁ Manufactured mechanisms: fireplace tongs, expandable coat hooks, nutcrackers, scissors, pliers, salad tongs, etc.

Procedure

1. Introduce the Mech-a-blocks during a class meeting:

- ✁ *We have some new materials in the science area. We call them Mech-a-blocks. Can you describe this piece (holding up a green triangle)?*
- ✁ *Do we have other shapes like this?*

Children may identify a triangular attribute block or building block.

- ✁ *How is this new one different from the attribute blocks?*

Children may say it's bigger, the color is different, it's made of a different material, this one has holes but the others don't.

2. Focus their attention on the holes and the fasteners:

Someone is likely to notice the holes in the pegboard pieces. Ask the children what they are good for:

- ✁ *Does anyone have an idea what we can do with the holes?*
- ✁ *Here's a clue. There is one other thing in the area: this small container with* ***fasteners****. Does anyone know how these work? What can you do with them? How do you use them?*
- ✁ *Do you know how to attach two things with a fastener, so they can't come apart?*

Every child may not realize that the fastener can be inserted into two holes in order to attach two pieces, and then the two ears of the fastener can be bent apart, to keep the fastener from coming out. Once someone makes this discovery, it is likely to catch on quickly!

3. Encourage them to make something:

Populate the science area with manufactured mechanisms. These will become the focus of Lesson 6, but it is a good idea to make them available from the very beginning, as sources for ideas.

- ✁ *When you are in the science area, you can use any of these pieces (indicating the Mech-a-Blocks shapes). See what you can make.*

- *When you make something special you want to share, you can keep it until you have had a chance to share it, but after that, we will take the pieces apart so we can use them again.*

Provide plenty of room and time to experiment. Children have made spaceships, cameras, houses, birds, camels, faces, tables, as well as abstract designs. Some first constructions are shown in Figures 1 and 2.

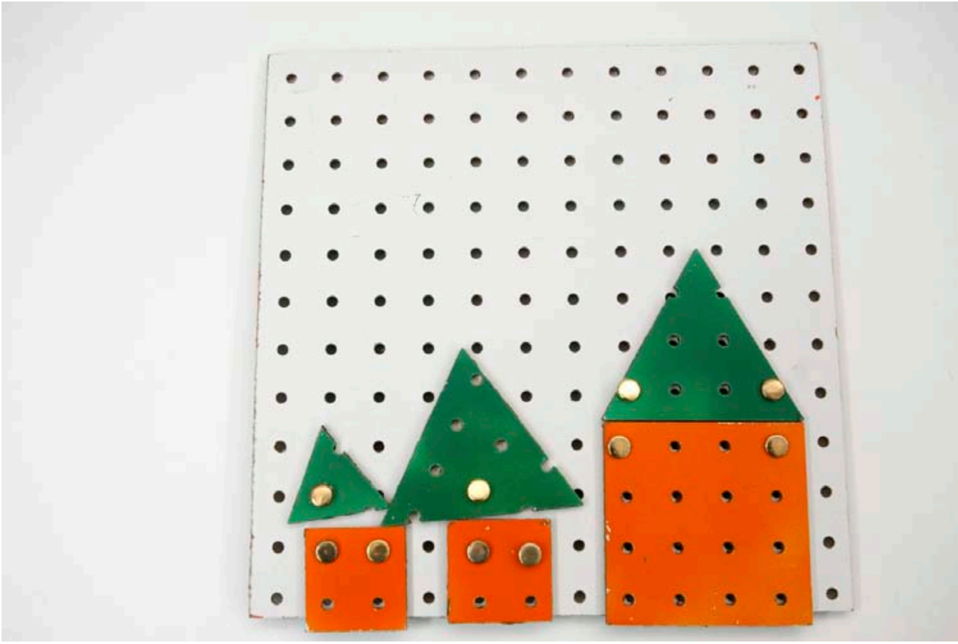


Figure 1: Houses made from Mech-a-Blocks

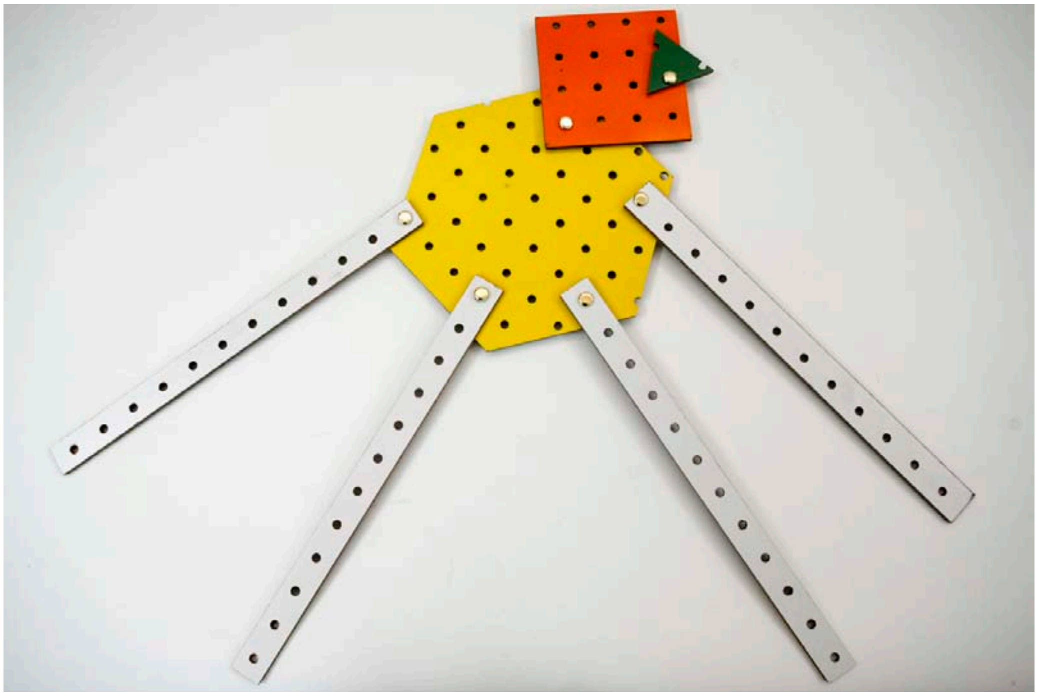


Figure 2: Four-legged creature made with Mech-a-Blocks

Science Notebooks

Record what you have made, using words and pictures.

4. Discussion

The children will make a variety of things. Look closely at the processes and products of the work. Select some constructions that are very different from one another, and ask the children who made them to show them to the rest of the class. Before each child presents his or her work, ask:

- ✁ *What does it represent?*
- ✁ *What do you have to do to make things move?*
- ✁ *How will it move?*

After the rest of the class has guessed, allow the child who made it to demonstrate it and discuss what it represents. Then guide the class in thinking and talking about each construction:

- ✁ *How is yours similar to what ____ made?*
- ✁ *How is it different?*
- ✁ *What problems did you have in making it? Did anyone else have a similar problem? What did you do to fix it?*

Save their constructions for the next lesson

Note: This "lesson" might last for several periods or more. It should continue as long as children are coming up with new ideas, and following them through.

Outcomes

Students should be able to construct with Mech-a-Blocks, explain how they did it, and demonstrate or describe any moving parts.

Glossary

Base: A stationary platform to which the moving parts are attached. The base usually remains stationary while the other parts move. The large rectangular pieces are intended to serve as bases, but any relatively large piece can serve as the base.

Fastener: A small pin that connects two pieces, preventing them from pulling apart.

Pivot: A fastener that allows other parts to rotate.

Strip: A long, narrow rectangular piece

Shape: Generic term for other pegboard pieces, besides strips and bases

Lesson 2: Structures and Mechanisms

Overview

By now, there should be numerous examples of children's work. Children next examine their constructions closely, and investigate some of the patterns that connect form and function. These patterns involve the different uses of fasteners, which determine whether or not the constructions have moving parts.

Materials

Mech-a-Blocks constructions from previous lesson

Procedure

1. Focusing on structures vs. mechanisms:

Select some constructions that have moving parts and some that don't. Demonstrate the difference, by holding the **base** of each one, and trying to make other parts move. The base is usually the largest piece. It's the piece you hold steady while trying to make the other parts move over it. Anything with moving parts is called a **mechanism**, while anything that can move only as a whole is called a **structure**. Write these two words on chart paper.

Help students sort their constructions into the two main categories, mechanisms and structures.

Science Notebooks Using words and pictures, show what happens when you try to move parts of what you made.

2. What do fasteners do? Focus students' attention on how they used fasteners. Use examples of their work to show three basic ways:

a. A fastener that goes **through one piece only:** *What (if anything) would be different about the way things would work if it weren't there?*

b. A fastener that goes **through the base and another piece**: *What is the job of this fastener? Which pieces can move and which ones can't?*

c. A fastener that goes **through two pieces but not the base**: *What is the job of this fastener? Which pieces can move and which ones can't?*

Help them see that type a. just moves with the part it is attached to – it does not change anything about the movement of the other parts. The second type (b.) is a fastener that cannot move itself, because it is attached to the base, but it may allow other parts to move, depending on whether there is a mechanism or a structure. Type c. fastenrs generally allow one part to move another part.

3. What makes something a mechanism or a structure? Using the discussion about fasteners, return students' attention to the categories of mechanisms and structures.

Demonstrate one of each, and have students identify the type b. fasteners in each one. Then ask them to look at their own constructions:

- ✄ *In a **structure**, what do you notice about the number of fasteners attaching a part to the base?*
- ✄ *In a **mechanism**, what do you notice about the number of fasteners attaching a part to the base?*

Outcomes

Students should discover that a mechanism uses at most one fixed fastener to attach a piece to the base, while a structure uses two or more fixed fasteners to attach a piece to the base.

Assessment

Show students a simple **mechanism** made with Mech-a-Blocks:

- ✄ *How could I turn it into a **structure**?*

Show students a simple **stru**cture made with Mech-a-Blocks:

- ✄ *How could I turn it into a **mechanism**?*

Troubleshooting

Students may notice that one part of a construction can jiggle a little while the base is still, and ask whether it counts as a "moving part." Our answer is "no." There is usually a little bit of play between the parts, due to the paper fasteners not fitting tightly in the holes of the pegboard. If a part can move only slightly, we still consider it a structure. A mechanism has to be able to rotate all or most of the way around a pivot.

In a mechanism, each part is attached to the base by at most one fixed fastener. A structure generally uses more than one. Figure 1 of Lesson 1 (houses) is a structure, while Figure 2 of Lesson 1 (four-legged creature) is a mechanism. You can always turn a structure into a mechanism by removing fixed pivots, or go from a mechanism to a structure by adding them.

Technical Background

Any device that has moving parts is a **mechanism**. If something has no moving parts, it is called a **structure**. A structure can move only as a unit – all the parts have to travel together. A desk, chair, box, board or stick is a structure, either because it has only one part, or because none of its parts is supposed to move independently of the other parts. A pair of scissors, stapler, tweezers, door lock or skateboard each has moving parts, so it is a mechanism. The following saying was circulating on-line:

- ✄ *There are only two tools you'll ever need: Duct Tape and WD-40™. Here's how you'll know which one to use: if it moves and it shouldn't move, use duct tapel if the opposite is true, use WD-40™.*

In our terminology, Duct Tape converts a mechanism into a structure, while, WD-40™ changes a structure into a mechanism! Common mechanisms are listed in Table 1.

The simplest mechanism consists of one part that can rotate around another, like a pinwheel or an arm represented by a stick. This kind of mechanism consists of three basic parts: a **base,** the part that doesn't move; a wheel or **lever** that does move around the base, and a **fastener,** which holds the lever in place, allowing it to turn but not slide. The base and lever can be any shape – not necessarily rectangular. The fastener – also called a **pin** or a **pivot** -- makes the connection to the base that allows turning but not sliding to and fro. Another property of a **lever** is that you normally push it or pull it at one point, the **input**, to cause a related movement you want at another point, the **output**. For example, when you use a pair of scissors, you squeeze the handles to make the blades move. The part you squeeze is the input, and the part that cuts is the output, and both can turn around a pivot (see Figure 1). Learning to identify inputs and outputs is a first step in developing notions of **cause**, **effect** and **system**.

