Chapter 4

STORIES

Mechanisms have immediate appeal to nearly everyone who examines them, and they can be approached at many different levels. Table 4-1 suggests some of the ways to approach the study of mechanisms, from the most elementary to the most challenging.

In this chapter, five elementary teachers tell the stories of how they approached the study of mechanisms in their classrooms. These teachers worked at a variety of grade levels, and toward a variety of goals. Some saw mechanisms as a vehicle for teaching language arts, while others were more concerned with science concepts, such as levers and simple machines. Each began with one or more of the "Getting Started" activities and proceeded to activities from the "Analysis" and/or "Design" categories. As you read through their accounts, you will see a variety of ways of structuring this progression.

The study of circuits can also be approached first through hands-on experiments, scavenger hunts, and classifying. However, as noted in Chapter 2, circuits cannot be analyzed in quite the same way as mechanisms because the moving parts (electrons) can be neither seen nor felt. On the other hand, modeling and design activities with batteries, bulbs, and switches quickly reveal what it takes to make a circuit work. The section on circuits features two teachers whose stories about teaching mechanisms are also included in this chapter. The integrative theme for both of these teachers was "controls." Their students came to see how both mechanical and electrical controls share the common property of "influencing something outside of its own structure."

Table 4-1

Approaches to the study of mechanisms

Getting Started

Hands-on manipulation and sketching

Scavenger hunts

Sorting and classifying

Analysis

Looking for simple machines

Identifying effort, fulcrum and load

Finding first, second and third class levers

Design

Modeling existing mechanisms using recyled materials

Concept design of a mechanism to accomplish a particular task

Design and testing of pop-ups and toys

Five Teachers' Stories About Teaching Mechanisms

Annette Purnell, a first-grade teacher, used the study of mechanisms as a vehicle for developing her students' intellectual and social awareness. Her unit begins with analysis of the motions of simple tools and ends with designing and testing working models of scissors.

Kathy Aguiar, a bilingual special education teacher, began with a vocabulary question: "What is a control?" After doing some scavenger hunts, her children identified the control devices on familiar appliances and wrote about what the controls do. Their work with controls helped them overcome some of their inhibitions towards writing.

Shirley Monterroso-Nieves, a second-grade teacher with little previous experience in science or technology, engaged her students in an extended unit on mechanisms. They began by trying to explain what the word "mechanism" might mean. The students looked at simple devices to determine what they do and how they move. By the end of the unit, the children were using the terms "fulcrum," "effort," and "load" in analyzing these devices.

Mary Flores, a resource room (special education pullout) teacher engaged her fourth and fifth graders in both analysis and design of mechanisms. They began by trying to define "mechanism," by exploring simple devices, and by categorizing them. Eventually, they were able to design, evaluate, and redesign complex contraptions such as windlasses and "book-turning machines."

Angel Gonzalez is a science specialist. He introduced the work with mechanisms by setting up an imaginary situation involving a king, prisoners, and evil vandals. Within a short time, his students were able to describe the operation of some fairly complex devices: a retractable ballpoint pen and a valve for controlling water supply. This unit on mechanical controls led directly to further work with electrical switches.

The First-Grade "Mechanism Detectives" *by Annette Purnell*

I asked a question: "What is a tool?" I wanted to find out how familiar that term was to my first-graders. Several children could name tools and many could not. Then as the children began to describe tools they were familiar with, others raised their hands or called out to contribute. Afterwards, we sat on the perimeter of the rug and passed around a one-hole punch to explore how it worked. The class watched as each child demonstrated it. One child traced the hole punch in the rest position. Another child traced it in its contracted position. When the hole punch was in its contracted position, two people had to help each other.

Annette Purnell has taught kindergarten and first grade at C.E.S. 42 in the South Bronx, New York, for many years. She is deeply concerned with both the social and the cognitive development of each child, which she sees as closely connected. Annette began her work with mechanisms by using the word "tool" as the stimulus for an experience chart.

After this initial experience, Annette wanted her students to examine a variety of mechanisms closely, both to see how they work and to figure out what they are used for. She called this activity "Be a Mechanism Detective."

The children met as a whole class. I asked them to divide into groups of three or four. I kept six children, those who need much scaffolding and modeling before they can be independent. I became part of their group.

Annette provided a variety of mechanisms for each group to choose from. She deliberately selected mechanisms that would probably not be very familiar to the children, so it would be a puzzle to figure them out. They included a nutcracker, a garlic press, a pair of ice tongs and a pantograph. The latter device is used to reduce or enlarge drawings.

The pantograph group was the group I worked with. I could not hear the other groups' talk since I was with a group. I noticed that two of the six children in my group became much more interested than the other four. They were excited about explaining how the pantograph worked. They may become a group of two in later work. They don't ordinarily choose each other, so it was good that they worked together.

Annette asked each student to write down how he or she thought their group's mechanism worked, and what it might be used for. One student's work is shown in Figure 4-1.

Close examination of mechanisms helps children to develop their awareness of cause-and-effect relations. Sharing is essential, either through reporting or writing. Shared work really helps to develop an awareness of audience. Written work forces the writer to organize and develop his or her thoughts.

Listening to their language is one of my primary ways of processing what they have learned. When I sit with one group I can't float. This is worrisome for me, because then I cannot hear the other groups' language until sharing time. Sometimes their reasoning and insights can be brilliant.

Forty-five minutes seems to be a good amount of time for this work, including both exploring and writing. Children who write more slowly don't always get a chance to finish. After thirty minutes of exploration, I call for them to look for a "stopping place" so they will have time to complete at least one sentence.

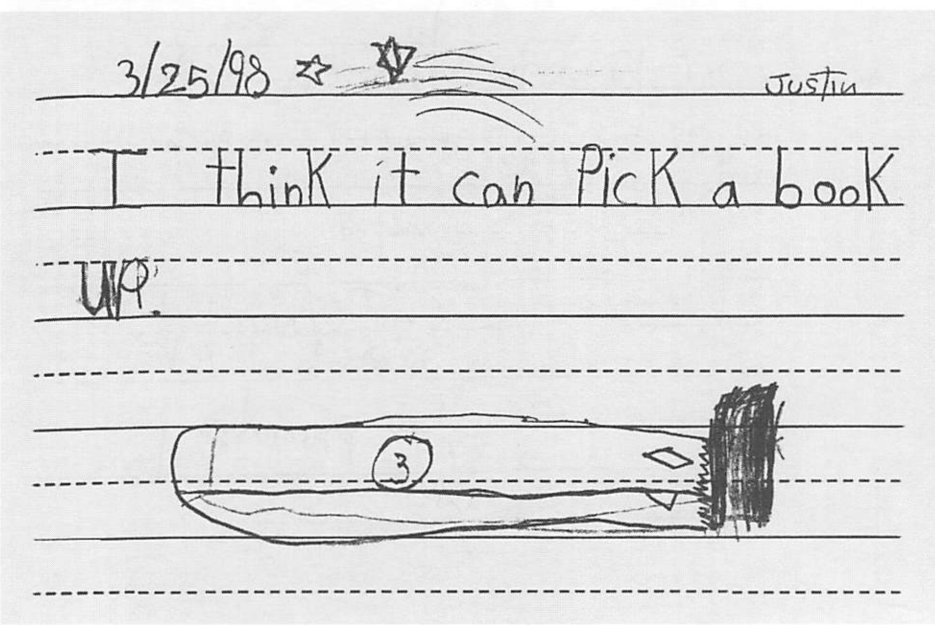
I see children in the same group writing the same observations. This is fine with me, because they are using one another for support. As they become more comfortable, their independence will flourish. I'll have them read their work to each other as a stimulus. I can also have each one write about a different aspect of the mechanism, which will vary the information of each child and encourage the socialization for listening.

Annette followed these "Getting Started" activities with in-depth investigations of a pair of scissors. She wanted her children to look very carefully at this already familiar device, to notice its patterns and motions and to make a paper model of it.

Before they started tracing, I led a brief discussion on looking for shapes. The children saw a triangle inside the two blades when they were in the open position. One child saw a triangle between the blade and handle on the left side and the same thing on the right side when the scissors were open. Another child described the holes within the handles as "circles."

Their next task was to trace the paths of the blades with their pencils. I modeled the method, using my

4-1: One mechanism detective's idea about a pair of ice tongs



finger to simulate the pencil. Each group of two had a single pair of scissors. Having only one scissors between them presented the opportunity for each student to watch, while the other was doing. There was another advantage in working in groups of two. When a difficulty arose, the need to solve it together reinforced their reading group theme on "What friends do and how they behave."

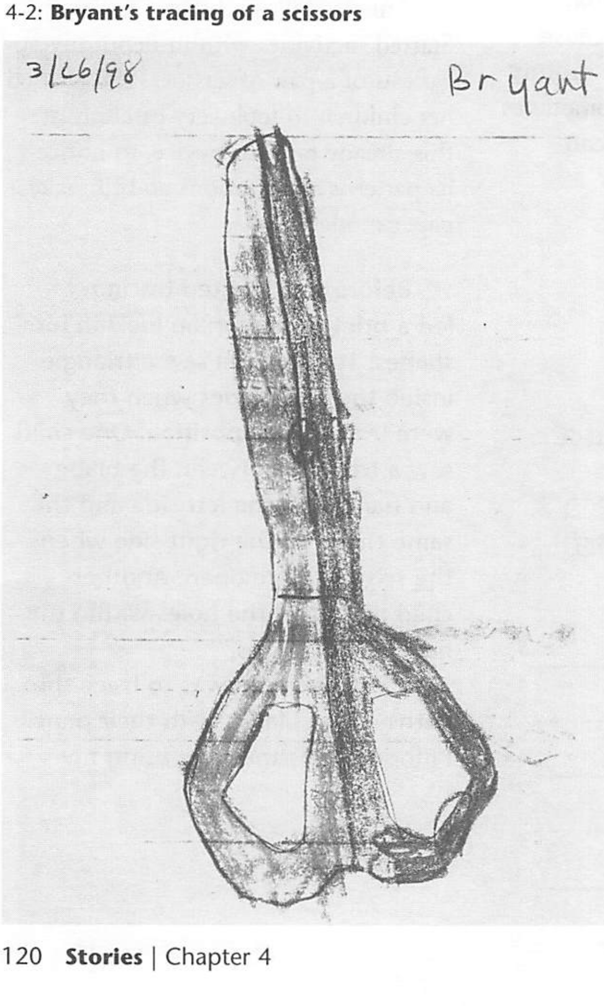
The tracings varied. Some children traced the entire pair of scissors first, while others traced just the path. Bryant's tracing of his scissors is shown in Figure 4-2, and his description of what it does is in Figure 4-3. Latisha explains how to use a scissors in Figure 4-4.

Difficulties arose when children attempted to follow the path and hold the scissors at the same time. It turned out to be impossible to do the whole job alone. When I saw this happening, I said, "I'm seeing your scissors moving. How can your partner help?" The "tracers" knew their difficulties, so they were able to get help. The results were paths that looked more like arcs. Those who went at it alone made paths that were straight lines. At the end of the activity, we came together to discuss it. I asked who found this task hard and who found it easy. For those who found it difficult, I asked what would have helped them. Several children found the movement of the scissors confusing. I would change the presentation by suggesting that they keep one part of the scissors fixed. The stationary part would make a better frame of reference for seeing the movement of the other part.

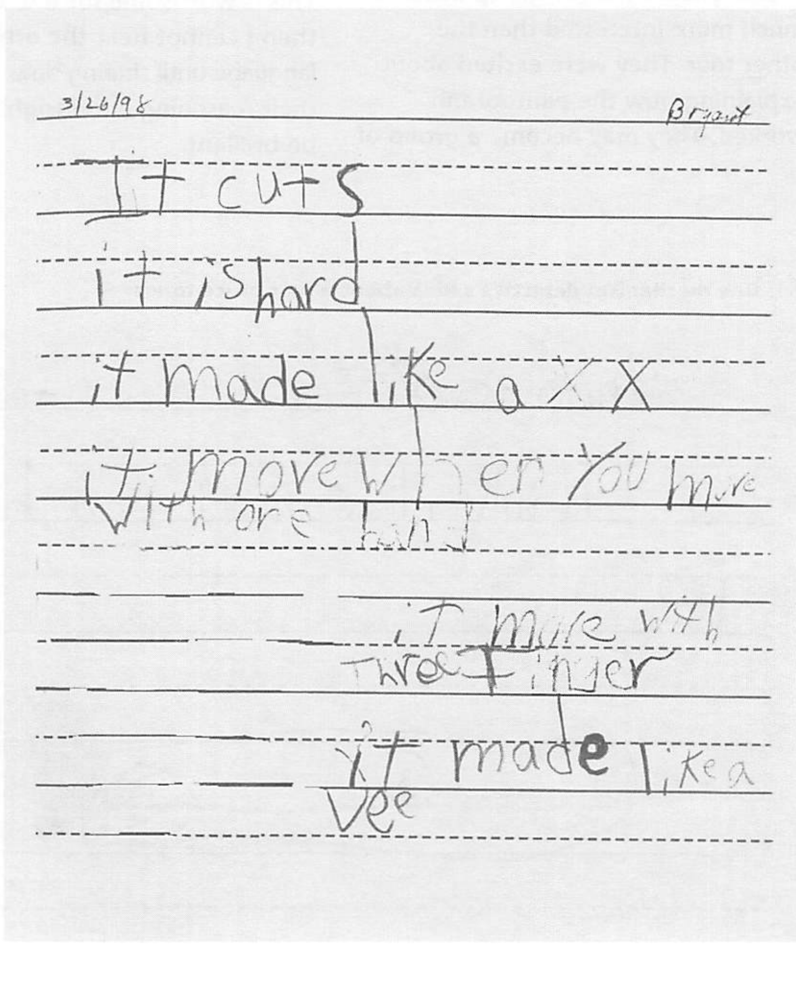
Annette's concluding activity involved modeling. Her children had to create a cardboard model of a pair of scissors. Annette pre-cut strips of oak tag, and also provided each group with paper fasteners and a one-hole punch. They had to figure out the rest. Some of the problems were:

- Deciding how to align the strips;
- Realizing that they needed to make holes;
- Figuring out how to use the one-hole punch to make the holes;
- Deciding where to put the holes;
- Determining how to use the paper fastener and how to secure it.