Type	**Examples**
Toys	pull toy, wind-up, robot, car, keyboard
Outdoor play	See-saw, carousel, scooter, skateboard, tricycle, tricycle bell
School supplies	scissors, glue stick, stapler, hole punch, folder, ball-point pen
Kitchen utensils	clip for sealing snack bags, can opener, salad and barbecue tongs, nutcracker, chopsticks for kids, ice cream scoop
Human body	Arms, legs, jaw, fingers, toes, head
Health & beauty	nail clippers, eyelash curler, pump dispenser, tweezers, hair clip
Home	Pedal-operated wastebasket, light switch, desk lamp, ironing board, folding mirror, folding chair, folding ladder, shopping cart, umbrella, door, door lock, mouse trap, faucet
Construction site	garbage truck, crane, front loader, backhoe, hoist

Table 1: Familiar Mechanisms

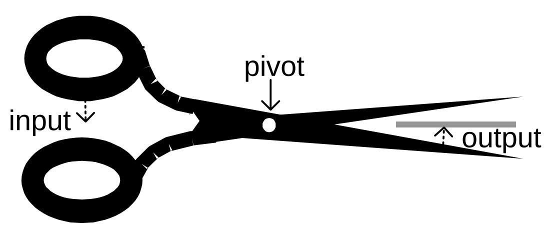


Figure 1: Scissors as lever

The three uses of fasteners are critical to determining whether something will be a structure or a mechanism. A **phony fastener** has no mechanical purpose. It just becomes part of the structure it is attached to. A **floating fastener** – because it can move independent of the base – is part of a mechanism. A **fixed fastener** could either be part of a mechanism – holding it together, and allowing one part to rotate – or part of a structure.

The key to making something a structure or a mechanism is the number of fixed fasteners:

- If a piece is attached to the base with one fixed fastener, it will be able to rotate, and therefore be a **mechanism** attached to the base. See Figure 2. In this case, another word for the fastener would be a **pivot**, because it allows something to rotate.

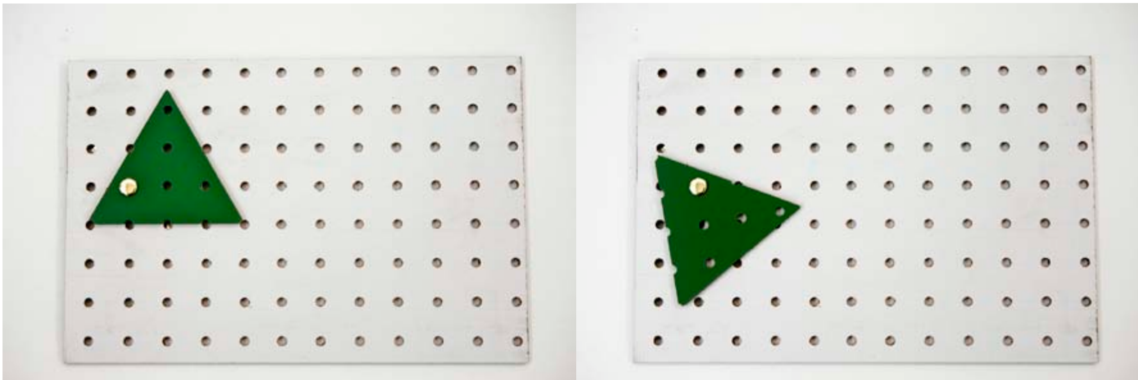


Figure 2: A mechanism made with two pieces and a fastener

- If a piece is attached to the base by two or more fixed fasteners**,** it will not be able to move separately, and therefore be part of a **structure** with the base, as in Figure 3.

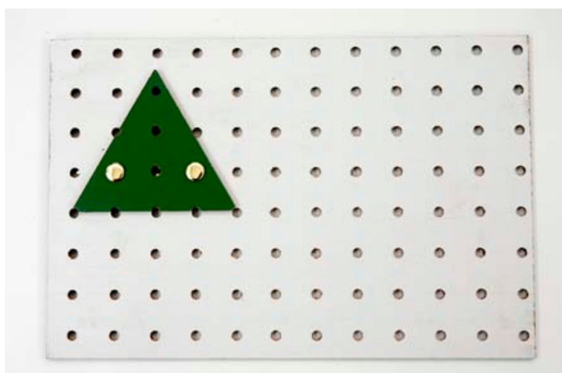


Figure 3: Adding a fastener turns a mechanism into a structure

Technical Background for Lesson 3 extends this discussion to include floating fasteners.

Glossary

Cause-and-effect: A feature of systems, in which one event makes another event happen.

Fixed fastener: A fastener that attaches another piece to the base.

Fixed pivot: A fixed fastener that allows one part to move, while the other stays still.

Floating pivot: A fastener that joins moving parts together with a

Input: The place on a mechanism that you push or pull in order to make another point move.

Mechanism: A set of attached pieces that has at least one moving part, which can move while another part (the **base**) stays still.

Output: The place on a mechanism where you look for movement, as a result of making the input move.

Phony fastener: A fastener that attaches to only one part, and has no mechanical function.

Structure: Something that has no moving parts, which can move only if all the parts move in the same way – by the same amount and in the same direction.

System: Something that has interrelated parts and includes an input and an output. A mechanism is a simple system, and there are also many other kinds of systems, most of them much more complex than basic mechanisms.

Lesson 3: A Mechanism with an Input that Controls it

Overview

This lesson begins with inputs and outputs and engages students in identifying them. Children are then challenged to figure out how to use one link to make another one move. To do so, they will have to invent the floating pivot, which attaches two links to each other but not to the base.

Materials

- ✂ Classroom set of pegboard Mech-a-Blocks
- ✂ One Butterfly-Net MechAnimation
- ✂ Post-Its™ or markers

Procedure

1. **Inputs, outputs and systems**:

Ask each students to quickly make a simple mechanism using one base, one fastener and one Mech-a-Blocks shape. In a whole-class meeting, ask the students who made them to demonstrate how to operate them. Ask the rest of the class to notice:

- ✂ *What is the part ________ is pushing (or pulling) to make it work?*
- ✂ *Name other things that you have to do something to, to make them work.*

Examples might include lights, pencil sharpeners, computers, video games, TVs, boom boxes, etc.

- ✂ *What is the part you have to operate on each of these?*

Help them develop a name for this part: the **input** or **handle**. Using the same Mech-a-Blocks constructions, ask the complementary question:

- ✂ *When you operate this input, what is it you want to happen?*

Ask the same question about the other examples they have suggested: lights, pencil sharpeners, computers, video games, TVs, boom boxes, etc. Develop the name for the action you want to happen: the **output**. There's also a word for anything that has an input and an output: it's called a **system**.

2. **Levers and handles**

Demonstrate the Butterfly-net MechAnimation (see Figure 1). Ask students:

- ✂ *What story is this telling?*
- ✂ *What do you think is making the net move?*
- ✂ *Where is the input? How do you know?*

✂ *Where is the output? How do you know?*

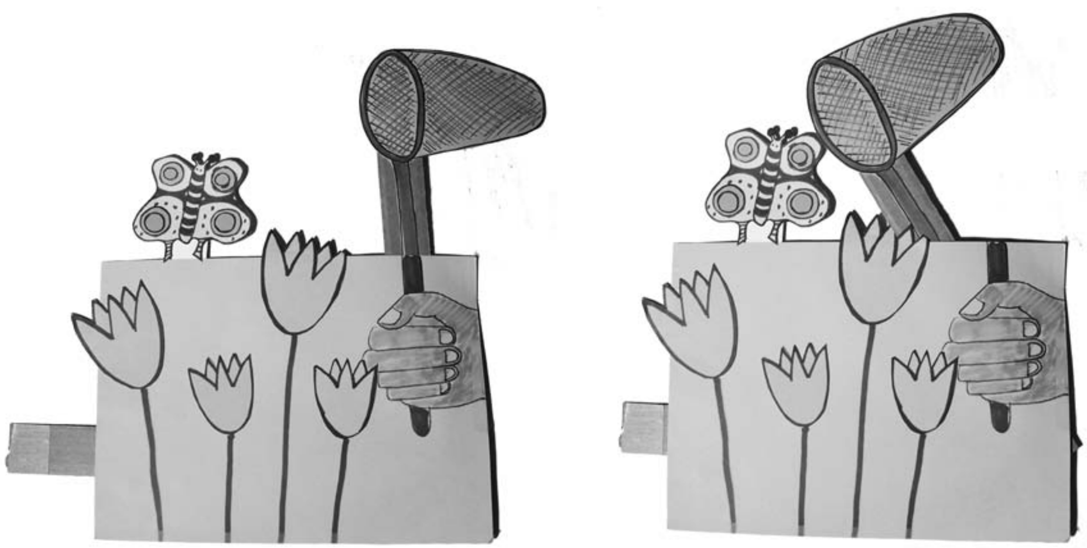


Figure 1: Butterfly MechAnimation

✂ *How does this input **control** the output?*

Then challenge them to:

Invent a way to make a handle for this mechanism. An input is a piece like this one (indicating input link of Butterfly MechAnimation) that I can use to control the output without touching it.

As an example, hold a pegboard strip near a simple lever attached to a base and ask, "How could I use this as the input to this mechanism?"

Allow a few minutes for them to try to come up with a way to make a separate input that controls the lever. Then convene the class again, so they can report on what they did. Students are likely to think of simply *pushing* the lever with the input, rather than with their fingers directly. Congratulate them on that solution, but then use their mechanism to demonstrate what happens when you try to *pull* the lever back with the input. Because they are not connected, the input will not be able to pull it back.

✂ *What's wrong with this?*

✂ *Why doesn't it work when I try to make it go the other way?*

Challenge them to think of a way around this problem, and provide a few more minutes for them to experiment.

3. The floating pivot: At least one student will probably come up with the idea of attaching the input to the lever with a fastener that goes through the two moving parts but not through the base. We will call this type of pivot a **floating pivot**. If students have not invented the floating pivot yet, make such a mechanism yourself, as in Figure 2.

Figure 2: Assembling a lever with an input: (left)) connecting the input and the lever with a **floating pivot**, legs up; (right) attaching the lever to the base with a **fixed pivot**

Figure 3: Showing how the input can control the lever moving it to other positions

Use Post-Its ™ or markers to label the two pivots in different colors, such as red for the fixed pivot and green for the floating pivot. Operate the mechanism so the whole class can see it, and ask:

- ✂ *What difference do you see between how the red and the green pivot work?*
- ✂ *Why does the input now **control** the output?*

Then challenge them again to make mechanism where one piece controls another.

4. Discussion: Lead a discussion based on what children have made. After each child presents his or her work, ask the class to chime in:

- ✂ *What do you think about ______'s mechanism? Where is the input? where is the output? What controls what?*
- ✂ *Did anyone make anything similar? What was similar about it? What was different?*
- ✂ *Did anyone have the same problem ______ did? What did you do to solve it? What advice do you have for ______ ?*

Science Notebooks

Using words and pictures, explain how you made a mechanism with an input, which controls it.

Outcomes

Students should be able to identify the input and output of a mechanism, tell if the input is a separate piece that controls the output (or is just another part of the same piece), and know how to make a mechanism with a separate input.

Assessment

Demonstrate a simple lever, attached to a base with a fixed pivot. Ask students to identify the input and output.

✂ How would they add an input that could control the lever?

Troubleshooting

An obvious way to attempt the design challenge would be simply to <u>push</u> the trapezoid with a strip, as shown in Figure 4. First, you see the lever with no separate input. Then a strip is lined up with the trapezoid, and used to push the trapezoid to the right. However, this method does not satisfy the goal of controlling the trapezoid, because when the strip is pulled back to the left, the trapezoid does not follow it.

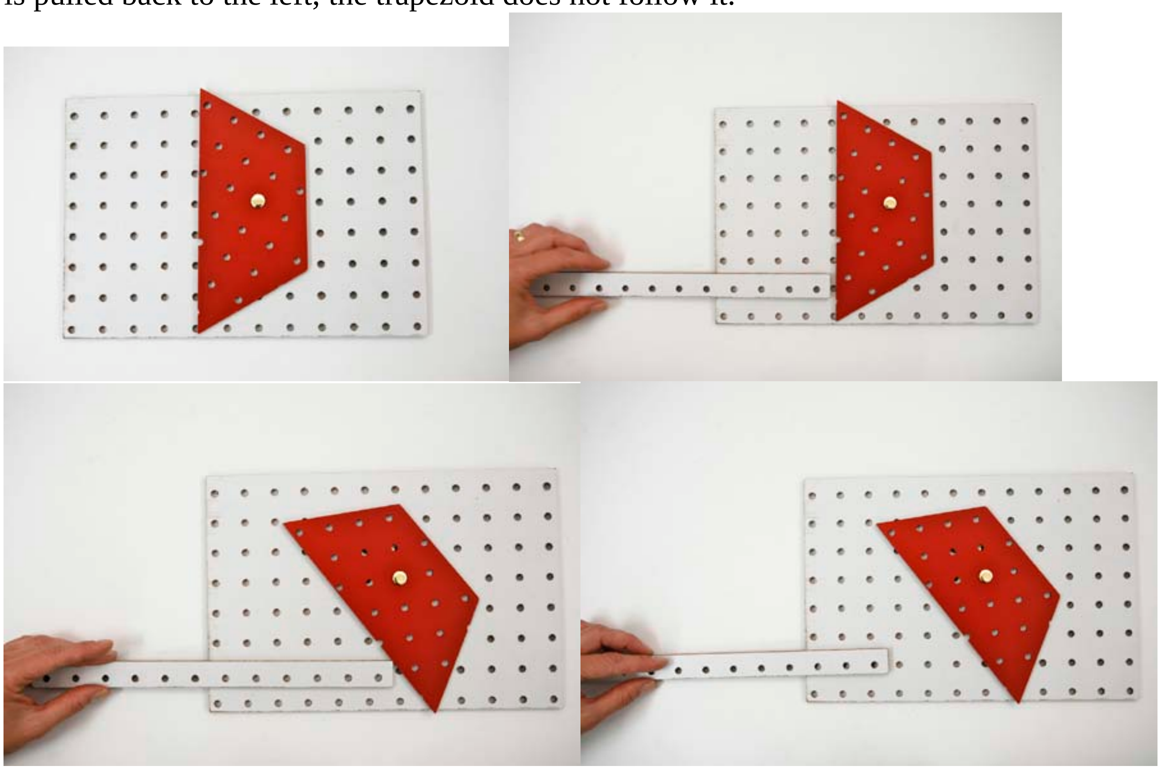


Figure 4: The strip does not control the trapezoid. It can push it to the right, but not pull it back to the left

In order for an input (the strip) to control a lever (the trapezoid), it needs to be attached to it somehow. Another idea would be to put a fastener through the strip, the trapezoid and the base, as shown in Figure 5.

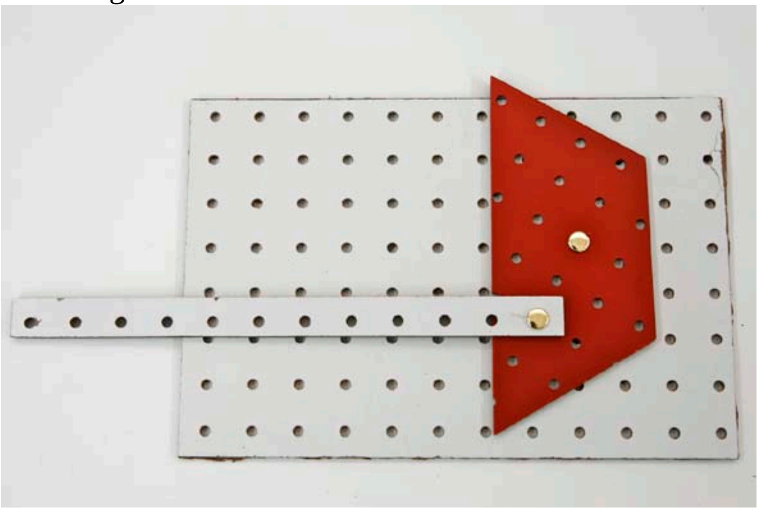


Figure 5: Second (failed) attempt to make Y control X

This second method is even worse than the first, because now the trapezoid can't move at all! Why not? As the Technical Background for Lesson 2 shows, putting two fasteners through a strip and the base makes the strip and the base into a **structure**. That is exactly what has now happened to the trapezoid.

The solution is to use a fastener that connects the strip and trapezoid to each other, but not to the base. As shown in Figure 2, the strip is first attached to the trapezoid with a fastener. Then the trapezoid is attached to the base with a fixed pivot, as shown in Figure 6. Notice that the legs of the fastener are pointing up. This will make it easier for the floating pivot to slide over the base.

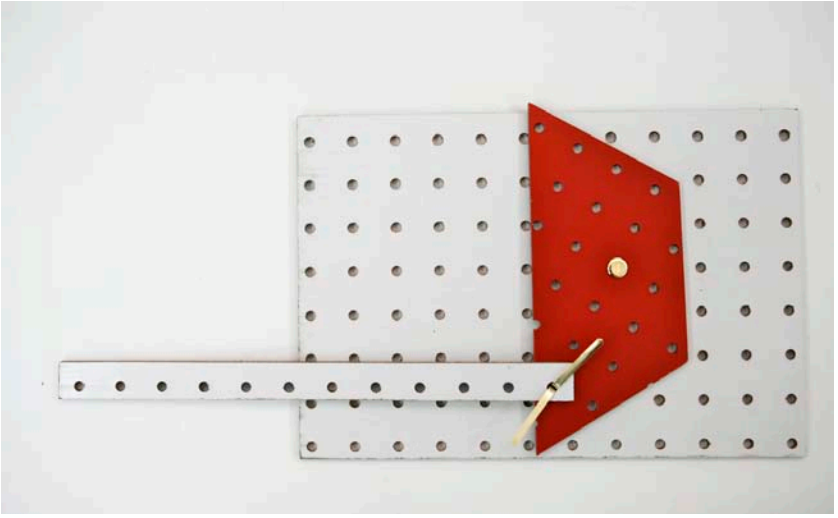


Figure 6: A mechanism that has an input strip controlling it

The result is a mechanism that meets the challenge, as shown in Figure 7. Pulling the strip to the left rotates the trapezoid clockwise (left), while pushing the strip to the right rotates the trapezoid counterclockwise (right).

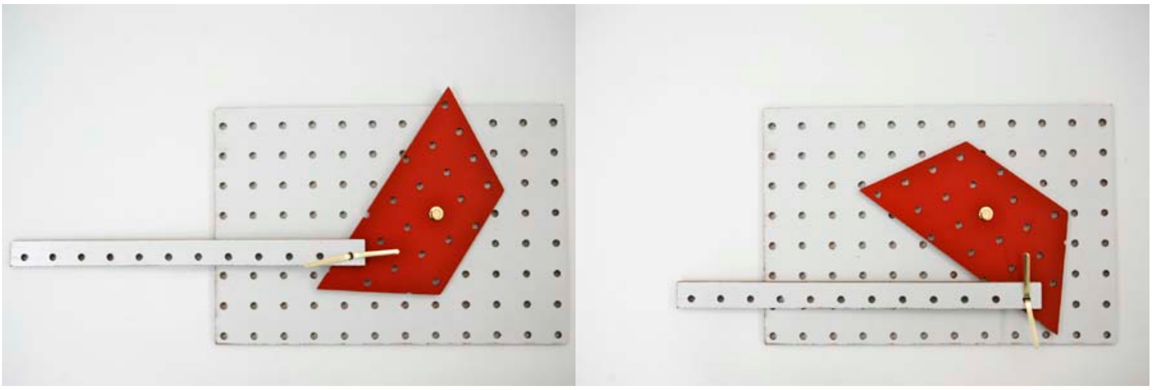


Figure 7: Strip Y now controls strip X

Glossary

Control: Something that determines what something else will do.

Fixed pivot: A fastener that attaches a lever to the base at one point, allowing the lever to turn but not slide away.

Floating pivot: A fastener that attaches one link to another, but not to the base.

Input controlling a lever: A link that can make a lever move in either direction because the two are attached by a floating pivot.

Lever: A rigid piece that is attached to the base at one point, allowing it to rotate but not slide.

Lesson 4: Mechanism Diagrams

Overview

Students think about how to record their pegboard mechanisms, develop drawing skills, and represent their work in their notebooks through drawings.

Materials

- Classroom set of pegboard Mech-a-Blocks
- Simple mechanisms with separate inputs from Lesson 3
- Chart paper and markers
- Drawing paper and pencils

Procedure

1. Why make diagrams? In a whole-class meeting, introduce the recording problem: Pegboard is recyclable, and we can use it again for something else. You can't take it home, because it costs too much. Suppose you made something, and then planned to take it apart, so you could use the pieces for something new.

- *How could you make a **record** of what you made, so you could make it again, or compare it with the new mechanism?*
- *Suppose you want to tell your parents or a friend about a mechanism you made?*

Conduct a discussion about these issues. Students will probably suggest making drawings.

2. Thinking about diagrams. A diagram looks like a drawing, but its purpose is different. A **drawing** is supposed to look as much as possible like the real thing. A **diagram** represents the important features, but not everything – just what you need in order to make it again. Provide some diagrams of your own as examples. Some of them could deliberately be hard to read. Engage students in thinking about what makes a diagram easy or hard to figure out:

- *How much of your mechanism do you need to show, in order for someone to know what you did, or for you to remember later?*
- *For example, do you really need to draw in every hole, or just the ones where you put fasteners?*

3. Making diagrams. Provide newsprint and markers, or paper and pencils, and encourage students to record their constructions in any way they choose.

4. Gallery walk. Once students have created their own diagrams, post them around the room, and conduct a discussion about what you can learn from each one. Find positive features of each one, and use the discussion to develop ideas about what makes a good diagram. You might also compare some of the drawings with the original mechanisms, to look for similarities and differences. The key question is:

- *Would another student be able to make the same mechanism you made if all the information they had was in the diagram?*
- *If not, what would you need to do to make the diagram easier to use?*

To explore this issue, you could deliberately make a mechanism incorrectly from a student's diagram that is missing some information, such as the distinction between fixed and floating pivots.

5. Using symbols in diagrams. Develop a list of symbols already in use in your classroom or school, such as red and green for which doorways to use, bathroom symbols, fire extinguisher symbols, etc. Connect these symbols in everyday use to the symbols they used in their diagrams:

- *How did we use **symbols** to show common things, so we don't have to make a complete drawing each time?*
- *What other things would you like to have symbols for?*

Help them think about which kinds of things are really different, and therefore need to have different symbols. For example,

- *How could we use symbols to tell whether something is a fixed pivot or a floating pivot?*

Science Notebook

At the end of the period, ask each student to remove his or her diagram from the wall and attach it to the Science Notebook.

Outcomes

Students should be able to represent a mechanism using a diagram, and understand how an effective diagram could be used to reconstruct the real thing

Assessment

Show students a Mech-a-Blocks mechanism, accompanied by a diagram that uses the same symbol for fixed and floating pivots. Ask them:

- *If I tried to use this diagram to make this mechanism, what would happen?*
- *What other information would I need?*

Troubleshooting

Figure 1 shows convenient symbols that make it easy to distinguish between fixed and floating pivots:

● Fixed pivot (attaches strip to base)
○ Floating pivot (attaches strip to strip)

Figure 1: Handy symbols for both kinds of pivots

Glossary

Diagram: A 2D representation that shows only the most important features of something.

Drawing: A 2D representation that shows as much information about something `as possible

Symbol: A gesture, sound, mark or image that represents an idea, action or object.

Lesson 5: Modeling Mechanisms

In this lesson, students compare two different kinds of materials for making mechanisms: pegboard and cardstock. Then they create cardstock models of their pegboard mechanisms. Finally, they look at other examples of modeling, and explore how a model is both similar to, and also different from the real thing.

Materials

- ✂ Children's Mech-a-Blocks constructions from previous lessons
- ✂ Classroom set of cardstock Mech-a-Blocks

Procedure

1. Comparing materials: Distribute the mechanisms from previous lessons. Provide each group with some of the cardstock Mech-a-Blocks shapes.

- ✂ *How are these cardboard pieces similar to the pieces you have been working with? How are they different?*
- ✂ *What would happen if I made a mechanism out of these cardboard materials?*
- ✂ *What would be better about mechanisms made from cardboard?*
- ✂ *What would be better if I made them from pegboard?*

2. **Cardstock models of pegboard mechanisms**. Review the diagramming activities from the previous lesson. Then present another idea for keeping a record of their work: "What if we had thin cardboard pieces in the same shapes and colors as the pegboard?"

Show them the shapes, strips and bases cut from cardstock.

- ✂ *How could you use these pieces to make a* ***model*** *of your mechanism?*

They could attach these pieces with fasteners, and make them both look and work like what they made in pegboard. These cardstock shapes are plentiful, so they could take these models home, and even take extra cardstock home to make new mechanisms.

Provide cardstock shapes and fasteners, and allow students to construct models of their original constructions:

Use this cardstock to make a mechanism that moves the same way as the one you made before, although it is made of a different material.

3. Improving the accuracy of the models:

The models students make at first will probably not be very precise. Use some of the students' examples to highlight this problem. If necessary, take them apart, and hold similar pieces one on top of the other to demonstrate the differences in hole locations.

- ✂ *Why doesn't this model work the same way as the original?*
- ✂ *Why is it important for the holes to be in the same places in the model as in the original?"*

- *How could we make sure to put the holes in the same places in the model as in the original?*

Science Notebook

Use words and pictures to show how you made your model

4. Discussion of models: In a brief whole-class wrap-up discussion, ask students for examples of models. They might suggest model cars, planes or boats; doll houses, clothing or furniture; stuffed animals; etc. If they don't include the mechanism models they have just made, ask if those should be added to the list. Then construct a class chart showing how each type of model is similar and different from the original.

Finally, conduct a brief discussion about these topics:

- *Were the new models better than the first models? How could you tell?*
- *What made the new models better?*
- *What is <u>similar</u> between the model and the original mechanism? Why are these similarities important?*
- *What is <u>different</u> between the model and the original? How important are these differences?*
- *What is a model good for?*

Outcomes

Students should be able to construct a cardstock model of a pegboard mechanism, and be able to compare the operation of the model with that of the original, listing pros and cons of each.

Assessment

Show students a pegboard mechanism, accompanied by an accurate cardstock model.

- *How are these similar? How are they different?*
- *What is better about each one? What is worse about each one?*

Show students a pegboard mechanism, accompanied by a cardstock model that has some incorrect hole locations.