4-2: **Bryant's tracing of a scissors**



4-3: **Bryant's explanation of a scissors**



While these steps might seem obvious to an adult, they require considerable thought and discussion among first-graders. The use of the hole punch was particularly interesting to them. Although they had examined them as part of their previous explorations, they had never actually used one to make a hole.

Figure 4-5 shows the scissors model Carlos made.

Here are some of the children's comments about the activity:

MARK:
The hole punch makes a hole. I put the paper fastener through the hole.

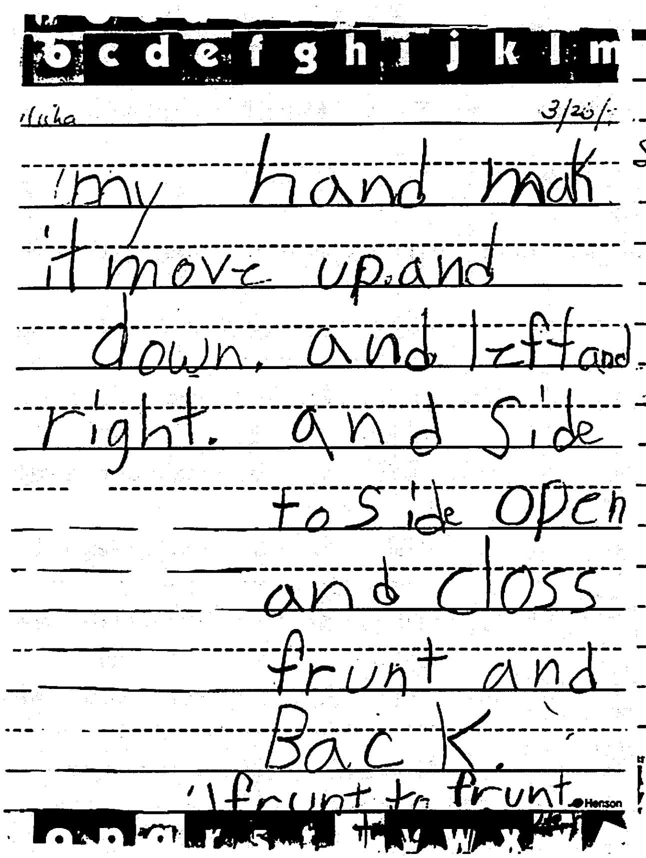
ARLEEN:
Leroy put the strips together. Then he put the paper fastener through the hole. Now we are going to see what else it can do.

STACEY/DOMINIQUE:
We put the paper like scissors. We used our fingers to see how the strips could do the same like our hands.

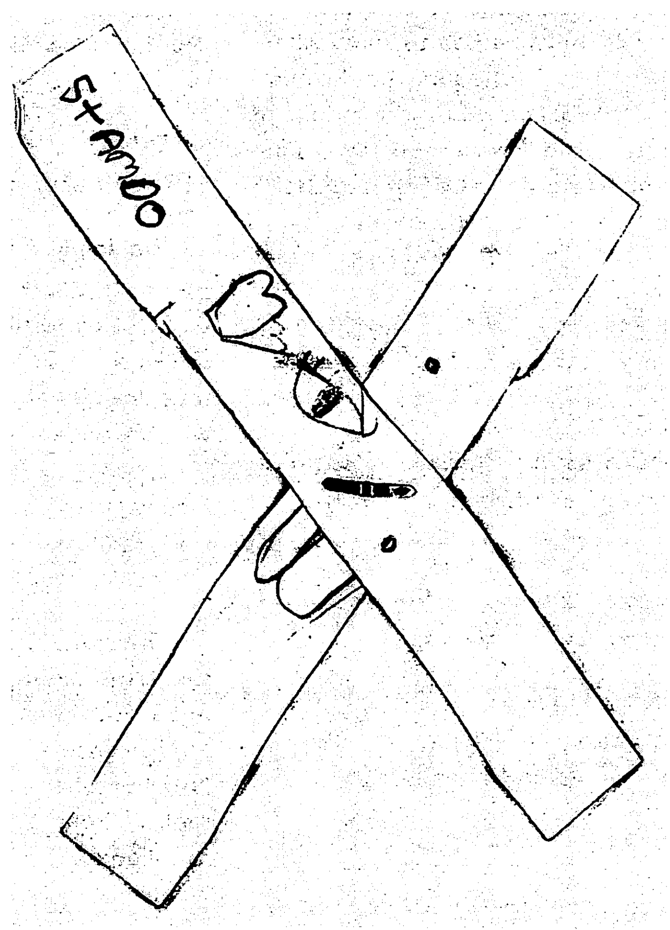
RASHAUN:
I put one strip on top of the other like an "X." I punched a hole in it with a hole punch. I put the paper fastener in it. Then I put the wings of the paper fastener down on the paper.

ANTONIA:
I put the strips together so it could look like an "X." Then Crystal asked for the hole punch and she made a hole. Then we tried to cut paper with the model scissors but it didn't work. We made it open and close. We could make it turn around and around like a toy.

4-4: **How to use a scissors**



4-5: **Carlos's model of a scissors**



Overcoming Barriers by Writing About Controls *by Kathy Aguiar*

Kathy Aguiar taught a third-grade bilingual special education class in the same school as Annette. She began the 1998-99 school year with some serious problems.

I was greeted with 15 bright-eyed bilingual special needs students. These students had a wide range of academic as well as emotional needs. Some of my students could be very aggressive. They would throw blocks and/or chairs. All of them showed signs of frustration while writing and reading. They also had very low self-esteem. The words most often spoken by them were:

- **"I can't."**
- **"I don't know."**
- **"I can't read this."**
- **"This is too much to write."**

Kathy's challenge was to convince these students that they could actually learn to read and write and that their participation in the process was essential. She selected controls as one of her major topics. The first activity was a scavenger hunt: *Find control devices in the classroom.*

Before my students were to find controls they first had to know what a control was. I thought that I could have several controls in the middle of the rug. Students were sitting around the objects on the rug. I posed the question: "What is a control?"

JOAN:
Nintendo—the buttons on the control makes the car move.

FREDDY:
La batería controla el reloj (The battery controls the watch).

JOSE:
On the cable box, the buttons control the channels.

YOKASTELYN:
The steering wheel moves the car to the right or left.

CARLOS:
The key lets the door open and close.

MARINA:
The pole controls the window.

We finally came to the conclusion that a control lets something else happen. While having this discussion, the students kept looking at and touching the objects on the rug, which were as follows:

- **a pen**
- **a wrench**
- **a radio**
- **a calculator**

The students were asked what the items had in common. They had not a clue. Then I introduced them to the concept of controls. I asked, "How or what is a control on the radio?" Some of the responses were as follows:

JENNIFER:
The button for the volume. It goes up and down.

FREDDY:
The button that turns it on/off.

JOAN:
The plug. If it is not plugged in then the radio won't work.

We continued this process for each object on the rug. Once I was satisfied that the majority of students understood the concept of controls, the students went back to their desks. The next part of the activity was for students to pair up. Each pair was to find controls within the classroom. The students were motivated and worked well together. They did not argue and tried to help each other. The results were as follows:

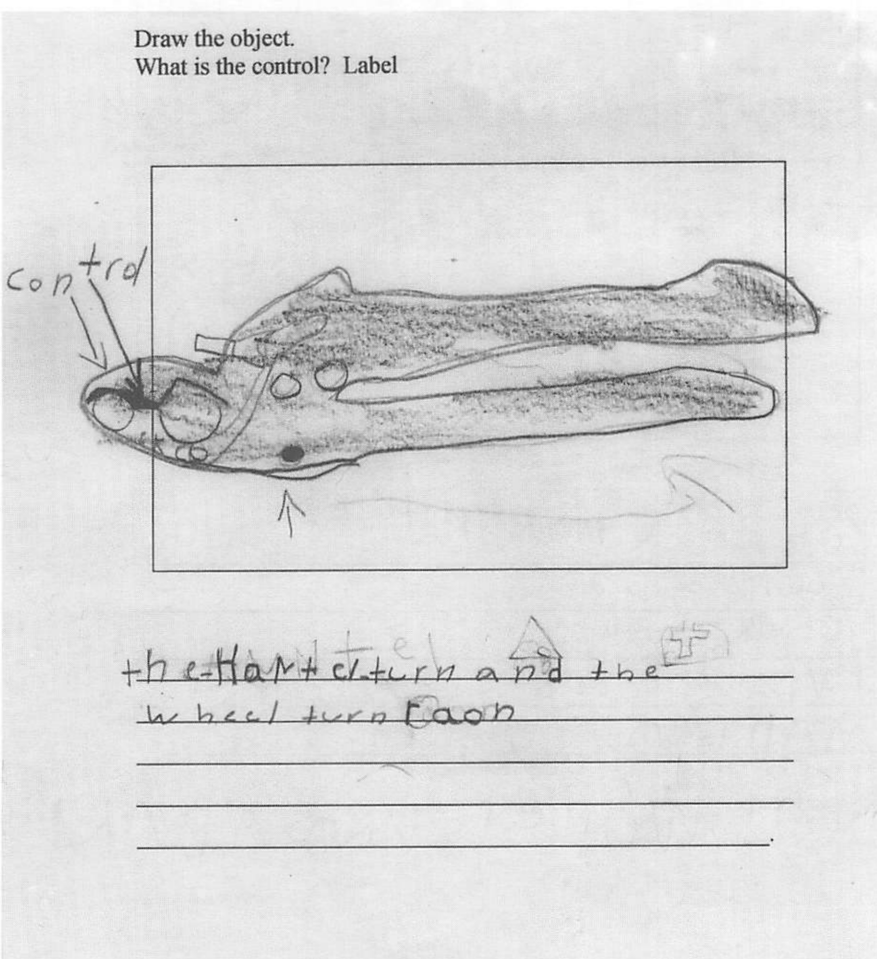
JOSE:
La pega junta dos papeles (The glue joins two papers).

ANDREW:
The batteries control the clock

JENNIFER:
The box holds the crayons.

Each student was able to explain how an item he or she drew was a control. They did become frustrated when it was time to write about the control. I did not obligate the students to write. Some children chose to write, while others simply drew and colored. (See Figure 4-6.)

4-6: **Looking for the control on a can opener**



In her reflections on this activity, Kathy recognized that the children used the word "control" in its everyday sense rather than its technical sense. They considered anything a "control" that causes another thing to happen. In its technical meaning, discussed in Chapter 2, the radio buttons would be considered controls, but not the plug, glue, box, or batteries. Only the buttons use minimal energy to control larger flows of energy elsewhere.

Nevertheless, Kathy was satisfied with this activity, because her primary goals were to engage the children socially and intellectually, and in ways they would not find threatening. Because they are familiar, interesting and fun, controls had proven to be an excellent vehicle for accomplishing these goals.

The next activity was to have students go around the school looking for controls. They were to record their findings on an activity sheet. When the activity was explained to the students, they were very willing to complete it. While planning this activity, however, I was concerned about several students' behavior. Once we were ready to go into the hallway, one of my students decided not to go. It took more than 15 minutes to finally get him into the hallway with the rest of the class. I began to think that this activity might not have been a good idea just yet. However, the rest of the class was very well motivated. They followed rules and looked for controls in an orderly manner.

We began this activity by looking at the classroom door as well as the lock. Many students saw the door and lock as controls. They were able to explain how they were controls. Each student then paired off with another. The hunt had begun. The students looked at everything.

YOKASTELYN:
The chair is a control. I couldn't sit there if the chair wasn't there.

JOSE:
The bulb controls the light.

RAUL:
The fire extinguisher controls the fire.

The hunt lasted for approximately 20 minutes in the hallway. We then came back in to the classroom. Students attempted to write about the controls they had found. The students became anxious when it was time to write. In reflecting on this activity, I felt that giving names of objects in the hallway could have alleviated some of the difficulty. Some students asked for spelling, while others used phonetic strategies to spell the words. We then shared our findings.

In general, this activity went well. The students understood the assignment. They went through the hallways quietly, trying not to disturb other students working. Sharing their findings proved to be valuable. They each found something different as a control. They were able to help one another in determining if the object was a control or not. They had a successful experience, which built up their self-esteem.

In terms of assessment, my first concern was to see if they could find control devices in the hallway. Once they found one, could they explain how it controlled? I felt that the next step would be to identify the control device with the thing controlled. The day before the activity, I let the class know that a friend was coming to take pictures of them. They seemed to be very excited.