- *How are these similar? How are they different?*
- *If I wanted my model to work more like the original, what would I need to do?*

Troubleshooting

An easy way to align the holes in the cardstock with the original pegboard holes is to lay the pegboard piece over the cardstock piece, and trace the holes location with a pencil. See Figure 1.

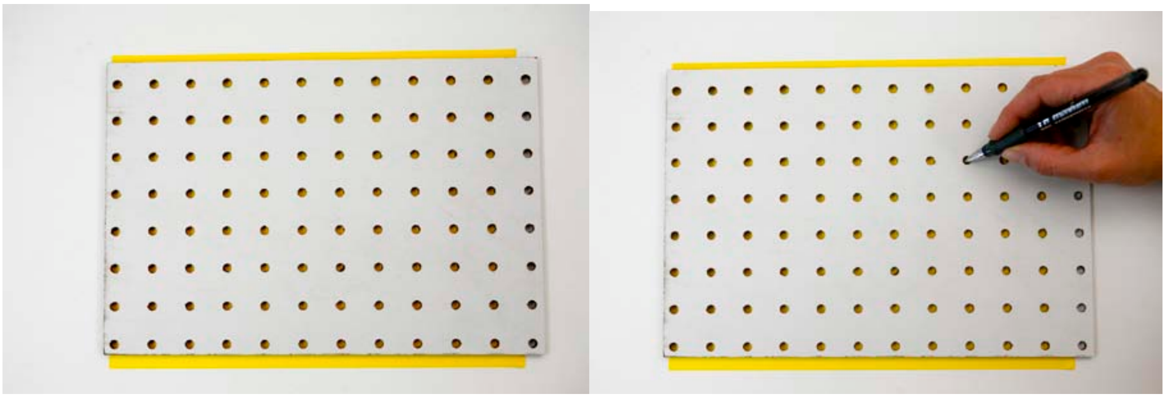


Figure 1: Using pegboard above cardstock, to mark the hole location on cardstock

Once you have marked a hole location, here is a procedure for punching the hole, so you can put a fastener through it:

1. Place a piece of cardstock on top of a soft surface, such as a rug or a thick piece of cardboard. Alternatively, you can put the cardstock over a piece of pegboard, making sure the mark is right over a hole in the pegboard.
2. Push the pencil point through the cardstock to make a small hole. The soft surface or pegboard hole should allow the pencil to go through. See Figure 2
3. Remove the cardstock from the soft surface or pegboard, and push a fastener through the hole you just made.

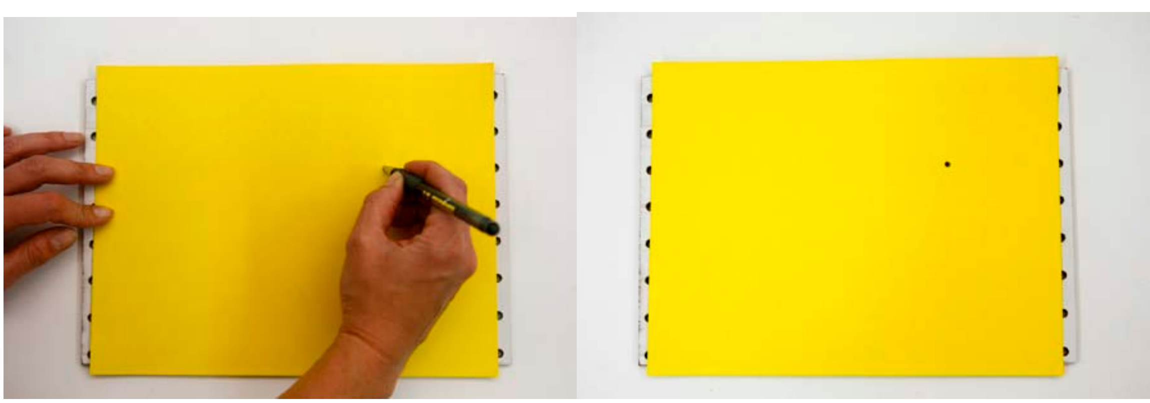


Figure 2: Using pegboard below cardstock, to punch holes in cardstock

Technical Background

The differences between cardstock and pegboard can be summarized as in Table 1.

Issue	**Pegboard**	**Cardstock**
holes	has them	has none
stiffness	Stiff – won't bend	Flexible – bends a lot
cost	Expensive – can't take it home	Cheap – you can use a lot of it

Table 1: Comparing materials

Table 2 shows some examples of models, which could arise from the discussion about modeling in general.

Original	**Model**	**Similarities**	**Differences**
Real car	toy car	Made of metal, both can roll	Real Car is bigger, goes by itself
Real house	doll house	Doors and windows	Real house is bigger, has lights and water
Real animal	Stuffed animal	Look similar	Different materials, real animal is alive
Doll	person	Look similar	Different sizes and materials, real person is alive and usually bigger
Pegboard mechanism	Cardstock mechanism	Inputs and outputs move the same way	Pegboard is stronger, harder to bend

Table 2: Comparing the model and the real thing

Glossary

Cardstock: Thin cardboard that can be used to make mechanisms.

Model: Something used to represent something else, in a way that is cheaper or easier to use than the original. A model retains essential features of the original, while omitting features that are unimportant or distracting.

Pegboard: A rigid material that has holes in it.

Lesson 6: Modeling Manufactured Mechanisms

Overview

This lesson provides another perspective on modeling. Students are encouraged to look at *existing mechanisms*, such as scissors, tongs and extension hooks, and identify their basic mechanical parts. They then capture the underlying forms by making models of these devices in pegboard or cardstock.

Materials

- Classroom set of Mech-a-Blocks: both cardstock and pegboard.
- Manufactured mechanisms that children can model. These could include scissors, pliers, tweezers, garlic presses, nut crackers, salad tongs, jar openers, fireplace tongs, expandable door hooks, retractable mirrors, and adjustable-arm desk lamps See Figure 1.

Figure 1: Sample mechanisms for modeling. Top row: scissors, nutcracker, jar opener; Bottom row: vise grips, fireplace tongs

Procedure

1. Review of modeling. Review the concept of modeling from the previous lesson: a model keeps essential features of the original, but leaves out those that are unimportant and/or get in the way of understanding. For example, a model of a Mech-a-Blocks construction doesn't need to include all the holes that *are not* used, but those that *are used* need to be in the right locations.

> ***Today we are going to make a different kind of model. We're going to start with something someone else made, and see if we can make something that works the same way.***

Provide examples of commercially made mechanisms. Each one should consist of links and pivots that can easily be modeled in pegboard or cardstock. Figure 1 shows five examples.

2. Modeling mechanisms made by someone else. For this activity, students should work in pairs. Give each pair a choice between pegboard or cardstock, and provide these materials, as well as fasteners, pencils for tracing, and crayons or markers, Post-Its™, paper, tape and scissors for decorating.

As students are working, visit the groups and assist them in thinking about how to proceed. What features of the original are important and which are not important? How are they deciding what sizes and shapes to use for the pieces? What method are they using to record the hole locations?

This work may take more than one period. Provide time for them to continue until they are satisfied with their models.

3. **Whole-class discussion**. Provide time for each pair to share their model. Ask each pair to talk about these issues:

- ✁ *What was the object you were trying to model? What is it used for?*
- ✁ *What did you do to make your model? How many pieces did you need? How many fasteners? How did you know?*

Review the issues about accuracy that came up in Lesson 5.

- ✁ *How is your model different from the real thing? How is it similar?*
- ✁ *What problems did you run into? What did you learn?*

Science Notebook

What did you make a model of?

How did you make your model?

How is it different from the real thing? How is it similar?

Outcomes

Students should be able to construct a model of a manufactured mechanism, and be able to compare the operation of the model with that of the original.

Assessment

Show students a manufactured mechanism, accompanied by an accurate pegboard model.

✁ *How are these similar? How are they different?*

Show students a manufactured mechanism, accompanied by a model that has some incorrect hole locations.

✁ *How are these similar? How are they different?*

✁ *If I wanted my model to work more like the original, what would I need to do?*

Lesson 7: Which way will it go?

Overview

This lesson compares the directions of the input and the output of a see-saw. Do the figures on the two sides go in the same or opposite directions? Then they explore how they could change the design to make both figures go the same way.

Materials

- Mech-a-Blocks pegboard bases and strips
- Cut-out figures of cat and mouse
- Tape for attaching cut-out figures to pegboard
- Markers and chart paper

Procedure

1. The see-saw: Demonstrate a Mech-a-blocks model of a see-saw, such as the one in Figure 1. Do not operate it yet.

Figure 1: Mech-a-blocks see-saw

- *Which way the mouse will go if the cat goes up?*
- *What about if the cat goes down?*

Record their answers, using a diagram and arrows on chart paper. See Figure 2.

Figure 2: Which way will the mouse go?

Then provide each student with cat and mouse cut-outs, and ask each one to make his or her own see-saw. Ask them to try the experiment with their own constructions:

- *If your cat goes up, which way does your mouse go?*
- *If your cat goes down, which way does your mouse go?*

Next, review the words "same," "opposite" and "direction:"

- **Direction** tells which way something is going. What direction did I push the mouse? ____. What direction did the cat go? ____
- **Same** means that if one goes up, the other goes ___. If one goes down, the other one goes ____.
- **Opposite** means that if one goes up, the other goes ___. If one goes down, the other one goes ____.

Finally, ask whether the see-saw makes the cat and mouse go in the same directions or opposite directions. Write the answer on chart paper.

Science Notebook

Draw your see-saw. Use arrows to show which way the mouse goes when the cat goes down.

2. Making them go the same way: Ask the students:

- *On the see-saw, the mouse and the cat go in opposite directions. What if the cat wanted to go in the same direction as the mouse? How could I change this see-saw to make that happen?*

Provide time for them to experiment with their Mech-a-Blocks. Try out any suggestion they come up with and test it to see if the input and output go in the same direction.

If they don't come up with it, present your own solution: first, remove the see-saw from the base. Then attach the cat a little to the right of the mouse. See Figure 3.

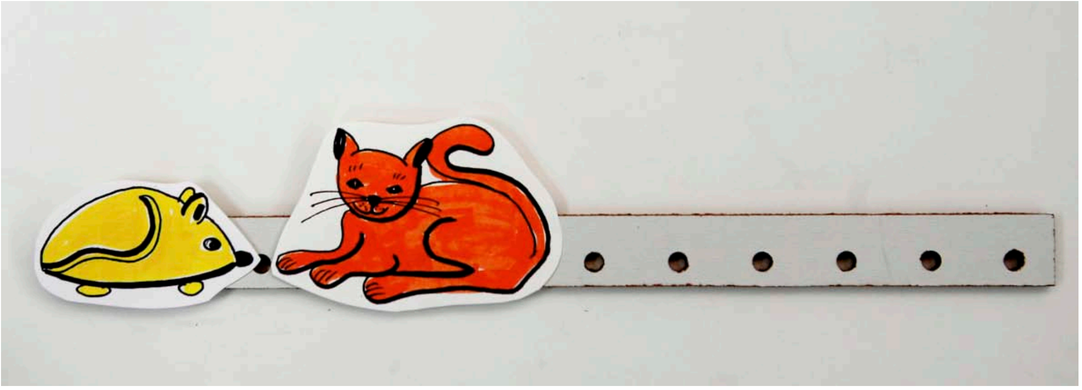


Figure 3: Putting the cat near the mouse

Finally, reattach the see-saw to the base, placing the pivot far enough to the right so they both fit comfortably on the left side, as in Figure 4.

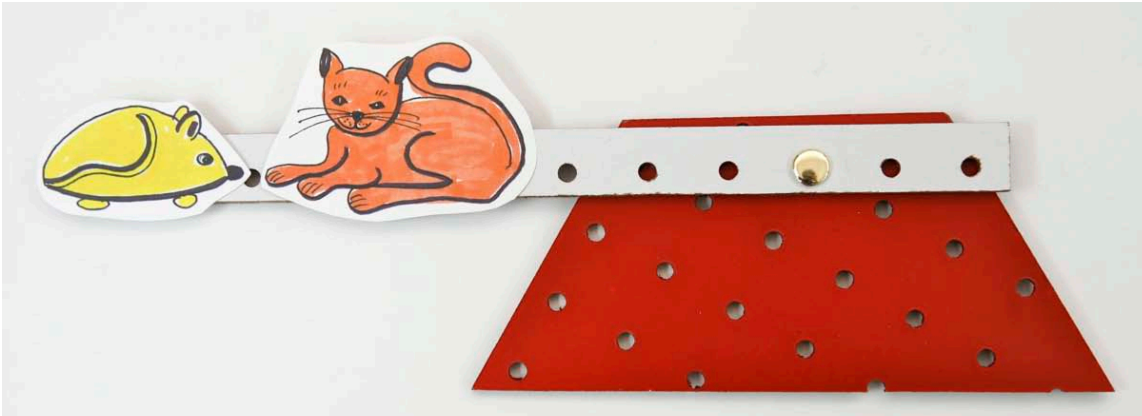


Figure 4: See-saw is re-attached to the base, leaving room for cat and mouse on the same side of the fixed pivot.