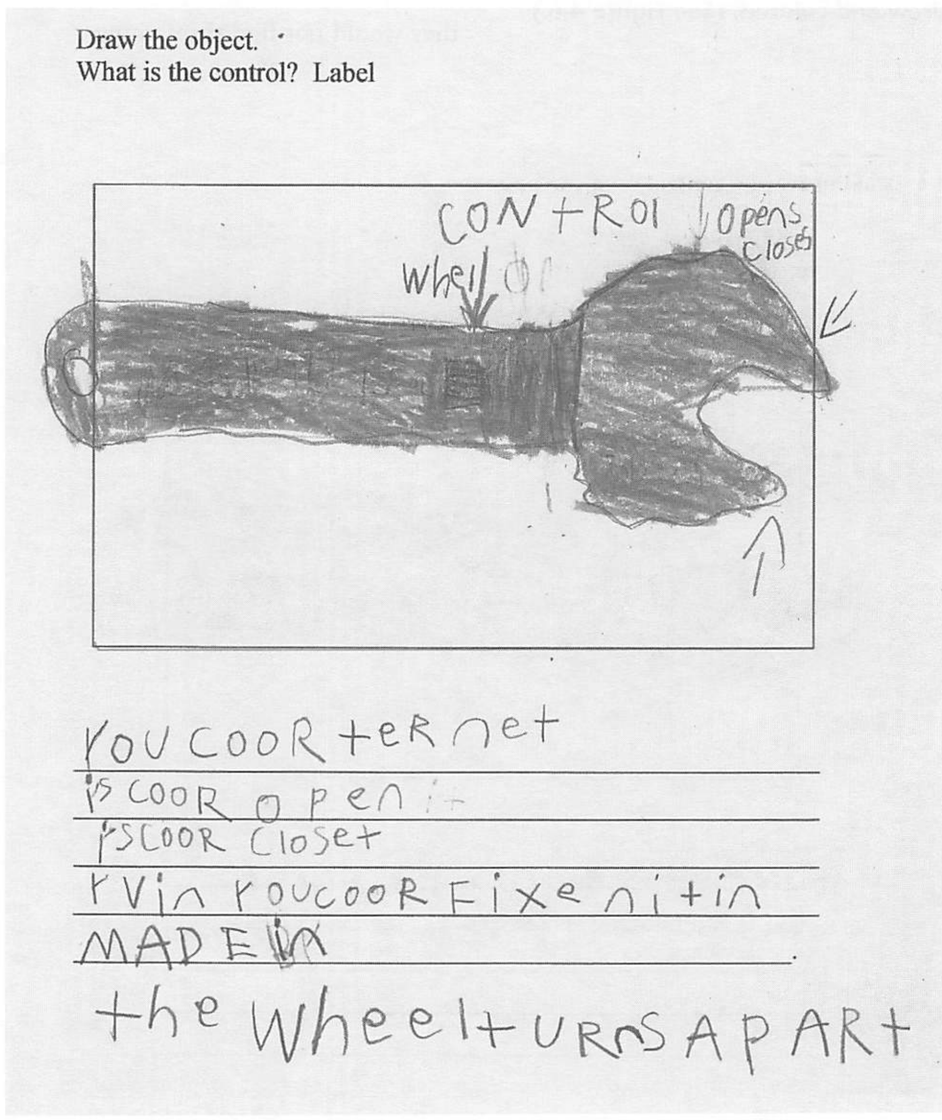
The big day came. I placed several different objects on the rug We reviewed what controls were. We began to focus on a stapler. What is it? What does it do? How does it work? What makes it move? Students began to notice things:

JOAN:
The stapler goes up and down. A screw makes it go up and down.

ANAYENCI:
The plastic strip pushes the staples.

JENNIFER:
Pega papel (attaches paper).

4-7: **Explaining an adjustable wrench**



Students were then divided into pairs. Each pair was given an object. They were to draw the object, and then describe where the control item was and how it operated. The control item may have been a button that turned something on/off when pressed. It could also have been a knob that controlled the volume or made something go on/off when turned.

Most pairs worked well. They quickly set out to draw the object given. The difficulties became evident once again with the writing aspect. They seemed to lack the vocabulary necessary to describe the motions they were observing. As I went from pair to pair, I noticed that all the students were having this problem. Many students dictated their responses to me and I wrote them down in order to relieve their frustrations.

In reflecting upon this activity, I felt that I should have anticipated some of the vocabulary words that might come up, for example, "spring," "knob," "turns," "up/down," "back/forth," etc. I should have had these words available in Spanish as well as English. This might have alleviated some of their frustrations.

In terms of assessment, students were able to point out where the control was. They were also able to determine how the object worked. Their frustration was with reading and writing.

After a discussion of this problem with *Stuff That Works!* staff, Kathy decided she would write a single word on the board, such as "control." Having drawn the object and identified the control device, all the students would have to do initially was copy the word "control" from the board onto their drawing. She could later expand their written vocabulary to include more words.

The next day I tried this modification to the previous activity I had done. The only word they needed to write was "control." At this point, they were not frustrated. The activity went very smoothly. I do not know if it was because this was the second attempt to do the activity, or because of the limited writing required.

Before long, Kathy's students were writing extensively about controls. An example is shown in Figure 4-7. At the end of the school year, Kathy looked at these drawings again. She observed, "It's hard to believe that these are the same children that I have now. They have come a long way."

Second-Graders Learn About Levers

by Shirley Monterroso-Nieves

Shirley Monterroso-Nieves teaches learning-disabled second graders at P.S. 96 in East Harlem, New York City. She became intrigued with mechanisms and felt that an extended unit on levers would create important learning opportunities for her students.

I must say that initially, the topic of mechanisms did little to motivate me, and thereby enable me to teach it to my second graders. In fact, I was very intimidated by the topic although I had engaged in some exploratory learning over the summer. There were many things that I did not fully understand, and I decided to do some more reading to feel comfortable with it myself.

As I began to sift through some of the very basic concepts in mechanisms, I decided to narrow my objectives for my students. I didn't think it would be developmentally appropriate for seven- and eight-year-olds to grasp the concepts of first-, second-, and third-class levers, nor did I view it to be so important. What I did see as valid learning concepts were:

1. **Its function or job: What does the mechanism do?**
2. **Cause-and-effect: How does it work?**
3. **The role of our body in using it: What must you do to it to make it work?**

Eventually, I wanted my students to be able to identify the mechanism's parts in terms of "effort," "load," and "fulcrum." I thought that if my students could pick up any mechanism and identify its three major parts, I would have accomplished a tremendous task.

What Does It Do?

Our journey into mechanisms began with an exploratory look at how a clothespin works. First I read them a short book called *How Does it Work?* This book gives a very simple, pictorial explanation of the operation of a train locomotive. I asked, "What do you think the book was trying to show us?" Esther raised her hand and said that it was showing how different machines work.

I held up a clothespin, the kind with a spring inside, and squeezed it open. I asked if anyone knew what it was. Robert C. raised his hand and said, "It's for clothes, to hang them outside." I said, "Yes, it is indeed a clothespin," and asked if anyone knew what its job was. The room was quiet for a moment, so I prompted on. "Does it wash the clothes for us? Does it dry them or make them look pretty? What does it do?"

Kathy raised her hand and simultaneously called out, "It holds the clothing so it doesn't fall down!" I praised her and asked who else had seen or used these before, and many of the children raised their hands.

Then I wrote the word "mechanism" on the board and asked if anyone knew the word. Cathy said something like "MEE-CHEW-NISMS" and Chris yelled out "Machines!" I was elated that they had gotten that far in decoding. Also, Chris's connection with the word "machine" was a perfect lead-in to defining the word.

I asked if anyone wanted to take a guess as to what the word could possibly mean, and it became quiet again. I noted that someone had already mentioned it, and after a few seconds said, "Chris, you used the word 'machine.' That's exactly what a mechanism is, except that it is a very small, simple machine. It's not as big as a car or boat, but I'll bet there are lots of little mechanisms that help cars and boats work."

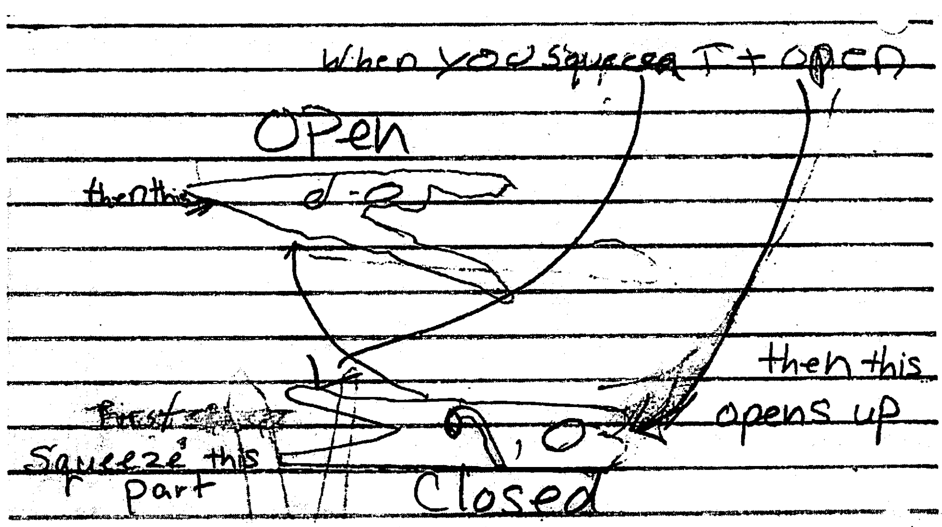
I explained that as a first step towards understanding how mechanisms work, I wanted them to try to figure out how this particular mechanism, the clothespin, works. I gave each child a clothespin and asked them to make maps of these objects. I used the term "map" instead of "diagram" since "map" was already a familiar term to them. I was not sure they were ready for terms like "fulcrum," "effort" and "load." Instead, I asked them to give the mechanism parts names like "top" and "bottom," and to identify and label the part of the mechanism that did not move. I also asked them to write a few sentences about how they thought it worked, and what you had to do to make it work.

Each of them was able to trace the outline with the help of a friend, and one or two attempted to make a sketch of what they saw. Although many of them were very adept at articulating what they had learned, very few were able to express it in writing. Except for Esther, Catherine, Pauline and Kathy, they all avoided the writing part of this activity like the plague. Figure 4-8 shows an example of the children's work.

To assist them in this process, I wrote the words "top," "bottom," and "doesn't move" on the board. Still, they did nothing to adhere to my request, and I didn't want to push the issue. I thought it might be too much for them to take in, in one lesson. I was amazed that they had an interest and were motivated at all! I guess that touching and playing with the mechanism is what appealed to them. This initial experience made me feel more at ease with the topic, and gave me ideas about how I would approach it in the future.

Shirley had an experience that was similar to Kathy's: the children loved playing with their mechanisms and drawing them, but stopped short when it came time to write. She also applied a similar strategy: writing useful words

4-8: **"Map" of a clothespin**



on the board for the children to copy. Although many of them did not accept the prompting, they subsequently became more confident about writing, as we shall see. *Stuff That Works!* staff asked Shirley why she had used the geometric categories "top" and "bottom" for identifying the parts of the clothespin, rather than functional categories, such as "input" and "output."

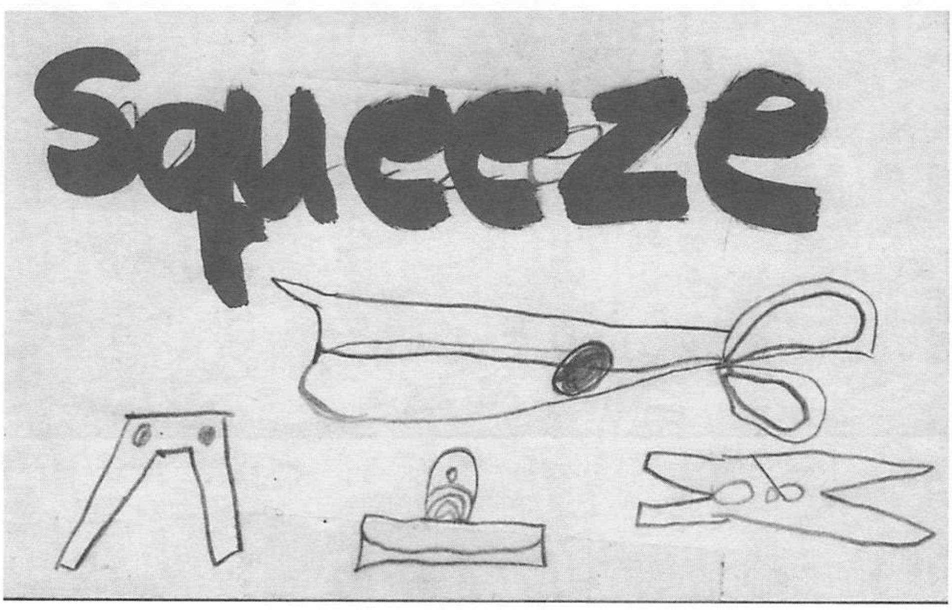
When I thought of this activity, I asked them to name the parts of the clothespin, such as top/bottom, because I wanted them to start thinking in terms of the relationship of parts to a whole. I wanted them to name the parts themselves, and see what they could come up with to establish a comfort zone. I came up with the top/bottom categories, but some of them used their own names.

My categories could have been a little fuzzy, because "top" for one child could have been "bottom" to someone else, and vice versa.

Perhaps it would have been better to label the "part that you squeeze" and the "part that does the job" – i.e., the teeth that hold the clothes on the line. I also thought about using words like "input/output," but I wanted to move eventually to terminology like "fulcrum," "effort," and "load." I didn't know whether yet another set of unfamiliar terms would just have made it more confusing. I could see them coming to me and saying, "But Ms. Nieves, you said we should call this 'input/output.' How come we have to use these new names now?"

Shirley followed the clothespin activity with a more extended challenge, which asked the children to determine the function and method of operation of a variety of mechanisms.

4-9: **One group's "squeeze" category**



How Does It Do It?

The second activity required children to work in cooperative groups. Various mechanisms were placed on a tray, along with a large sheet of construction paper, pencils, and magic markers. I brought in the following mechanisms for them to look at:

- **Clothespins;**
- **Scissors: children's, adults', kitchen types;**
- **Spring clips: magnetic clips for a refrigerator, hair clips, bull dog clips;**
- **Ice cream scoops of different types;**
- **A corkscrew;**
- **Spatulas and large spoons;**
- **Nutcrackers;**
- **Potato peelers of different shapes and sizes;**
- **A garlic press;**
- **Can openers of different types, including a "church key";**
- **A hole punch;**
- **A screwdriver;**
- **A compass; and**
- **A door stopper.**

I asked them to do three things with these devices:

1. **Figure out what they are.**
2. **Determine what function they serve.**
3. **Categorize them according to what you have to do to make them work.**

We reviewed what a category is, and I held up various mechanisms to show what I had to do to make them work. As I was demonstrating, they came up with these categories:

- **Squeeze (Figure 4-9)**
- **Open and close**
- **Push**
- **Pull**
- **Scoop**
- **Use your hand**

The last category meant that your arm or hand becomes part of the mechanism.

Coming up with the categories was the easy part. It was another matter to get the entire group to agree on what category a particular mechanism belonged to. It was a challenge to decide who would lead the group, who would be the coach, and who would draw which object.

Miriam decided that she would solve these problems by doing it all herself. Her group was slightly upset with her, but they amused themselves anyway by further exploring the mechanisms. Meanwhile, Miriam explained in writing what she understood about the mechanisms (Figure 4-10). She was the only one to use words to categorize the mechanisms. The others used outline drawings to show which mechanisms went in each category as shown in Figure 4-9.

Afterwards, each group presented its work in front of the whole class. They had to justify why they placed the devices under each category. Most of them took this as an opportunity to pick up the objects and demonstrate how they thought they worked. This was good for the children who until then had taken a back seat in the project. It gave them an opportunity to participate orally, which some learning disabled kids are more adept at. They all had a blast!

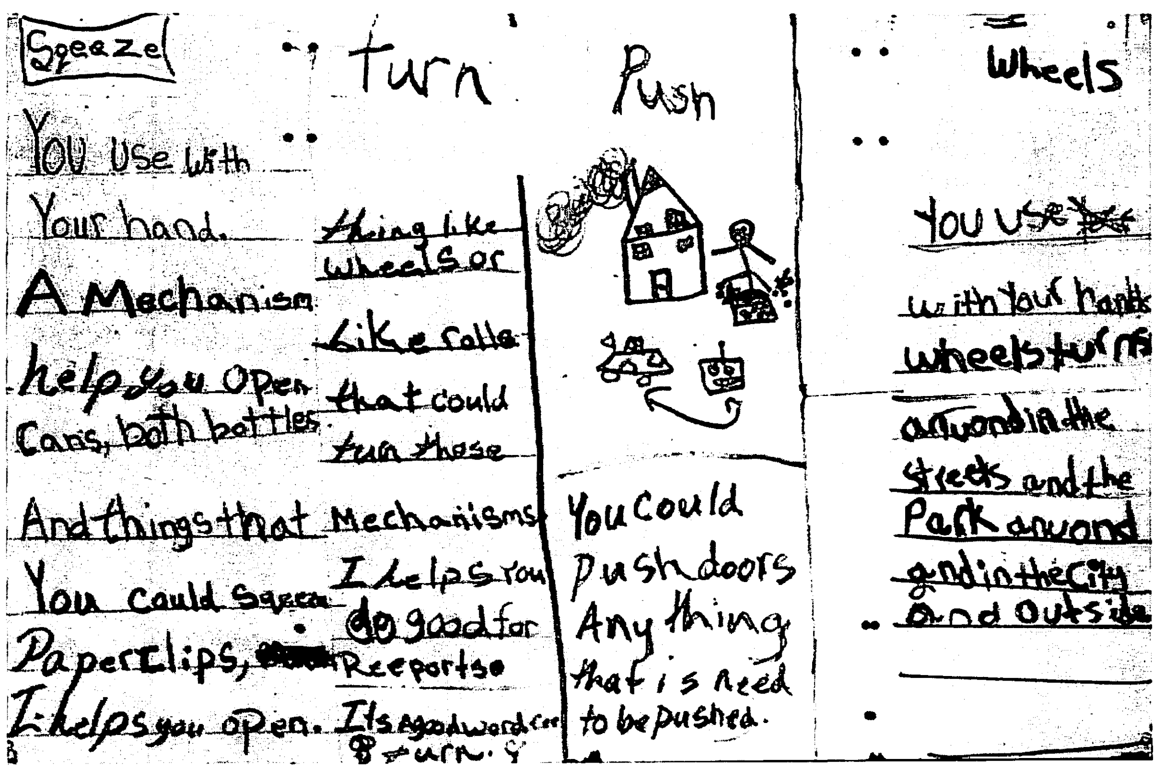
It was nice to see them take such an interest, and it motivated me further. I would add that many of the mechanisms, which I brought from my home, were foreign objects to the children. Quite a bit of the period was taken up with trying to figure out what the mechanisms were and what job they do. They were able to identify 90% of them correctly.

Shirley's goal was to develop an understanding of levers among her children. To do this, they would need to be able to identify the fulcrum, effort, and load of some devices. She felt that the fulcrum was the easiest of the three to find, because it is the only part of a lever that does not normally move. She developed the following activity to help her children find the fulcrum of a pair of scissors.

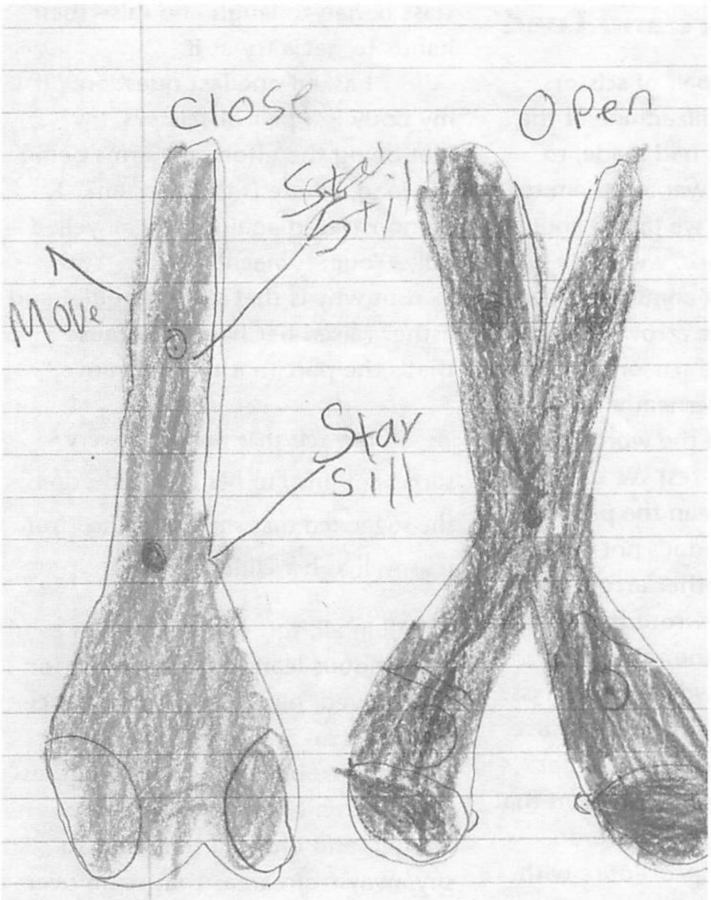
Which Parts Move, and Which Parts Do Not?

I asked the children to take a careful look at scissors. They were to figure out what parts move, and which parts stand still, when the scissors is cutting paper. In order to show this understanding, I asked them to draw the outline of the scissors while it was closed, and another outline while it was open. Eric's work is shown in Figure 4-11. These drawings helped them see the relation of parts to the whole, and how they are interconnected. I had also brought them closer to understanding and identifying fulcrum, effort, and load, without the intimidating vocabulary that I would introduce later.

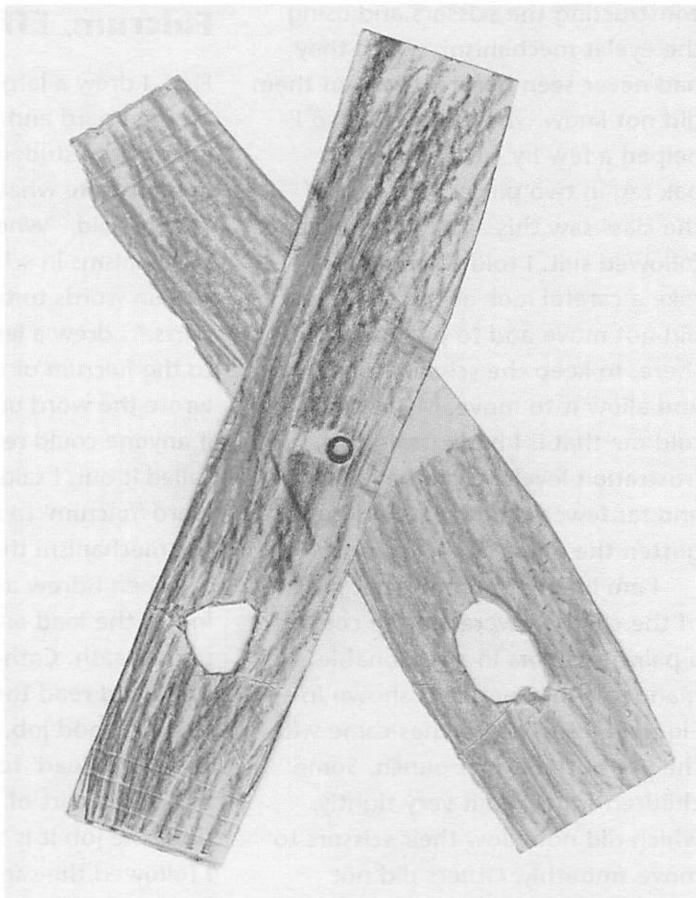
4-10: Miriam's categories



4-11: **Eric's diagrams of scissors**



4-12: **Model of a pair of scissors**



Although I had written the words "move" and "stay still" on the board to assist those who were less adept at writing, it didn't seem to help everyone. Only half the students complied with this aspect of the project. The others either didn't have time to finish or were more concerned with how the scissors looked than with how it worked.

Next, Shirley moved on to the concepts of effort ("If I do this...") and load ("...then this happens."). This approach to understanding "effort" and "load" ties these terms in with the most basic concepts of cause and effect.

Based on the dialogue that took place, I do know that approximately 95% of the class understood which parts moved and which didn't, even if they didn't write it down.
I tried to circulate around the room so that I discussed these elements with each child at least twice. If it was unclear to a child, I demonstrated what I meant by pointing to each part and asking which ones moved and which did not. By breaking the mechanism down to its parts, they were able to see the connection of the effort and the load: if I do this (effort), then this happens (load). They could also see the stationary role of the fulcrum, which holds the pieces together while allowing the flexibility of movement. It was a learning experience for all of us.

Shirley's next activity engaged the children in making models of scissors, as Annette did. Shirley used eyelets instead of paper fasteners. (Chapter 1 describes the eyelets and eyelet tool in greater detail.) Also, Shirley used the scissors models to further develop notions about fulcrum, effort, and load.

Constructing a Model

The next part required the children to construct a pair of scissors using oak tag and eyelets. Each child received a 6" x 11" piece of oak tag, a pair of scissors, and a hole punch. Five tables shared four eyelet punches. I demonstrated how the eyelet tool worked and gave them scrap sheets to practice on. I explained that the eyelet punch is more effective if you first punch a hole in each piece of oak tag with the hole punch.

The children were very excited about constructing the scissors and using the eyelet mechanism, which they had never seen before. Many of them did not know where to begin, so I helped a few by cutting the oak tag in two pieces. The rest of the class saw this as a good idea and followed suit. I told them all to take a careful look at the part that did not move and to put the eyelet there, to keep the scissors together and allow it to move. My instincts told me that if I hadn't said this, frustration levels would have risen and far fewer children would have gotten the point of the lesson.

I am happy to report that most of the children were able to construct a pair of scissors in a reasonable manner. (An example is shown in Figure 4-12.) The glitches came with the use of the eyelet punch. Some children squeezed it very tightly, which did not allow their scissors to move smoothly. Others did not squeeze tightly enough, and this led to the scissors eventually falling apart. Yet most of them were successful. I complimented them on all their hard work and ingenuity.

Shirley felt that the time had come to introduce the terms "fulcrum," "effort," and "load." She wanted to make these "science" words come alive for them, so they could also make connections with other kinds of mechanisms.

Vocabulary Build-up: Fulcrum, Effort and Load

First, I drew a large pair of scissors on the board and utilized one of the scissors the students had made, to demonstrate what I wanted them to know. I said, "When we talked about mechanisms in science, we used certain words to talk about different parts." I drew a large arrow pointing to the fulcrum of the scissors, and wrote the word underneath it. I asked if anyone could read the word. Anita called it out. I said, "Yes! We use the word 'fulcrum' to mean the part of the mechanism that does not move."

Then I drew another arrow pointing to the load and wrote the word underneath. Catherine raised her hand and read the word to the class. I said, "Good job, Catherine. We use the word 'load' to tell people that this is the part of the mechanism that does the job it is supposed to do." I followed the same procedure with the word 'effort' and Esther read it for us this time. I said, "Terrific job, Esther. We use the word 'effort' to show that we must do something to this part of the mechanism in order to get the rest of it to do its job."

Shirley then reinforced the word "effort" by using the example of "putting a lot of effort into your work." To make these ideas and terms come alive she then lay on the floor and pretended to be a pair of scissors.

I lay on the floor and asked, "Michael, will you put the effort into the scissors to make it work? And Marie, you hold the piece of paper at the other end of the scissors. Now Mike, open and close the scissors with your effort while I cut the load."