3. Class discussion. Ask students whether or not this works, and if it does, what you changed to make it work. See Figure 5.

Figure 5: Now they both go the same way

Science Notebook

Draw a see-saw that makes the cat and mouse go in <u>opposite</u> directions.

Draw a see-saw that makes the cat and mouse go in <u>the same</u> directions.

3. **Discussion:** Conduct a whole-class discussion comparing the two kinds of see-saws.

- ✁ *What do you notice about where the fixed pivot has to be when the cat and mouse go in opposite directions?*
- ✁ *What has to be true for them to go in the same direction?*

Outcomes

Students should learn to distinguish between **up** and **down** movement, and compare two movements to see if they are in the **same** or **opposite** directions.

They should learn that when the fixed pivot is **in between** the input and output, the two motions will be in opposite directions. If both input and output are on the **same side** of the fixed pivot, the input and output will move in the same direction.

Assessment

Show students a mechanism that works like a see-saw, with the cat and mouse on opposite sides of the fixed pivot.

✁ *How would you change it to make the cat and mouse go in the same direction?*

Technical Background

A see-saw is an example of a **lever**. When I push the cat down, I am using him as the **input**, because that is the part I am operating. The result is what happens to the mouse, so the mouse is the **output**, or effect I am looking for. The third feature of a lever is the **fixed pivot**, which attaches it to the base.

In the language of levers, there are special names for these three essential features:

General Term		Language of Levers
Input	⇔	Effort
Output	⇔	Load
Fixed Pivot	⇔	Fulcrum

There are three ways to arrange the effort, fulcrum and load. Based on the arrangement, levers come in three categories, which are called 1^{st}- 2^{nd} and 3^{rd} class levers:

1^{st} Class:	Fulcrum …	is in between …	Effort and Load
2^{nd} Class:	Load …	is in between …	Fulcrum and Effort
3^{rd} Class:	Effort …	is in between …	Fulcrum and Load

An ordinary see-saw is a **first-class lever**, because it has the fulcrum (fixed pivot) in between the input (cat) and output (mouse). In a first-class lever, the input and output always go in **opposite** directions, because the fixed pivot is at the center of a circle and the input and output are on opposite sides.

Some other examples of 1^{st} class levers are shown in Figure 6. A scissors is a 1^{st}-class lever because its input or effort – a handle – is located on the other side of the fulcrum from its output or load – the blade that actually does the cutting.

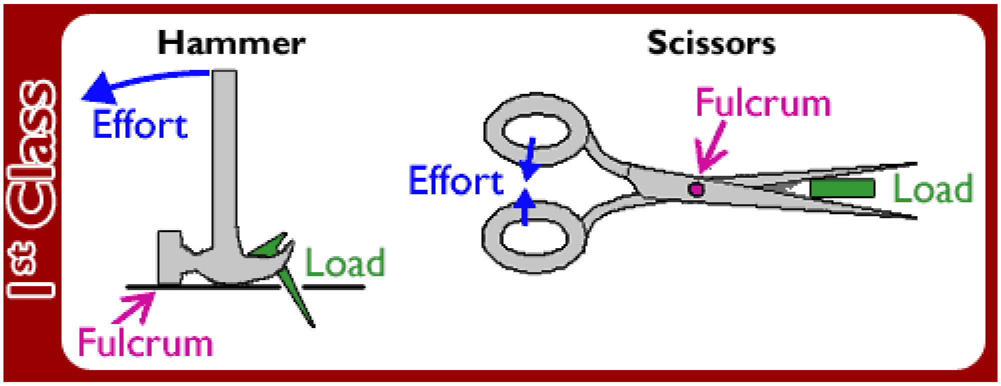


Figure 6: 1st Class levers

Figure 7 shows some 2nd Class levers. A nutcracker is an example because the fulcrum is at one end, the handles are at the other end, and the load – where the nutcracker crushes the unfortunate nut – is in between.

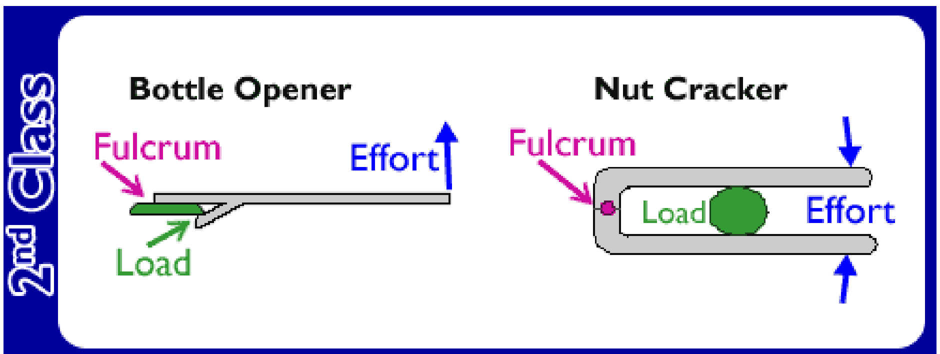


Figure 7: 2nd Class levers

Figure 8 shows 3rd-Class levers. In a staple remover, the input or effort is where you squeeze, which is in between the fulcrum at one end and the load – where the staple actually gets pulled out – at the other end.

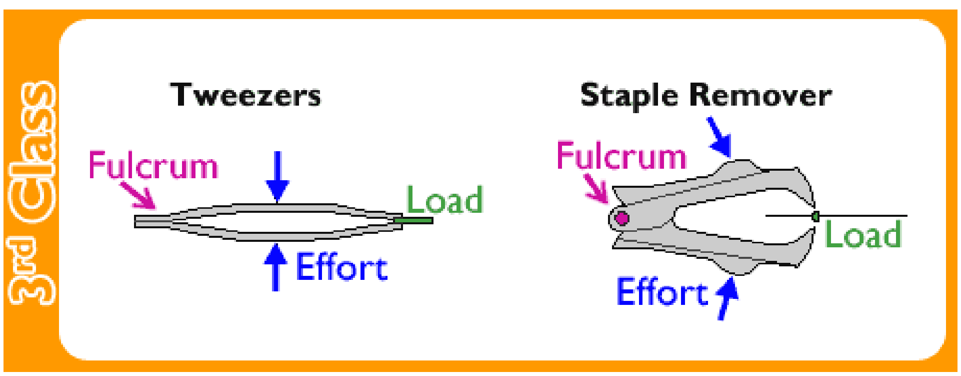


Figure 8: 3rd Class levers

When I put the cat and mouse on the same side, as in Figure 5, I am converting the lever to a third-class lever. The cat, which is the input, is in between the output (the mouse) and the fulcrum.

I could also use the see-saw in Figure 5 as a second-class lever, simply by making the mouse the input and the cat the output. Then the input would be at the opposite end from the fulcrum, with the ouput in between, making it a second-class lever.

Table 1 and Figure 9 show additional examples of each class, plus diagrams showing the locations of the effort, fulcrum and load in each case.

Scissors Snack food clip Barbecue tongs Leather punch Clothes pin Lemon squeezer hole punchers	Crab cracker Lemon squeezer Garlic press Egg slicer Garlic Press	Garlic separator Tweezers Staple remover Reverse tweezers Tongs

Figure 9: More examples of 1st- 2nd- and 3rd-Class Levers (clockwise from top left)

In a 1st Class lever, the pivot located in between the input and output forces them to move in *opposite* directions: if the input goes down, the output has to go up, just like in a see-saw. Which one moves further? It could be either one – it depends on how far the input and output each is from the pivot.

In a 2nd- or a 3rd- Class lever, both the input and output move in the *same* direction, because both are on the same side of the pivot. A 2nd Class lever has the input further from the pivot, so it will move further than the output. In a 3rd Class lever, the opposite is true. Table 2 summarizes these relationships, including diagrams of all three classes.

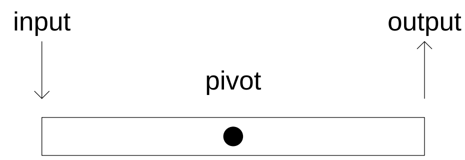
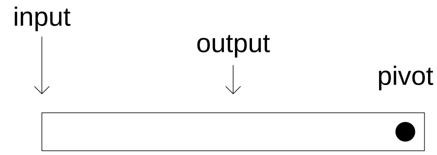
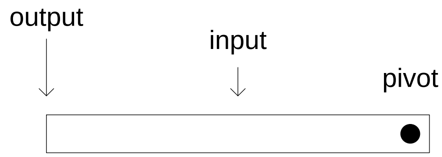
<table>
<tr><th>Class</th><th>Diagram</th><th>Directions of motion</th><th>Amounts of input and output motion</th></tr>
<tr><td>1st</td><td></td><td>Input and output move in opposite directions</td><td><u>Variable</u>: depends on distances of input and output from pivot</td></tr>
<tr><td>2nd</td><td></td><td rowspan="2">Input and output move in the same direction</td><td>Input moves further than output</td></tr>
<tr><td>3rd</td><td></td><td>Output moves further than input</td></tr>
</table>

Table 2: Directions and amounts of motion for each lever class

Glossary

Effort: Another word for input, used with levers.

First-class lever: A lever in which the fulcrum is in between the input and output.

Fulcrum: A pivot that attaches a lever to another part, usually a base.

Input (of a mechanism): The place on a mechanism that you push or pull in order to make another point move.

Lever: A device with an input (effort) and output (load), which can rotate because it is attached to a base by a pivot (fulcrum).

Load: Another word for output, used with levers.

Output (of a mechanism): The place on a mechanism where you look for movement, as a result of your making the input move.

Second-class lever: A lever in which the output is in between the input and the fulcrum.

Third-class lever: A lever in which the input is in between the output and the fulcrum.

Lesson 8: How to Get a Better Ride

Overview

This lesson focuses on distance traveled by an input or output of a lever. Students discuss what makes for a "better ride" on a see-saw: is it better to go further or not as far? Based on their decision, students notice whether the cat or mouse gets a better ride, when both are traveling in the same direction. Then they figure out how to rearrange the cat and mouse so the other one gets the better ride. Finally, they try to adjust the distances traveled when the directions are opposite.

Materials

Mech-a-Blocks see-saws from previous lesson

Procedure

1. **Demonstrate** the same-direction see-saw from the previous lesson. See Figure 1.

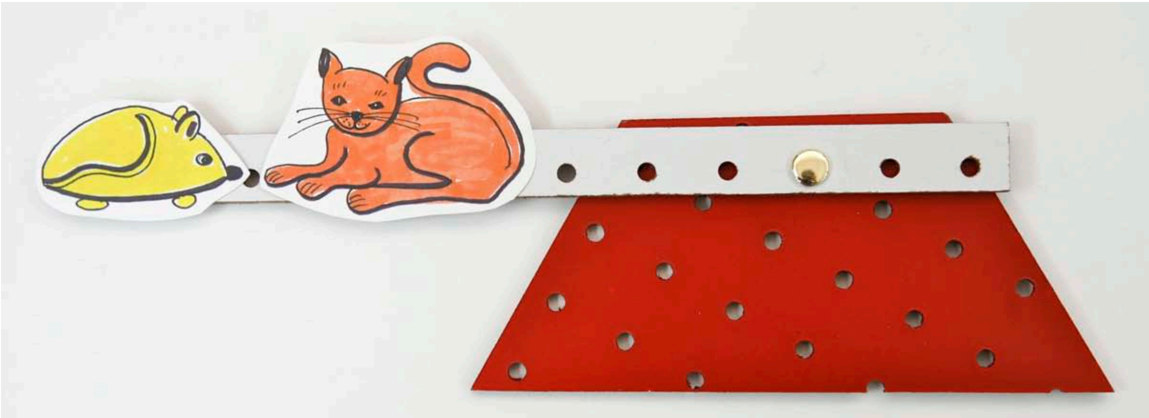


Figure 1: See-saw that lets cat and mouse go in the same direction

Distribute the see-saws students have already made that look like Figure 1.

✂ *Do the cat and mouse go in the same or opposite directions?*

Lead a discussion about different distances you can travel in the classroom, distance from home to school, distances you can walk and distances you can't, etc. Ask two students to walk two different distances simultaneously. Which one went further? Be careful to distinguish distance from direction. Two trips could have the same *distance*, but be in different *directions*. Two trips could be in the same direction, but with different *distances*. If a distance is more, we say you have to go **further**. If it's less, then the trip is **not as far**.

Then demonstrate the see-saw, showing how it moves up and down, as in Figure 2.

Figure 2: Movement of the cat and mouse

To make the difference in movement obvious, trace each path with a pencil or marker. Have someone hold the see-saw steady on chart paper, while you trace the movement first of the cat, and then of the mouse, as in Figure 3.

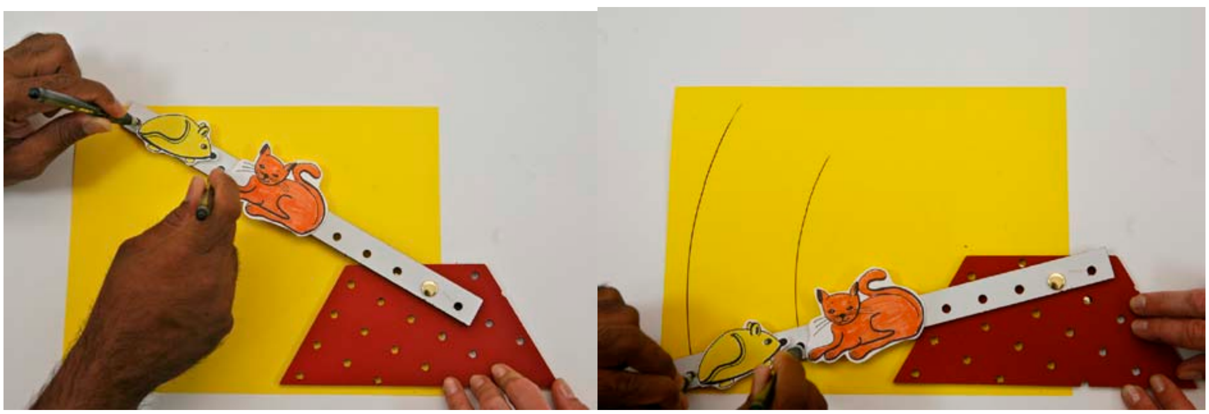


Figure 3: The path each one follows

Ask students:

- *What difference do you see between how the cat moves and how the mouse moves?*
- *What makes one ride better than another?*
- *Who gets a better ride – the cat or the mouse? Why? What else do you notice about them?*
- *If the other one wanted the better ride, what would you have to do?*

Distribute materials and challenge students to:

Make a see-saw which gives the cat a better ride (goes further) than the mouse.

See Figure 4.

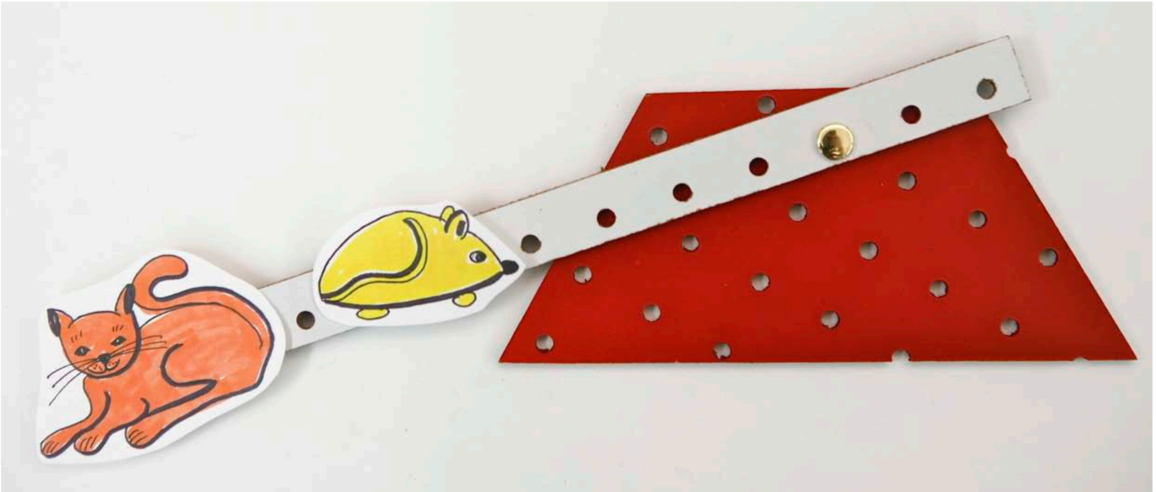


Figure 4: Now the cat gets the better ride.

3. Different distances, different directions: Review the first see-saw they made. The cat and mouse went in opposite directions. Present the following challenge to the students:

> ***Now the cat still wants to get a better ride than the mouse, but this time in the opposite direction. Change your see-saw so this will happen.***

Help them think about what you have to change to make them go opposite. Once they have placed the cat and mouse on opposite sides of the fixed pivot, ask them to find out which one goes further.

4. Controlling the distances. Then ask them to arrange the cat and mouse so the cat goes further than the other. See Figure 5.

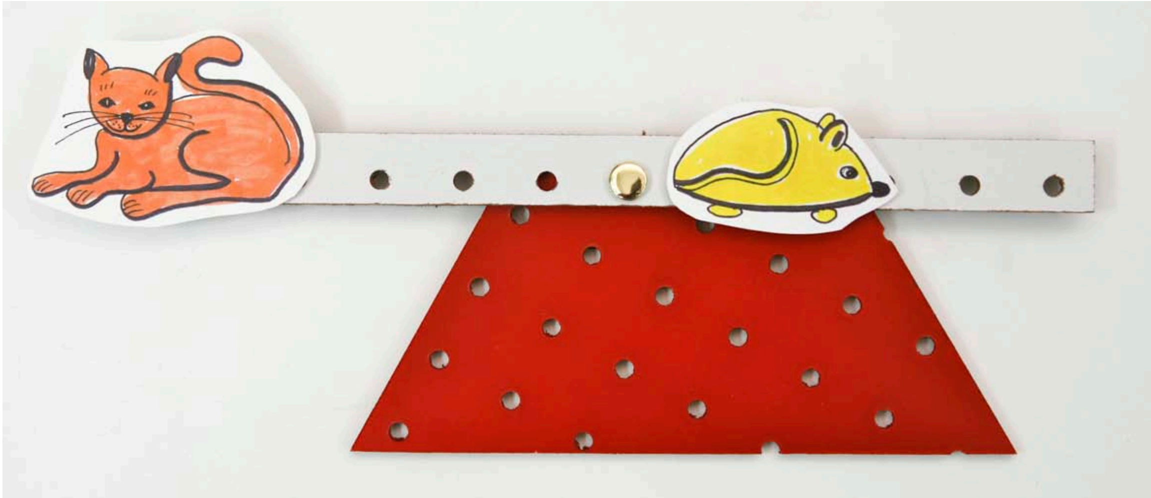


Figure 5: Cat and mouse go in opposite directions, and the cat still gets a better ride

After they have tried to solve this problem, review what they made. Test some of their see-saws to see if:

- The cat and mouse go in opposite directions; and
- The cat gets a better ride.

If students have trouble seeing who gets the better ride, test it by tracing each ride, as in Figure 3.

- *Does the near one or the far one (from the fastener) get a worse ride?*
- *If one of them wants a better ride, where do they need to be?*

Science Notebook

- Draw a see-saw that makes the cat go further than the mouse, in the same direction.
- Draw a see-saw that makes the cat go further than the mouse, in opposite directions.

Outcomes

Students should learn that the further something is from the fixed pivot, the further it will travel.

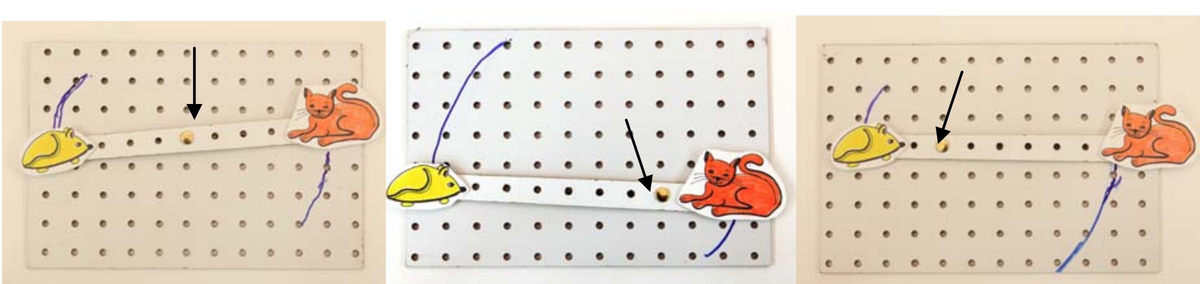
Assessment

Show students a see-saw like in Figure 4, where the cat and mouse go in opposite directions, the cat further than the mouse:

- *How could I change this so the mouse goes further than the cat, still in opposite directions?*
- *How could I change this so the mouse goes further than the cat, but now in the same direction?*

Troubleshooting

Students may have difficulty seeing how the location of the fixed pivot affects the distance traveled. If so, you might set up the seesaw, as in Figure 5, and then move the fixed pivot, to different a hole each time, to see the effect on the movements of both cat and mouse. See Figure 6.



a) b) c)

Figure 6: Changing the fixed pivot location to see the effect on movement of cat & mouse

In a), the pivot is in the center, and the cat and mouse move about equally. In b), the pivot has been moved to the right, and the mouse moves more. In c), the pivot is towards the left, giving the cat a better ride!

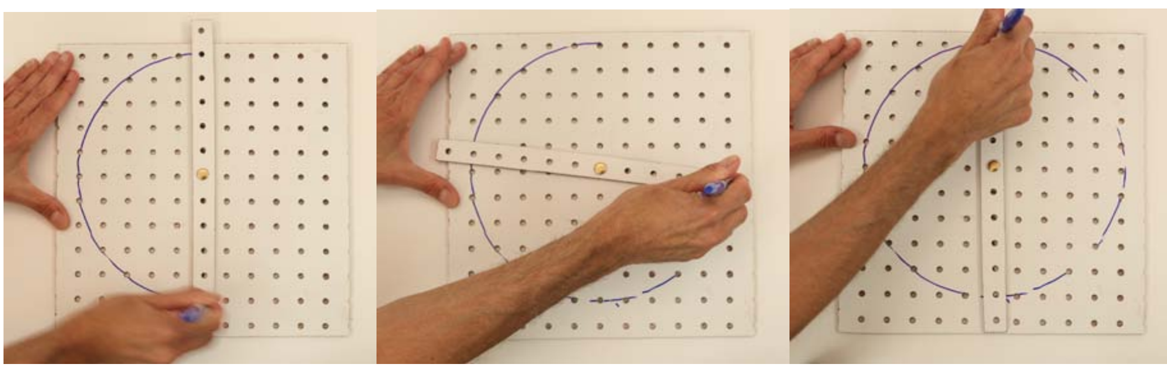
Technical Background

As an object is moving, it passes through many different points on its journey – in fact, an infinite number, because a point is infinitesimally small! It's hard to think about infinity, but fortunately, there is an easy way to describe all of the points the object has passed through. By mentally joining all the points together, you get a line or curve that connects all the points, like in the game, "Connect the Dots." In geometry, the line or curve that does this is called the **locus** of the points. For example, if you drop something while standing still, the locus will be a vertical line from where you dropped it to the floor.

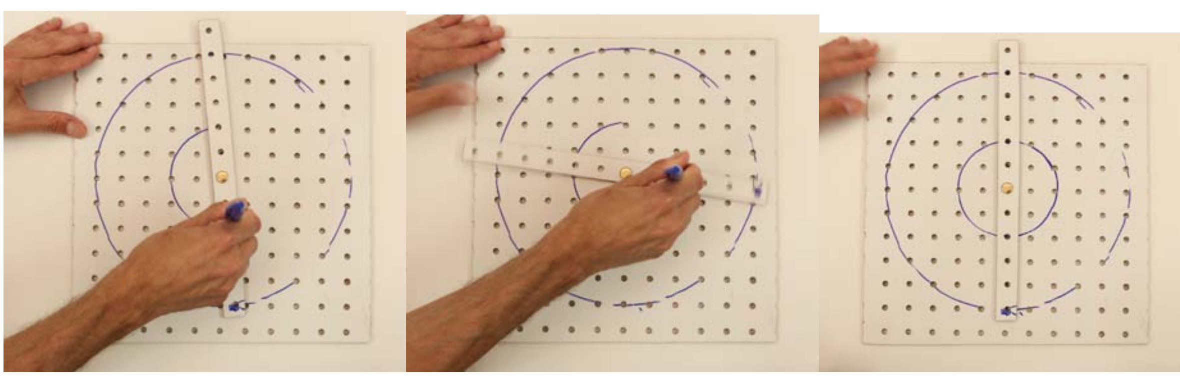
In this lesson, students examine the **path** traveled by a lever, which is an example of a locus of points. Because the fixed pivot forces the lever to rotate, the output path must be part of a circle, whose center is at the fixed pivot – in other words, an **arc**. The central question in the lesson is:

- ✂ What controls the length of the output path?

Figure 7 shows the paths the outputs of two levers follow if you trace all the way around.



a) A circle drawn using a hole that is far from the fixed pivot



b) A second circle drawn using a different hole c) Comparing the two circles

Figure 7: Using a strip of pegboard as a compass, and then comparing circle sizes

What makes one of these paths longer than the other? Just that it is further from the fixed pivot. The distance of an output from the fixed pivot is called the **radius** or output arm. The distance around a full circle is called the **circumference**. If the output doesn't complete a full circle, it travels in an **arc**, which is just part of a circle. The path the output travels is then called the **arc length**. See Figure 8.