I demonstrated and the whole class began to laugh and raise their hands to get a try at it.

I asked one last question: "If my body is a pair of scissors, my feet being the effort, my arms being the load, where is the fulcrum?" I demonstrated again. They all yelled out, "Your stomach!" I said, "Yes! But why is that?" It was quiet and Esther raised her hand. "Because that's the part that doesn't move."

Shirley felt that this was a very successful unit. In her final reflections, she suggested that she had gained from it as well as her children:

All in all, this curriculum was a tremendous learning experience for all involved, particularly me. Science, for me, is an area that I am deeply attracted to but for which I feel most inadequate. I know myself as a learner, and I have a tendency to shy away from areas that seem overwhelming and intimidating. I must begin my journey as a child, one step at a time. I'm only happy to have my kids around to accompany me along the way. They make the trip much more exciting and far more rewarding.

What Shirley accomplished with these second-graders is impressive, particularly given her initial hesitation. It would be interesting to know to what extent the children's understanding of "effort," "fulcrum," and "load" would transfer to other devices. The simplest transfer would be to a similar mechanism, such as a pair of pliers. More difficult would be finding the effort, fulcrum, and load of a second- or third-class lever, such as a nutcracker or a tweezer.

Mechanisms in a Special Education Resource Room: From Pop-Up Books to Conga Machines *by Mary Flores*

Mary Flores is a resource room teacher in C.E.S. 42 in the South Bronx, the same school where Annette Purnell teaches and where Kathy Aguiar taught. She works with small groups of children, no more than eight at a time, from both lower and upper elementary grade levels.

My resource room setting is out of the norm. I have five groups with no more than eight students at a time. If my lesson doesn't work with one group, I have the opportunity to change the activity and do it differently with the next group. By the time I have finished with the fifth group, I have polished the lesson.

Mary believes very strongly in active learning. For several years, she has been using mechanisms as a topic that engages her special education students and provides opportunities for developing their literacy. Before beginning a formal unit on mechanisms, her children had been trying to make pop-ups as part of a bookmaking activity.

We began studying mechanisms back in November. However, it was not defined as such. I brought in samples of books I'd made at a book arts workshop. I included many different design possibilities for students to look at and replicate. My books included pop-up mechanisms, sliding mechanisms, and doors within the book that opened and closed.

The bookmaking served as an incentive to get the students to write. I decided to have the students examine and make the mechanisms in pop-up books. The students incorporated the designs found in a variety of pop-up books to create their own. Many of them had difficulties in this area. Some of their books took on the appearance of my models.

Several months later, Mary returned to the topic of mechanisms, with an extensive unit that made the progression from "Getting Started" through "Analysis" to "Design."

March 9

Today we began the study of mechanisms. I asked the students in one group, mainly third graders, to sit in a circle around a chart tablet. I asked them to define the word "mechanism." They were unable to, but instead began identifying objects they thought were mechanisms. William began the KWL chart by stating that mechanisms are "in vehicles and electric things." No one else responded.

I asked the students what word they could find inside the word "mechanism." Lismarie said that it sounded like the word "mechanical." I asked for an example, and she said, "like a pedal on a bike. It does something." William said, "I see the word 'mechanic.'" Other students raised their hands and I wrote all the answers on the chart tablet:

- **For vehicles/wheels on the car**
- **Electric things**
- **Pedal on a bike/it does something**
- **How stuff happens/like if you're making computers, you have to go through steps**
- **Math/symbols**
- **Calculators/pencil sharpeners**
- **Electric stuff**
- **Telephone/television/CD player**
- **Pen**
- **Things that run on batteries**

At some point, the students ran out of ideas. I said, "I am going to give you a clue about what a mechanism is. Your arm is a mechanism. Now define the term 'mechanism' for me." They added these to the list:

- **Things that move/your arm**
- **Magnet**
- **Hammer/screwdriver/door lock**
- **Tools**

After exhausting their responses, I handed out mechanisms and a worksheet entitled "What's My Mechanism?" (Figure 4-13)

The mechanisms included:

- **Eyelash curler (Figure 4-14)**
- **Garlic press**
- **Bug catcher**
- **Wire stripper**
- **Wrench**
- **Pincers (reverse tweezers)**

Many of the students did not know what their mechanisms were. Although things went relatively smoothly, I am not sure where I am going next. Do I introduce more simple mechanisms, or have them build their own?

In the afternoon, I conducted this same activity with a fourth-grade group. They were the only group that already knew what the word "mechanism" meant. I had to limit the discussion because I was anxious to get to the activity. We could

4-13: **"What's My Mechanism?" worksheet**

Name: Stephanie Darnell Date: March 12 1998

What's My Mechanism?

1. Examine your mechanism. How does your mechanism work?

works like a Scissor. you open the handles

2. Sketch the mechanism in the open and closed position.

3. What is the function of your mechanism?

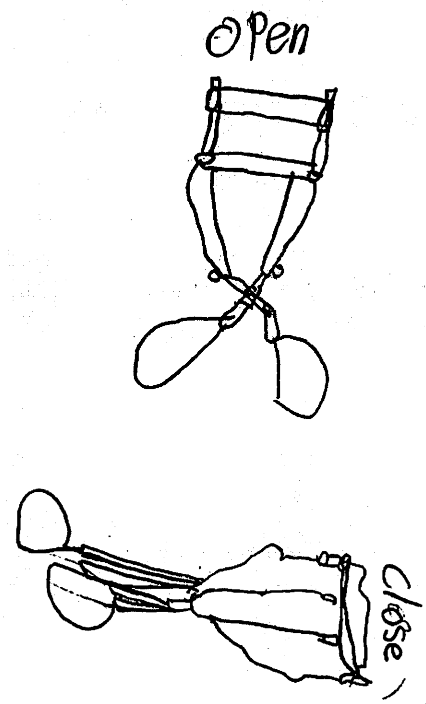
when It is Opened I look Just like Closed it look like a cooing utensil.

4. Write down your experiences and questions

Why does it look a Chair with handles?

(Eyelash Curler)

4-14: **An eyelash curler, open and closed**



have kept on going. Here is the list they generated:

- Certain kinds of tools
- Mechanical objects
- Inventions/like a robot
- Tools that do certain jobs/ monkey wrench, crank, slingshot
- Chairs: wheelchair because it has a lever, folding chair
- Ball bearing/things that move
- Computer, typewriter, fan, faucet, car, broom, door lock, door knob, staple gun, hole puncher
- "We are mechanisms because we move around." (Victoria)

What do I do with all this great stuff!

After being assigned their mechanisms, this group of students had little difficulty determining the functions of their mechanisms, as shown in Figure 4-15. I just had an idea! I will have them categorize the mechanisms.

March 18

I instructed the morning students to begin grouping the mechanisms. Things did not go smoothly. They did not understand the term "grouping." I had to think quickly. How could I get them to understand the concept? I tried to explain how to group without grouping for them.

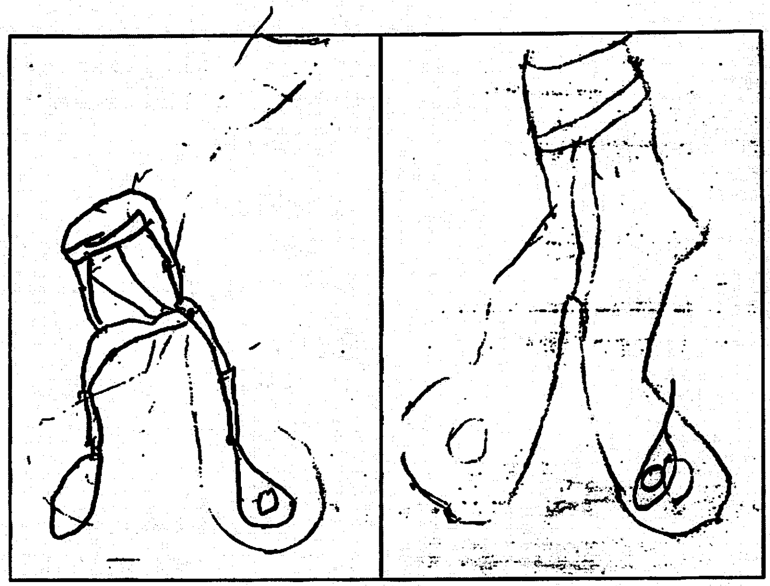
Dario and Tanya completed the activity rather quickly. They said, "One group opens and closes and the other group does not." It was not the kind of answer I was looking for. I had wanted them to group by function. No dice!

Later that day, I conducted the same activity with my fourth-graders. Considering the problems the other groups had had with the term "grouping," I played a game with them. I asked all the students to stand in a circle, and instructed them to group themselves according to their own similarities and differences. The possible categories were endless. I wrote their ideas on the board:

- Buttons/no buttons
- Earrings/no earrings
- Blue pants/gray pants
- Keys/no keys
- Glasses/no glasses
- Teacher/students

4-15: **The eyelash curler explained**

Name: Patrick Cru Date: 3/17/98



1. Examine your mechanism. How does your mechanism work? You have to stick your finger inside of the two holes you spread them and the top opens.
2. Sketch the mechanism in the opened position and in the closed position.
3. What is the function of your mechanism? I think it's an eyebrow plucker
4. Write down your experiences and questions. on the front of the eyebrowplucker it says "cover girl" It also looks like one.

- Girls/boys
- Bald-headed/hair
- Barrettes/no barrettes
- Shoes/sneakers
- Jackets/no jackets
- Chains/no chains
- Belts/no belts

Afterwards, I brought over my own collection of mechanisms and had the students identify them. As they named them, I listed their responses on the dry eraser board. I identified the ones they could not name. The mechanisms were:

- Ratchet wrench
- Eyelash curler
- Retaining ring remover
- Garlic press
- Combination wrench (box/open end)
- Phillips-head screwdriver
- Adjustable wrench
- Wire stripper
- Needle nose pliers
- Scissors
- Hammer
- Pincers
- Staple remover

I divided the students into two groups and assigned each group to an area. The two areas had been set up to include similar mechanisms. Each child was handed a worksheet entitled "Where Do I Go?" (Figure 4-16)

The worksheet originally read, "Categorize the mechanisms into two groups. Tell why you divided them the way you did." I realized that this task was too simple for this group. I went over to the computer and changed the worksheet to read "Categorize the mechanisms. List all the ways you can divide them."

Moises and Cynthia worked cooperatively. They took turns categorizing the mechanisms as Moises wrote down his group's responses. At one point, Moises called me over and said, "Can you figure out how we categorized them?" He had turned the tables on me!

Derrell and Victoria were having trouble working cooperatively. They were each trying to categorize the mechanisms individually, instead of working together. I told them that they had to resolve the problem in order to complete the task. I noticed that Derrell had found six ways to categorize the mechanisms and Victoria had found five (Figure 4-17). I informed them that if they put their responses together, they would have a total of 11 categories, which was more than the other teams had! They liked that idea, and completed the assignment without further incident.

Mary felt that she had accomplished a great deal with this last group. The grouping game was a natural lead-in to the categorizing activity, and the students had come up with some exciting discoveries. But what should she do next? Mary wanted to engage her students in some design activities, but felt that they needed some preparation. She decided to introduce the concept of simple machines. Analyzing the operation of these basic devices would give them the background they needed for design.

4-16: **"Where Do I Go?" worksheet (original version)**

Where Do I Go?

Name of Engineer Dario German

Categorize the mechanisms into two groups. Tell why you divided them the way that you did.

These mechanisms open And close	These medanisms do not open and close
wire splicer	hammer mon
garlic press	key wrench
Pliers wrench	Socket remver
paper clip remover	Flat head Screwdriver
pincers	Phillips head Screwdriver

The reason why I divided them in this way was because ~~I felt~~ tem and it mad work.

March 24

I spent the last few days planning my next move. I decided to introduce the concept that mechanisms are composed of simple machines. I placed various objects on the floor and asked the students to tell me which were the simple machines. The items included the following:

- A wheel,
- A pulley,
- A wedge,
- A lever, and
- A ruler.

The ruler, of course, was the spoiler. They fared well. Once they had found the simple machines, I picked each one up and asked, "How would this machine make your job easier?" Here are some of their responses:

MOISES:
If you have four wheels, you can make a car and it can carry the heavy loads.

DERRELL:
You can put a string on it and roll it up.

Teacher:
How would I use the pulley?

MOISES:
If I put a pulley on each side of the rope in this room, I can send a letter to my girlfriend who's on the other side.

PRISCILLA:
To hang up clothes and to put up pictures in your room...

EBONY:
You can use it to pull up water to your window.

CYNTHIA:
Say you want to get a toy that fell, and you live on the second floor. You don't want to go outside and get it, so you get that and tie a string that goes down and you take the string and you pull it up so the toy can come up.

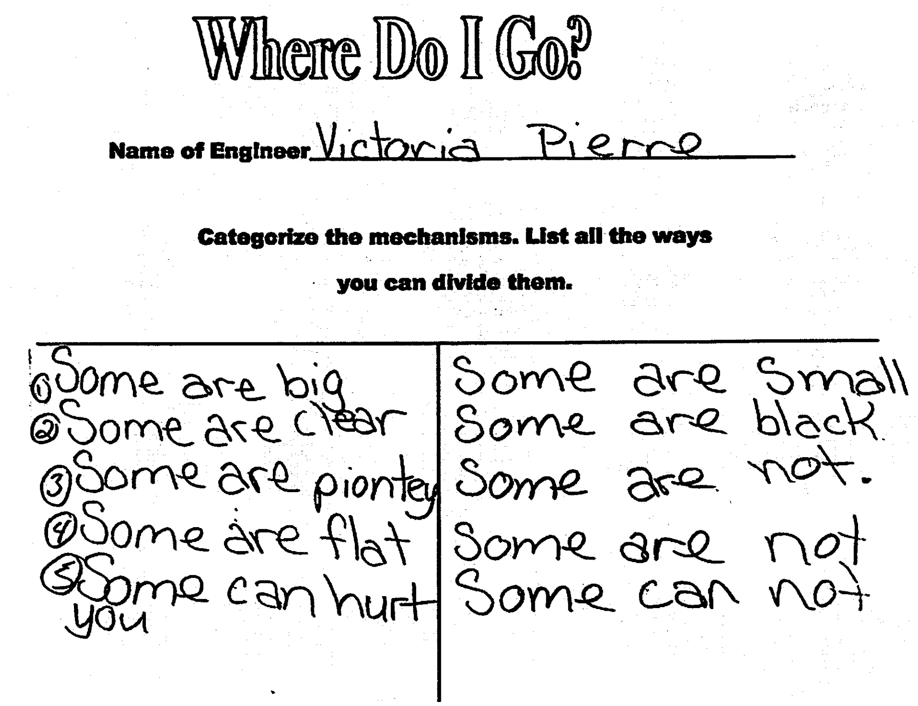
EBONY:
You tie a fishing rod and take a long string. You pull it up and you pull a fish out of the water and you cook it.

VICTORIA:
You could, like, put a rubber band between the room and then you hang it

PRISCILLA:
When you're going to work, you could put your suitcase on the pulley and let it slide to the other side, and then you could grab it and go to work easily.

I felt that the students were making connections between the simple machines and real life experiences. My hope is that they will apply these understandings to the design of their own mechanisms.

4-17: **"Where Do I Go?" worksheet (new version)**


Where Do I Go?

Name of Engineer Victoria Pierre

Categorize the mechanisms. List all the ways you can divide them.

① Some are big	Some are Small
② Some are clear	Some are black
③ Some are piontey	Some are not.
④ Some are flat	Some are not
⑤ Some can hurt you	Some can not

March 25

I got the idea to have the students examine some illustrations of "Rube Goldberg" devices and figure out how they work. In particular, I wanted them to find the simple machines in his wacky inventions. After discussing whether his inventions would work, I gave them the following challenge:

"Design a mechanism that would allow you to stand away from a table, and turn a page in a book on the table without touching it with your hands."

They began by mapping their designs. Moises's plan (Figure 4-18) suggests that his probably could work.

Prior knowledge of mapping helped them design blueprints that showed detail (Figure 4-19).

I tried to get them to think about some of the simple machines that could be used to make their inventions. I showed them the materials that I had for them to use: wooden spools, wheels, empty paper towel rolls, toilet paper tubes, Styrofoam, paper cups, etc.

March 30

Students in my fourth- and fifth-grade group retrieved their maps and set out to do the task at hand. Patrick, Heriberto, and Ricardo gathered their materials and began constructing their devices. They needed very little prompting from me.

Nicole's invention was not designed to open a book, but rather was a "Conga Dancing Machine" that will "dress me for Flamenco in the morning." Nicole and Shelva

were the only students who strayed from the assignment. I was pleased that they were all so engaged. When I called time, they were disappointed. We still have not had time to share.

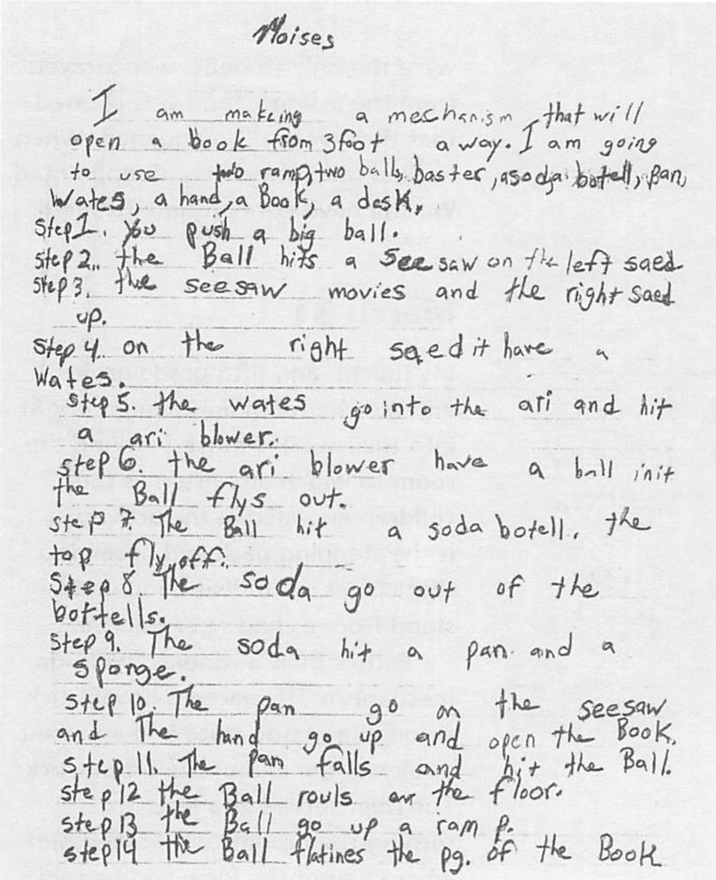
March 31

My fourth- and fifth-grade group entered the room and plunged right into their work. I moved around the room to watch and listen as the children engaged in the activity. It is the stepping back and observing that allows me to learn and understand from a child's perspective.

Patrick built a windlass wind-up mechanism. He placed a broomstick through a plastic crate and attached a ruler to the end of the broomstick. The ruler served as a lever for turning the broomstick. I asked him where he got the idea, and he said, "A book." It was similar to a design found in the book *Wheels at Work*. He felt a sense of accomplishment. After testing his invention, he stated, "I want to make another one." He found a box and began building his second windlass.

It is the reworking that allows students to move to a higher level. Patrick is demonstrating a form of self-evaluation by reflecting on his progress and redesigning his invention to make it better. Christina is using the eyelet tool to make linkages that extend outward. She attempted to use the linked pieces as a ramp. It was not rigid enough. There were too many joints. She needs to redesign her mechanism.

4-18: **Moises's plan for a page-turning machine**



Moises

I am makeing a mechanism that will open a book from 3foot away. I am going to use two ramp, two balls, baster, a soda botell, pan, Wates, a hand, a Book, a desk,
Step 1. You push a big ball.
step 2. the Ball hits a See saw on the left saed
step 3. the seesaw movies and the right saed up.
Step 4. on the right saed it have a Wates.
step 5. the wates go into the ari and hit a ari blower.
step 6. the ari blower have a ball init the Ball flys out.
step 7. The Ball hit a soda botell. the top fly off.
Step 8. The soda go out of the bottells.
Step 9. The soda hit a pan and a sponge.
Step 10. The pan go on the seesaw and The hand go up and open the Book.
step 11. The pan falls and hit the Ball.
step 12 the Ball rouls on the floor.
step 13 the Ball go up a ramp.
step 14 the Ball flatines the pg. of the Book

4-19: **Ricardo's book-opening machine**

It rarely happens that a newly designed product works perfectly the first time. Design is a back-and-forth process, where the problems with one design lead to improvements in the next. Too often, children are socialized to believe that failure is to be avoided at all cost and eradicated whenever it does occur. As a result, they find it difficult to accept failure as an inevitable and productive feature of the design process. Mary's students have reached the point where they can look at their own designs and learn from their shortcomings. They see the failures in their designs as opportunities to do better next time. This is a process that even adults have difficulties with. It is a remarkable achievement for these youngsters.

Watching the students design, test and redesign their mechanisms is encouraging. I have gained insight into how students come to make meaning. I can see that they have applied many of the concepts that they have learned. I attribute their learning, in part, to prior knowledge in the areas of mapping and environmental analysis and design. Additionally, these activities allow students to self-evaluate their progress. I usually ask students, "Can you explain what you did?" I want students to be able to explain the process, so I can be more tuned in to their learning.

April 1

Disaster struck the resource room today, and this is no April Fool's joke. My morning fourth- and fifth-grade group entered the classroom and began a futile search for their mechanisms. I asked if they remembered where they had left them. They answered, "By the chalkboard." My heart sank. The chalkboard is beside the garbage can. I suspect that the custodian mistook the mechanisms for garbage and disposed of them.

I could not hide my disappointment. However, the students took it much better than I did. Heriberto commented, "Don't worry, Ms. Flores. We'll just do it again, and this time I'll do it better." Talk about redesign!

Fortunately, the afternoon group had placed their inventions in a box, which was still intact. Cynthia, Ebony, and Victoria chose to work on Cynthia's design (Figure 4-20). I know that as they attempt to build this mechanism, they will run into many problems. They will have to learn of the flaws in the design through trial-and-error.

I invited several of the students to share the process they were going through as they tried to build their mechanisms. I thought today was going to be disastrous, but it could not have gone better! Here is some of the dialogue:

TEACHER:
Can you discuss the process you went through in building your invention?

PRISCILLA:
I began by making the hand with cardboard. Then I decorated the box. I got the string to make my project. My mechanism did not work. My hand did not work because I put too much tape, and it's breaking.

TEACHER:
How will you redesign your invention?

PRISCILLA:
I will make it work by putting a little bit of tape, and making a new hand and putting string where it belongs.

TEACHER:
How is this project making you feel?

PRISCILLA:
It's making me angry, because I tried hard to make my mechanism work, but now I have to make another one.

TEACHER:
Moises, can you explain how you approached the activity?

4-20: **Cynthia's design**

Cynthia March 25, 98
CC842x Class 4-408

Step 1: Throw a ball at the bell

Step 2: alot of balls start to Fall out of the bell

Step 3: The balls Fall into one bowl

Step 4: it tips over into Bowl number two.

Step 5: bowl two tips over and the balls go into bowl number three.

Step 6: The wait of the ball pushes Bowl number four.

Step 7: bowl number four hits a another bell.

Step 8: The S

MOISES:
I made a blueprint. Then I wrote the process. Then I started to get all the materials. I made the ramp from cardboard. Then I made the hand. That was the hardest thing to build. That's because the first time I made it, I made the fingers out of regular pieces of paper. Every time I tried to flip the page, the fingers flipped over. Then I had to make it again. This time, I made the fingers out of cardboard. It worked. I improved the ramp, because it was always bending. I put two sheets of cardboard, one straight and the other one a little bent. It made it stronger. Then I started to look around the room to get ideas for how I can build the air pressure thing (a meat baster). I decided to use cardboard and a little bit of string. I'm going to have to get some plastic from my house.

TEACHER:
What kind of plastic?

MOISES:
You know, like, the plastic that's on the umbrella so it can stretch a little bit. I'm going to need something to keep the air in. Then I'll push it out. It has to be fast so it can push the marble inside it. I have to have something that's heavy so it can hit the baster.

TEACHER:
How does it feel to be an inventor?

MOISES:
It feels like, you know, like when you're having a test, and all of a sudden you feel that tingly feeling in your stomach, and you forget the words. That's how it feels.

I believe that it is crucial to set aside time for this kind of sharing. I know that teachers struggle with finding ways to capture children's language. What facilitates my documentation is that I can sit at the computer and type their responses as the students answer my questions. These discussions allow me to assess the student's progress. I want to know that the students can design, test, and redesign their inventions until they are satisfied.

King Angel Appeals for Help with His Broken Ballpoint Pens!

by Angel Gonzalez

Angel Gonzalez is the only science cluster teacher (specialist) in the Family Academy, a small public school in Central Harlem. He sees the school's two fifth-grade classes for two 90-minute periods each per week.

"King Angel wants to free his imprisoned subjects (the fifth-grade serfs) from his dungeon. However, vandals have damaged all of the special pens used to sign the official release forms. He would like to hire someone to fix his pens so that he could sign their freedom decrees. King Angel will hire a subject (student) to repair the pens if s/he can convince him that s/he is a capable pen-repair technician.

"Try to convince King Angel that you can fix his pens. You want your freedom, as well as that of all the fifth-grade prisoners. To qualify as a repairperson, you must provide:

- **A written explanation of what you think could be damaged in the pens;**
- **A diagram of what you think the pen looks like inside.**

You will be called to share your expertise before the King and his subjects."

After presenting this challenge, Angel showed his students one of the pens and demonstrated it, without taking it apart. Here is what Nerisa wrote:

Dear King Angel:

I'm a trained technician. I've been through science school, college and high school. Ever since I was little, I wanted to be a scientist. I fixed my little brother's toy car because it was broken. I've been fixing things ever since.

Sincerely, Nerisa,
Your technician

- *The spring could be broken*
- *The bottom part could be rotten*
- *The ink pen could need more ink*
- *The clicker is probably not good, or a piece is probably broken inside.*

Then Angel had the students work in pairs. He distributed a pen and a work tray to each pair. Putting the small parts in a tray prevents them from rolling away or getting lost. Angel emphasized that the pens must be returned in working order. Each group had to sketch the parts of the pen and explain how it works and how it might be fixed.

They enjoyed the challenge and took it up enthusiastically. (See Figure 4-21.) To illustrate the kinds of drawings I wanted, I showed them the exploded drawings of mechanisms and appliances in the book *Visual Dictionary of Everyday Things*. This book illustrates well what I wanted them to do.