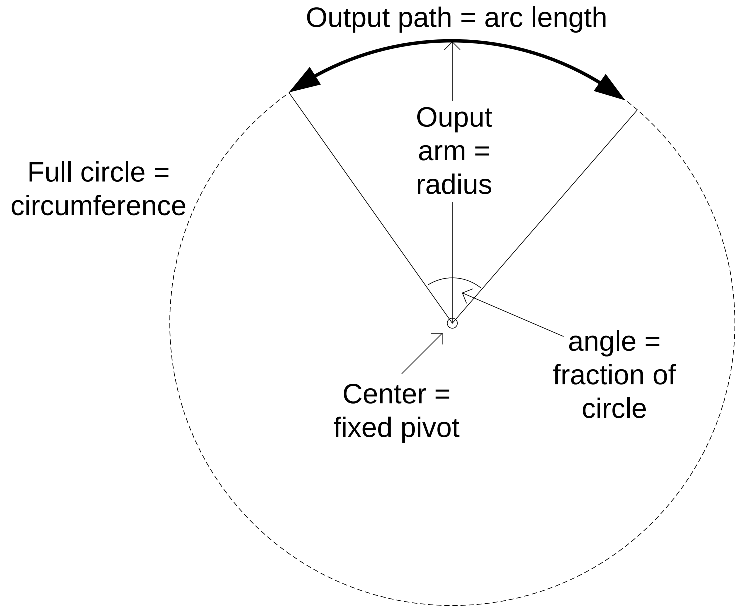


Figure 8: Circle relationships

Suppose there are two outputs that both rotate on the same lever, as in Figure 3. Since they are on the same lever, they have to rotate through the same **angle**, or fraction of a full circle. The one with the longer radius will travel the furthest. Figure 9 shows two output paths that have the same angle.

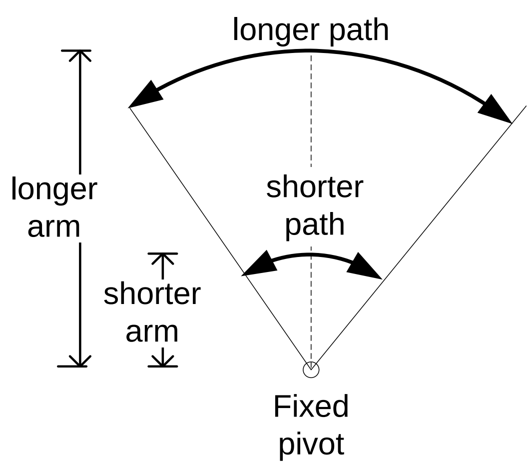


Figure 9: Comparing arc lengths and arm lengths

In each case, the center of the circle is at the fixed pivot. The radius of each circle is one of the arms. The longer output path is bigger than the input because its radius (arm) is longer. In fact, **ratio of arm lengths** is **equivalent to the ratio of path lengths** (output to input). When two ratios are equivalent, they are said to be **in proportion**.

The reason these two ratios are in proportion is that is that the ratio of circumferences of two circles is in proportion to the ratio of the two radii, according to the formula:

$C = 2\pi r$, which reads as “Circumference equals two times pi times radius.”

An arc is only a fraction of a circle, so it might not seem obvious why the arc lengths, as well as the circumferences, should also be in proportion. They actually are, because but both input and output arcs have the same angle, which means their fractions of the circumference are the same. Therefore, the arc lengths are proportional to the arm lengths. If you double an arm length, the arc length doubles too. The terms and relationships are summarized in the Glossary.

Glossary

Angle: A number describing a fraction of any circle

Arc: Part of a circle

Arc length: Distance traveled in following an arc

Circumference: distance all the way around a circle

Center: When making a circle, this is the only point that doesn't move; one end of the radius is attached here

Locus of points: Line or curve that connects all the places that a point passes through

Output arm: Distance on a lever from fixed pivot (fulcrum) to output point; radius of input circle

Output circle: Circle centered at fixed pivot that output point could follow if it could rotate all the way around

Output path: Path actually followed by output point

Pi: Ratio between the circumference of a circle and twice the radius (also called **diameter**)

Proportion: Relationship between two ratios, which says that they are equivalent; for example, the ratios 2 to 1 and 6 to 3 are in proportion

Radius: Distance from the center to any point on a circle

Ratio: Relationship between two numbers, such as 2 to 1

Lesson 9: Catching the Butterfly

Overview

This lesson begins with a cardboard "MechAnimation," which uses a mechanism to make a movable net catch a stationary butterfly. The students cannot see the mechanism inside, which consists of a handle attached to a lever with a floating pivot. The lever is attached to the base by a fixed pivot, in between the floating pivot and the output (butterfly net). Students are challenged to create their own mechanism that works like this MechAnimation. To help them do so, they explore how the location of the fixed pivot – above or below the floating pivot – affects the direction of motion of the output.

Materials

- Pegboard Mech-a-Blocks bases (one per student) and large strips (two per student)
- Paper fasteners
- Small amount of red and green clay or Post-Its™
- Butterfly MechAnimation (one per class) – see Figure 1
- Cutout figures of butterfly and net

Procedure

1. **Demonstrate** the Butterfly MechAnimation to the whole class. See Figure 1.

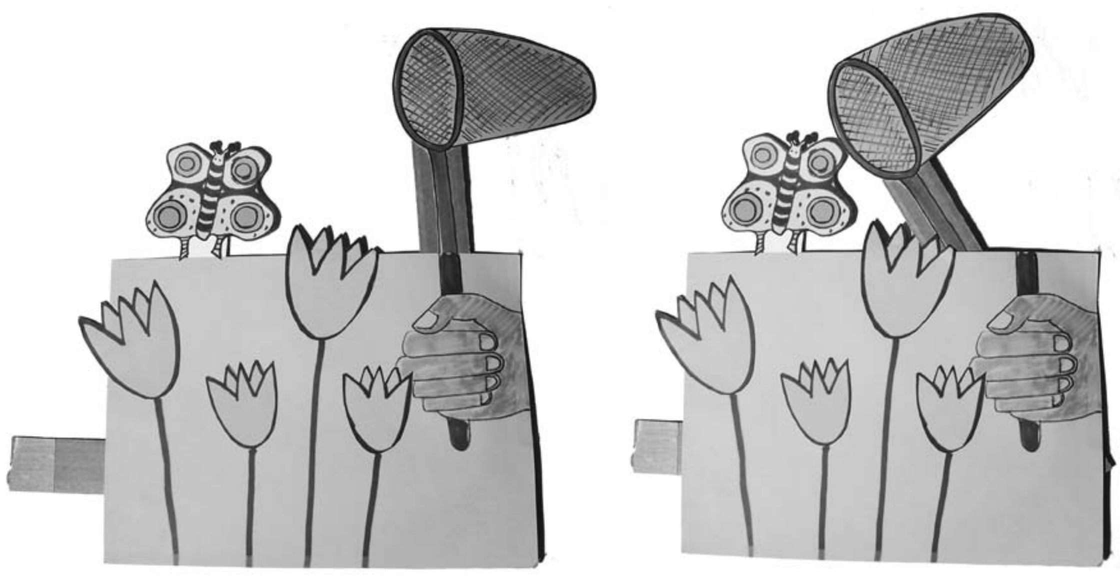


Figure 1: Butterfly MechAnimation, showing the next in the up position (left) and then about to catch the butterfly (right)

Explain that a MechAnimation uses a mechanism to tell a story. Ask:

- ✂ *What story does this MechAnimation tell?*
- ✂ *What do I have to do to make it work?*
- ✂ *What happens when I do that?*
- ✂ *How do you think it works?*
- ✂ *Would you like to make your own MechAnimation?*

2. What's inside it? Review the idea of a mechanism with a separate input, from Lesson 3. The input controls the movement of the mechanism. Ask students to focus on what they can see in the MechAnimation:

- ✂ *Where is the handle? How do you know?*
- ✂ *Where is the output? How do you know?*
- ✂ *When the handle moves this way (to the students' right) which way does the ouput go?*

3. The unhappy butterfly net: Review the concept of a model. In this lesson, we'll use pegboard models to understand our MechAnimation. Pegboard is easier to use than cardboard, so everyone will use it to make a mechanism that works like the mechanism in the MechAnimation.

Provide students with pegboard bases, strips and fasteners, and butterfly and net cutouts. Ask each student to follow the steps in making and testing this construction, as you demonstrate each one:

a. Assemble two links with a floating pivot as in Figure 2. The horizontal one will become the handle, and the vertical one will become the lever. Make sure the ears of the floating pivot are pointing up towards you, so they won't get hung up as you try to slide it along the base.

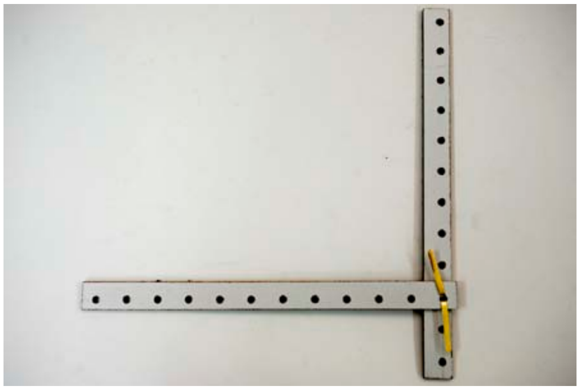


Figure 2: Two links assembled before attaching to base

b. Attach the lever to a base with a fixed pivot *below* the handle. In Figure 3 (left) the fixed pivot is marked by an arrow. Attach the cut outs of the butterfly and net.

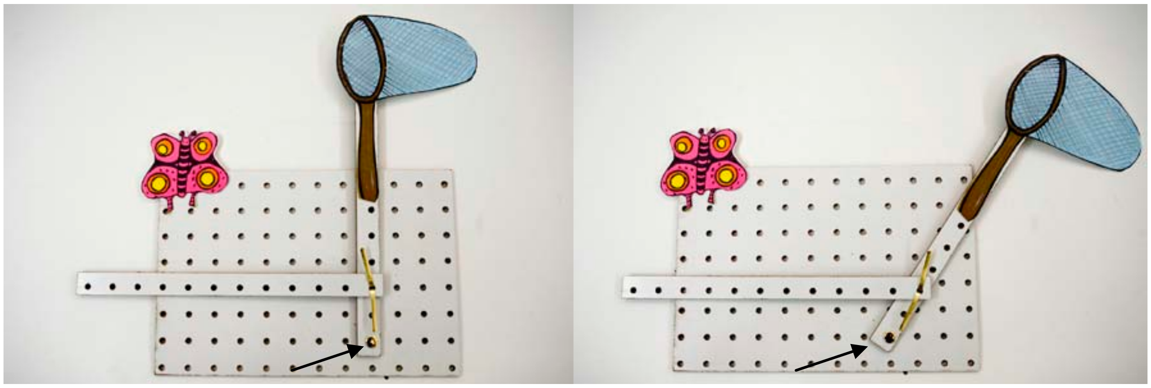


Figure 3: Unhappy Butterfly Net: the floating pivot has ears up the fixed pivot (marked by arrow) is below it

c. Push the input to the right, as in Figure 3 (right), and show the class how the net moves away from the butterfly, instead of towards it.

Students should notice that the net doesn't catch the butterfly, because it goes to the right when you push the input in. In order to catch the butterfly, the net would have to move to the left. A good name for it might be an <u>Unhappy Butterfly Net</u>. Make sure that each student has made their own model before proceeding to the next step.

4. Making the butterfly net happy: Challenge students to change their unhappy nets to make it possible for them to catch the butterflies:

✂ *What goes happens when you use your mechanism to try to catch the butterfly?*

✂ *What would need to happen differently in order to catch the butterfly?*

✂ *How could you change it to make it work correctly?*

After students have had some time to work on their models, convene the whole class to see what they have come up with. Allow students time to share their ideas, and question one another about what they have done, and how well it works. If students have not come up with a solution, provide the one shown in Figure 4:

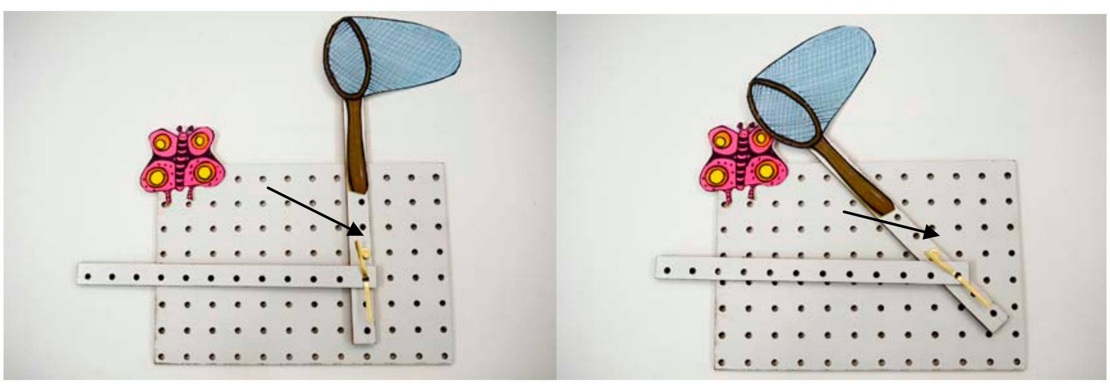


Figure 4: The Happy Butterfly Net, whose fixed pivot (marked by arrow) is above the floating pivot

In Figure 4 the fixed pivot is <u>above</u> the floating pivot. Push the input to the right, and let them observe how it now catches the butterfly! This model should work the same way as the original MechAnimation: pushing the input to the right makes the net go to the left.