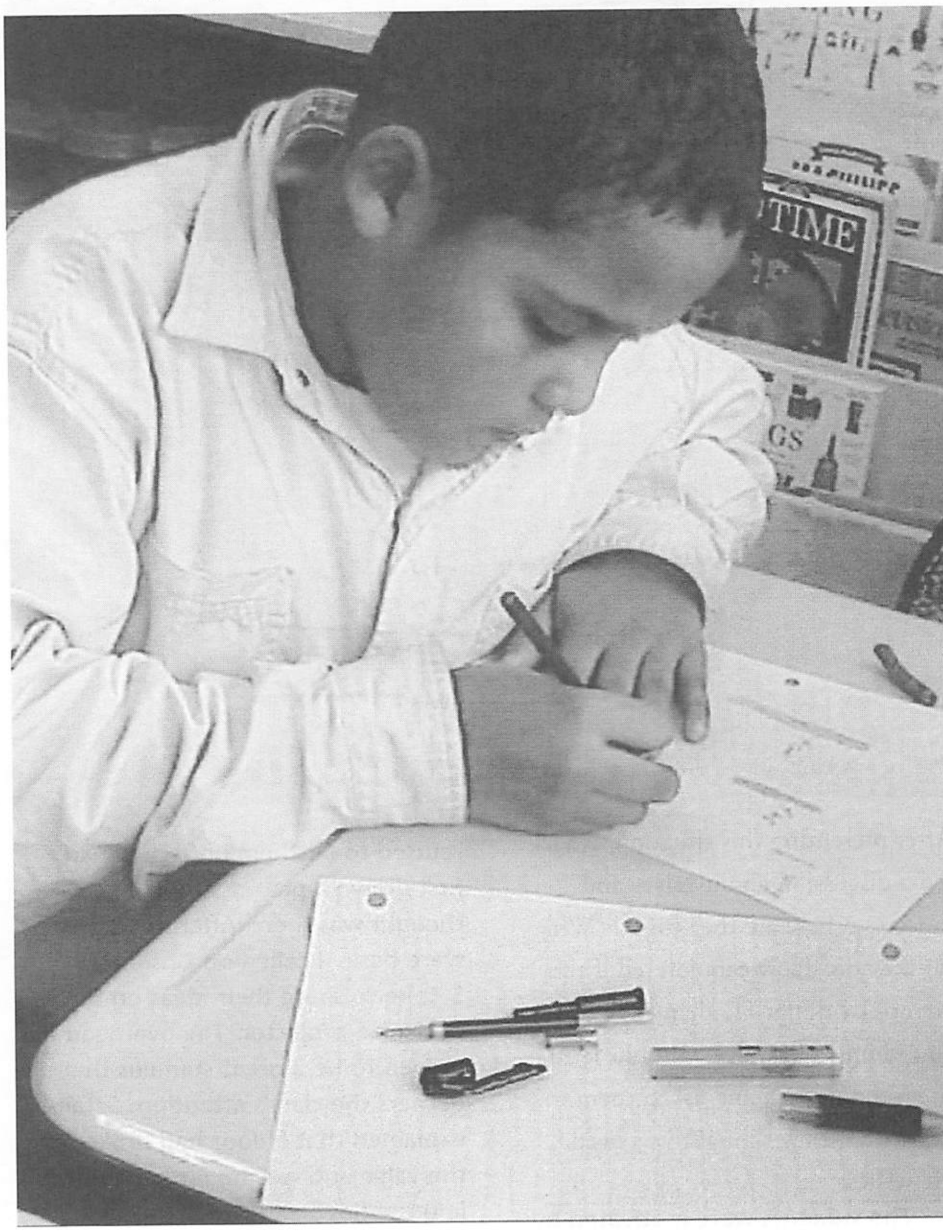
These pens have an automatic release feature that retracts the pen when the clip is lifted slightly, for example, by putting the pen in a shirt pocket. Nicole's drawings are shown in Figure 4-22. What Nicole calls "the puller" is the pocket clip.

NICOLE wrote:
The spring helps the pen go up. On the pen there is oil so the spring could go up easily. The sucker is the thing that spins. It is connected to the pusher. The pusher is what you push. The top part shows the sucker and part of the ink tube. The bottom part holds the sucker and the pusher. I call the sucker the sucker because it looks like a fancy straw. I call the spring the spring because that is its name and because I could not think of another name. I called the top part that because that's what it is. The puller is what you pull to make the pen go back in. The ink holder holds the ink. Without that the ink would be all over the place. The pusher makes the pen go up so we can write. The bottom part holds the puller, pusher, and sucker. There is wax so the ink won't fall out.

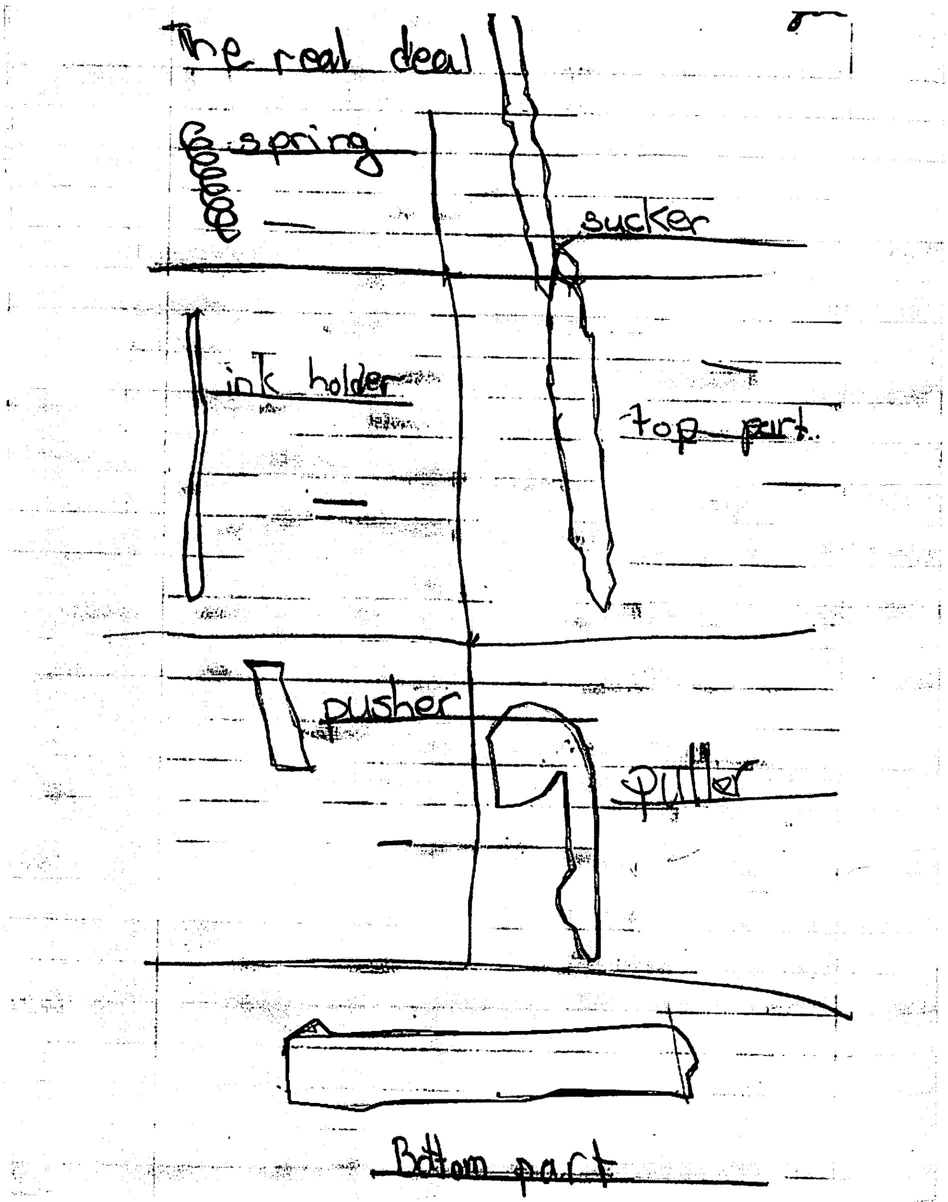
Angel felt that the activity had gone well. The story about the king drew them in and generated excitement. They were able to compare their initial hypotheses with what they actually found inside. Most important, they began to develop a sense of how a collection of parts can function together to form a mechanical system that is much greater than the sum of its parts. He followed the ballpoint pen challenge with a similar activity involving water-supply valves. Again, he presented the students with a hypothetical situation:

"Water is spilling everywhere. It's being wasted. There's a drought. You need to save water and conserve. Your job is to fix the valve that's wasting millions of gallons, the valve of a garden faucet outside of a house. The town will reward the valve repair person with one million dollars."

4-21: **Esterling analyzes and sketches the pen parts.**



4-22: **Nicole's drawings of the pen parts**



After presenting this situation, Angel led a discussion about valves and faucets. Where are they found? What do they do? How can you tell if they are not working? He then showed them an example of a valve, without letting them too near it, and asked them to draw what they thought was inside. He writes:

The students were motivated by the hypothetical situation. They were anxious to look inside the valve, but I refused to let them until they had first drawn a picture of what they thought was there. After the drawings were done, I called on Unslo and Setaire to share their ideas on the overhead projector. The overhead has proven to be a great stimulus that garners the class's attention. Setaire explained that a door had broken in the valve and was no longer controlling the flow.

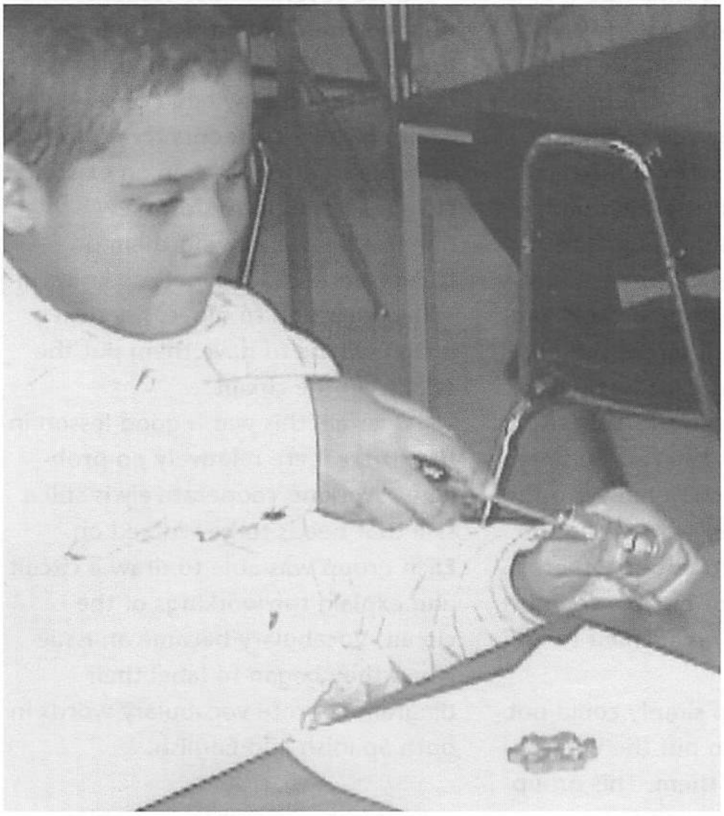
Next, Angel distributed a valve to each group. After they had spent a few minutes playing with them, he provided screwdrivers so they could take them apart. He had already loosened the screws, so they would not be too difficult to remove. Esterling is shown at work in Figure 4-23. Tenisha made a drawing of the inside of the valve, shown in Figure 4-24, and wrote the following explanation:

The valve works by your turning it and a black piece comes up to let water out. When you turn it again the black piece goes down and the water stops. It was interesting because me and Dashaye replicated a valve. We learned how it works and how to build one.

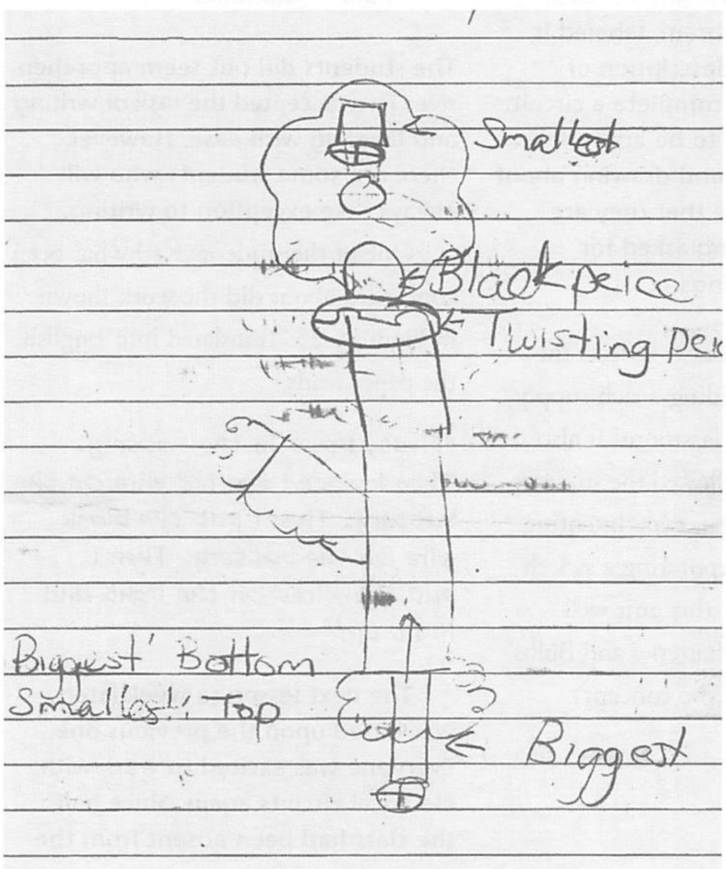
Angel saw this work as a prelude to learning about switches and other electrical controls, which are discussed in the next section. He wrote the following evaluation:

Both fifth-grade classes enjoyed dissecting the valves and putting them back together. I feel that these initial experiences in hypothesizing, observing, sketching and writing about how a control works will lay the groundwork for the upcoming work of analyzing and creating their own controls. They are clearer on what a control is. I will keep the class focused on those devices that manipulate/influence something else outside of their own structures.