4. Comparing models: Focus students' attention on the differences between the two models. The second model worked but the first one didn't:

- ✂ *What is the difference between the ways the two models move?*
- ✂ *What is the difference between the how the two models were made?*
- ✂ *Why does the second one work, but the first one doesn't?*

If students have difficulty seeing the differences in construction, help them by color coding the fixed pivots and the floating pivots, so the differences are more obvious. For example, you could make the floating pivots green (for "GO") and the fixed pivots red (for "STOP"). In Figure 5, the fixed pivots are marked by arrows, and the floating pivots' ears are visible.

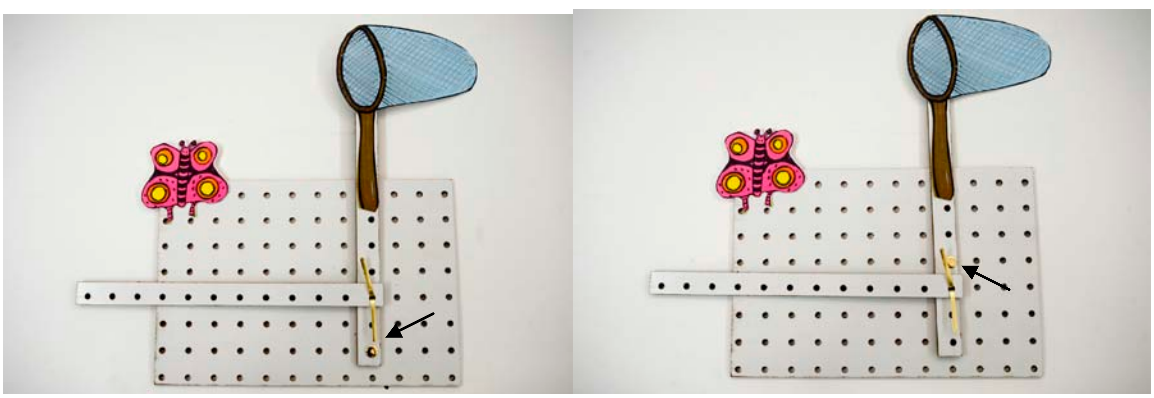


Figure 5: The Unhappy Butterfly Net (right) compared with the Happy Butterfly Net (left) using arrows to show locations of fixed pivots

Using the color code, children should notice that the only thing that's different between the two models is the location of the fixed pivot. This location changes the way the output moves when you push the input to the right. Help them structure and remember their findings by constructing and posting a class chart, like the one in Figure 5.

Science Notebook

Show how you would make an Unhappy Butterfly Net.

What would you have to do to change it into a Happy Butterfly Net?

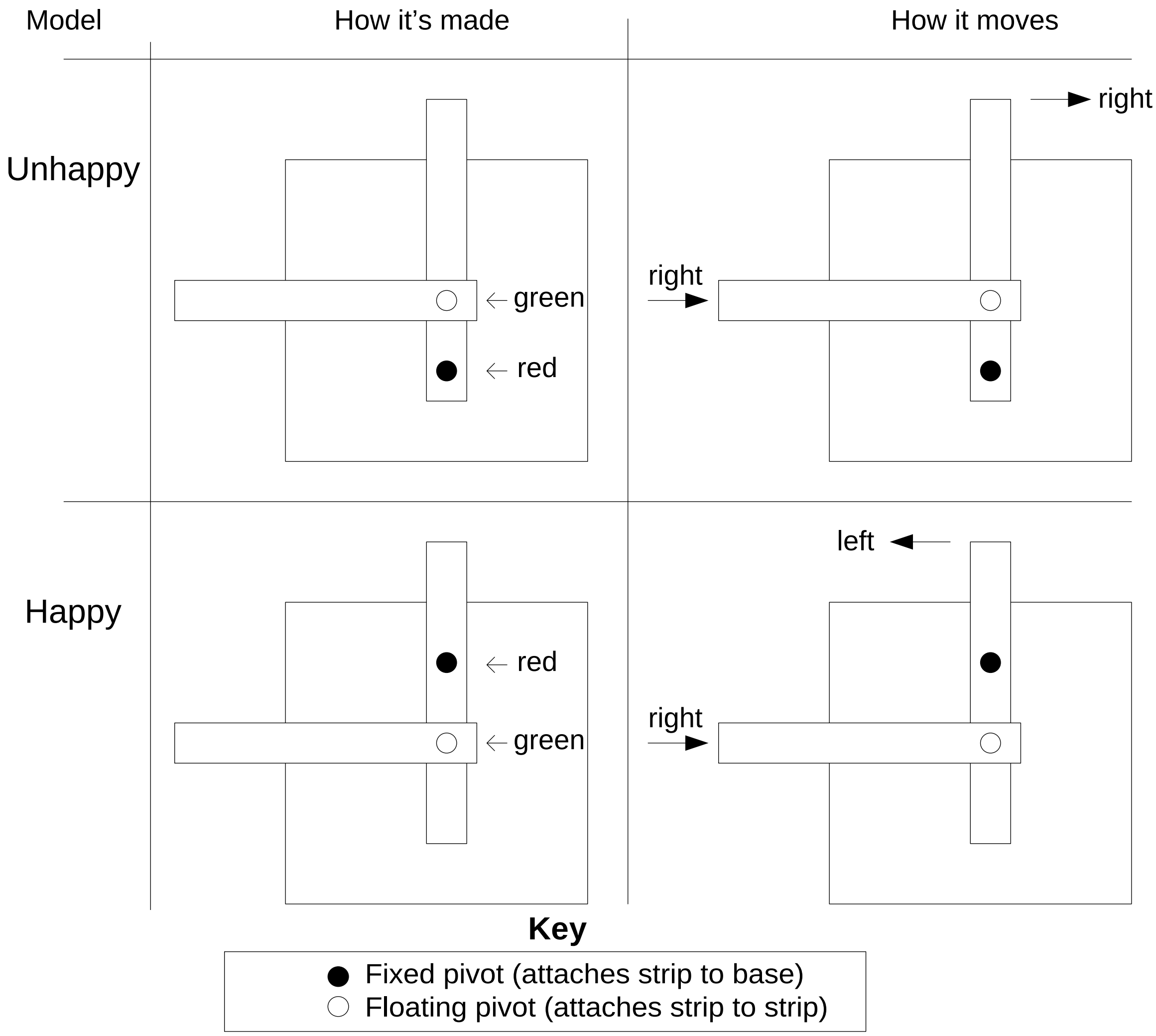


Figure 5: Comparing the Happy and Unhappy Butterfly Nets

Outcomes

Students should recognize that the location of the fixed pivot affects the direction of motion:

- If the fixed pivot is <u>above</u> the floating pivot, the input and output will go in the <u>same</u> direction.
- If the fixed pivot is <u>below</u> the floating pivot, the input and output will go in <u>opposite</u> directions.

Assessment

Show students an <u>Unhappy Butterfly Net</u>. Ask:

- *What would I have to change to make it <u>Happy</u>?*

Technical Background

This lesson gets at the difference in directions of motion between first and third-class levers. In the language of levers, a fixed pivot is called a **fulcrum**. Figure 6 reveals the **first-class lever** at the heart of the Happy Butterfly Net mechanism. Because the fulcrum is in between input and output, they have to go in opposite directions, just like in a scissors or see-saw. See also Technical Background for Lesson 7.

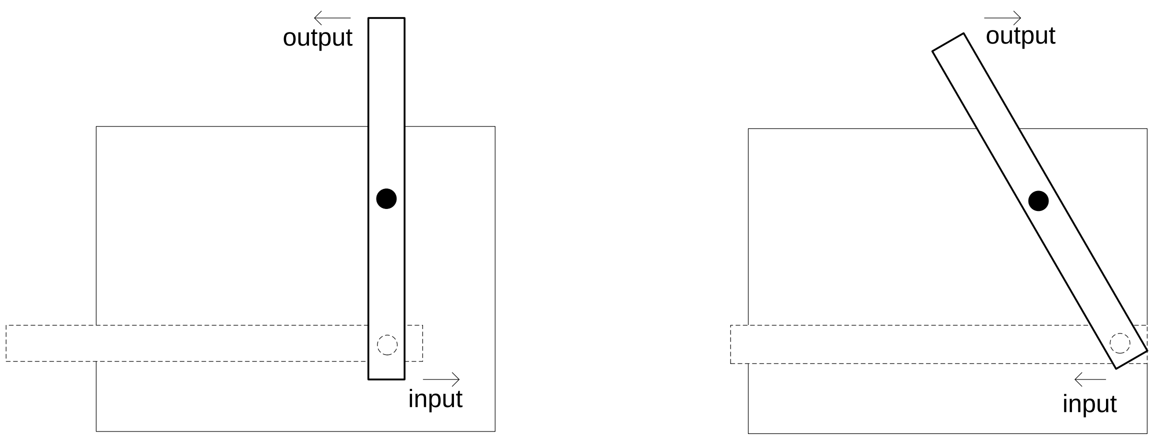


Figure 6: How a first-class lever is the key to the Happy Butterfly-net mechanism

Figure 7 is a similar diagram showing how the Unhappy Butterfly Net mechanism is based on a **third-class lever**. Here, the input is at one end, and the fulcrum is at the other. Because the input and output are on the same side of fulcrum, they have to move in the same direction, like in a tweezers or salad tongs. Note that second-class levers work just like third-class levers, except that the input and output locations are reversed. In a second-class lever, therefore, input and output also travel in the same directions.

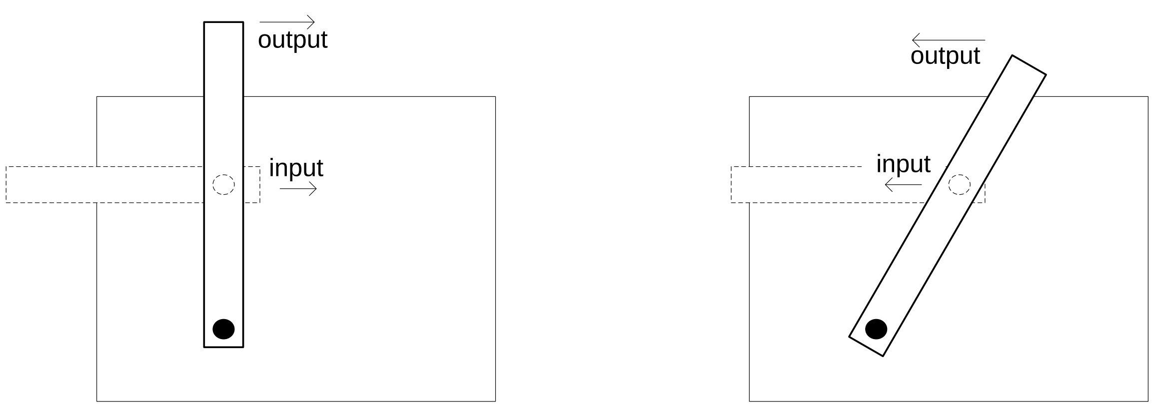


Figure 7: How a third-class lever is key to the Unhappy Butterfly Net Mechanism

Lesson 10: Make your Own!

Overview

Students use what they have learned to design and make new MechAnimations.

Materials

Cardstock and pegboard Mech-a-Blocks

Procedure

1. Designing and making: Students have the opportunity to make new Mech-a-Blocks constructions, using cardstock or pegboard or both. Encourage them to use what they have learned in the past few lessons about how to control the direction of motion, and the amount an output moves.

2. Sharing: Ask each child to demonstrate what he or she has made to the entire class, and ask the class to guess what it represents.

3. Display: If possible, provide a way for student work to be available to a wider audience. Some suggestions are:

- ✁ **Bulletin board or poster display**: Mech-a-Blocks can be attached to poster boards or bulletin boards. By using push pins strategically – for example, at the corners – you can avoid interfering with the mechanism, allowing viewers to try them out to see how they work. Pegboard models will require the longer pushpins to keep them mounted. If students have made pictures or written descriptions, these can be posted too.
- ✁ **Museum table**: For visitors, including parents, staff and other children, the Mech-a-Blocks can be displayed loose on tables with signs inviting viewers to guess what they will do and then test them.
- ✁ **Invention Convention:** You can stage a science-fair style event, to give children an opportunity to explain what they made and how it works to parents and other visitors.
- ✁ **Puppet show:** You could coordinate all of the MechAnimations around a common theme, and use them for staging a class puppet show.