Angel's concluding comment refers to the confusion between the technical definition of "control" and the word's everyday meaning. He wanted the children to realize that the control must be distinct from the thing controlled.



4-23: **Esterling dissects a valve.**



4-24: **Tenisha's sketch of the inside of a valve**

Two Teachers' Stories About Teaching Circuits

Kathy Aguiar, whose work with mechanical controls is described above, turned to electric circuits later in the year. By this point, her children had become much more confident about writing. They designed their own circuits with switches and wrote about how they worked. Angel Gonzalez, whose work with pens and valves we have just seen, describes how his students devised their own switches from common materials, and used them to create "electric code senders."

Third-Graders Teach Each Other Circuits

by Kathy Aguiar

Kathy Aguiar's unit on mechanical controls had taken place near the beginning of the school year. At that time, many of her students would become very frustrated when asked to write. Later in the year, she returned to controls, focusing this time on electrical controls.

Today I began exploring electricity with my students. Since only a handful of students came to school, I thought it would be a fun activity to do. I also thought that I would be able to give one-to-one instruction to those who might need it.

I began the lesson by asking what electricity is. The responses included:

ANDREW:
It gives you a shock.

CARLOS:
It helps to turn on the TV

RAUL:
You can plug the light or stereo on.

I then continued by asking what electricity does for us. Again the responses varied.

ANDREW:
It puts the Nintendo on.

FREDDY:
It helps to put on the light in the refrigerator.

CARLOS:
It turns things on.

We got into a discussion as to what items use electricity. Many objects were discussed. I then read excerpts from a book called *Electricity and Magnetism.* This book helped to clarify all the things we had discussed.

Next, Kathy asked her students to construct circuits using batteries, bulbs, and wires. This is the basic activity of science curriculum units on "Batteries and Bulbs," but for Kathy it was only a prelude to what would come next.

Once the book was read, I told the students that they were going to be given a battery, wires, light bulb, and a battery holder. They then would have to find a way to light the bulb. The class of eight students was divided into three groups. The groups went to work. Carlos and Natalie's group finished first. There was so much excitement when Carlos lit the bulb. Members of the other groups were very curious about how Carlos was able to light the bulb. They came immediately to Carlos's table.

At this point, I wasn't sure if I should let them look at the set-up or not. I decided to send the other students back to their own groups. I asked, "What's the fun of finding out from someone else?" I instructed them to try to light the bulb on their own. The other groups did eventually light the bulb.

Two out of the three groups had a difficult time for different reasons. One group had many leaders but no followers. Once they were able to settle upon a chief, the rest became easy. The only direction I gave to the group was that they were to decide on a way to work together. Otherwise they would not be able to finish the task on time. This seemed to motivate them.

The third group simply could not determine where to put the wires or how to connect them. This group received some help from Carlos, which enabled them to complete the task. In terms of assessment, each student drew a diagram, labeled it, and wrote a brief description of the steps taken to complete a circuit. They did not seem to be apprehensive about writing and drawing about the work. I suppose that they are accustomed to being asked for drawings and writings.

What happened next reflects the importance of providing a rich supply of materials in the classroom. It also shows how Kathy followed the students' interests as they began experimenting with switches. Incorporating a switch in the circuit moves this unit well beyond the typical "Batteries and Bulbs" activity, and revisits the concept of a "control."

Once several of the students finished their assignment, they began to look at other things I had. Some of them found a switch. I observed a group of three students trying to incorporate the switch in an existing circuit. I let them try for a few minutes before moving them on to another task. They let me know in which direction to move. My next lesson will be to have them put the switch on the circuit.

Over all, this was a good lesson in that there were relatively no problems. Working cooperatively is still a skill that needs to be worked on. Each group was able to draw a circuit and explain the workings of the circuit. Vocabulary became an issue when they began to label their diagram. I wrote vocabulary words in both Spanish and English.

- **Wires — alambres — cables**
- **Battery — bateria — pila**
- **Bulb — bombilla**

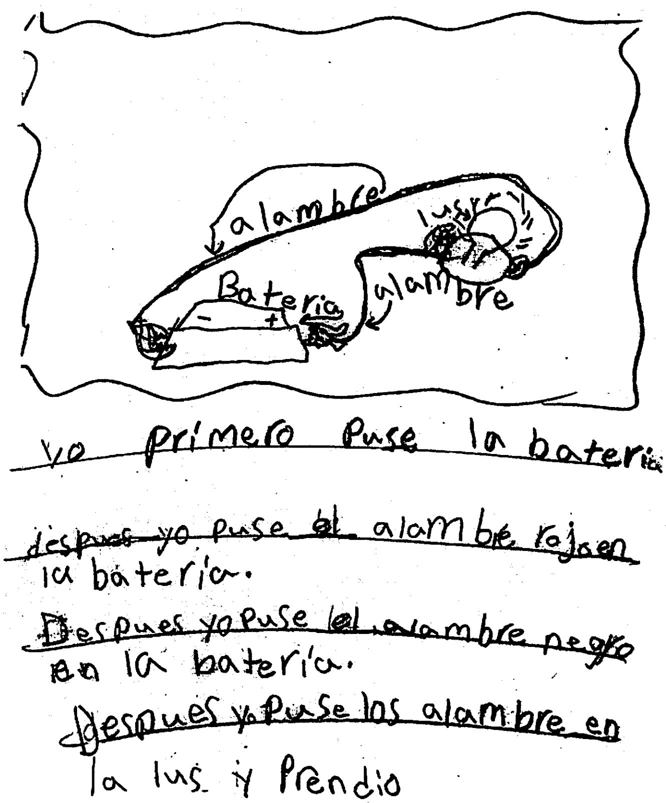
The students did not seem apprehensive. They accepted the task of writing and labeling with ease. However, there are some students who will always take exception to writing.

One of the students Kathy has been concerned about did the work shown in Figure 4-25. Translated into English, the paper reads,

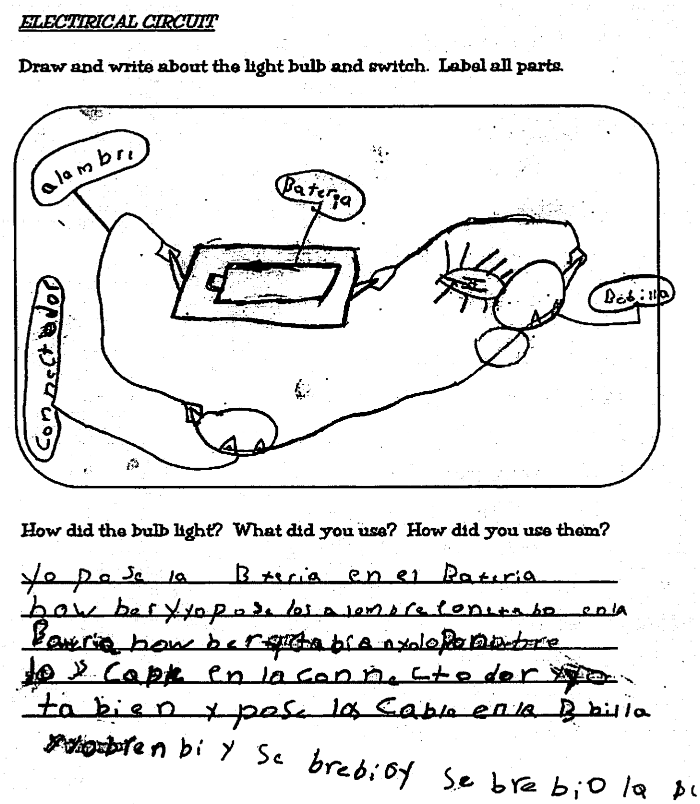
"First, I put in the battery. Then I placed the red wire on the battery. Then I put the black wire on the battery. Then I put the wires on the light and it lit up!"

The next lesson (a week later) was based upon the previous one. Everyone was excited to work with electrical circuits again. Since half the class had been absent from the

4-25: **Explanation of how to light the bulb**



4-26: **Explanation of the circuit with the switch**



previous lesson, I decided to re-read the excerpts from *Electricity and Magnetism*. Students who had been present the first time had a better understanding of the excerpts. Those who were hearing it for the first time asked questions that the other students were able to answer.

YOKASTELYN:
What are these things?

FREDDY:
Wires.

YOKASTELYN:
What do they do?

FREDDY:
They take the current from the battery to the bulb.

This exchange (which took place in Spanish) surprised me because Freddy usually does not provide accurate answers.

Afterwards, we began to discuss the purpose of a switch. The consensus was that the switch could turn something on or off, make it loud or soft, or change a station. It could be something you would push, pull, or turn. Students were given two tasks. First, they were to build battery/bulb circuits. For the second task, students were to incorporate switches in their circuits. The switch was to put the light on or off. Students were then divided into four groups. Students who had done the previous lesson were not in the same groups as those who had not. Each group was given a battery, battery holder, three wires, and a switch.

Students were very eager to begin. They began to build the circuit without the switch. Two out of the four groups did not have a problem with the basic battery/bulb circuit. They moved on quickly to attempting to incorporate the switch into the circuit. These groups had difficulties in putting the switch in. The other two groups had difficulties with the first task. They had not been able to make the bulb go on. Some students from one group went to the other groups for help. Once they found what they were looking for, they went back to their original group. They were able to turn the light on and off using the switch.

As usual, Kathy used their work as an opportunity for them to express themselves in writing. She asked them to draw their circuits and describe the components and how they used them. An example is shown in Figure 4-26.

Translated, it reads:

"I put the battery in the battery holder. I connected the wires to the battery holder. Also I put the wires in the switch, and I put the wires on the bulb. I turned the switch on and the light came on."

Students did express how they were able to get the bulb to light. They did not seem to be troubled by writing about the procedure they followed. They requested the spelling of words such as "battery," "wire," and "switch." Once the words were given, they continued to write about the process. Their drawings really helped me to see at a glance whether they understood the concept of a circuit. I found that if a student could not draw the circuit, then more than likely that student could not explain it or write about it.

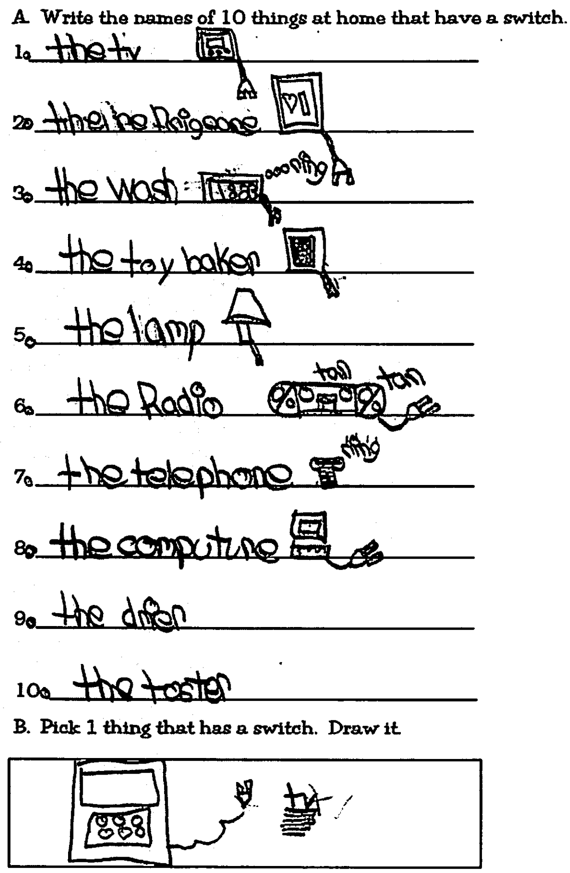
Overall, this was a good lesson. It sparked the students' excitement. Students were very motivated. They were willing to work cooperatively. The only difficulty I kept running into was with vocabulary. I try to anticipate all the necessary vocabulary words students might need in English and Spanish. However, there have been times where certain words have come up that I was not prepared for.

In terms of assessment, I knew that a student understood what they had done if the student was able to:

- **Match their drawing with their written work, and**
- **Explain orally what they had written.**

For homework, students were to find 10 items that required switches. One list is shown in Figure 4-27.

4-27: **List of ten things controlled by a switch**



Fifth-Grade Inventors Devise Intrusion Alarms and Code Makers *by Angel Gonzalez*

We have already visited Angel Gonzalez's science room at the Family Academy in Central Harlem. Angel regarded his students' investigations of retractable pens and valves as preparation for work with electrical controls. He began this unit by showing them how to make a complete circuit with a battery and a bulb. He then formulated another "situational challenge," which was modeled on the broken valve problem discussed earlier.

"Now that you have a circuit connected to a battery, can you come up with a device that will control the flow of 'electric juice' so that it does not get wasted? You are to invent an electric switch that can turn electricity on or off in a circuit, just like a faucet that controls the flow of water. The switch device must work in a consistent and a reliable fashion. It must not be the simple disconnecting and reconnecting of a wire, bulb, or battery to break the circuit."

With this problem, Angel introduced the idea that the flow of electricity is similar to the flow of water. In order to control it, a device is needed that is similar to a faucet or valve. Like Kathy, he wanted to expose them to a rich variety of devices, which would stimulate ideas about how they might proceed.

Various broken appliances and toys were made available to the students so they could dissect them and explore how the switches worked. The materials included keyboards, game controllers, flashlights, lamps, radios, tape players, computer "mouses" and more. I encouraged students to open up any switches they could, to see how the key parts function to regulate the flow of electricity. Some students made displays of the devices and shared how they thought the switches worked.

After some dissections and explorations of some switches, I asked the class to list as many switches as they could find in our classroom or in their homes. They were to list them and identify the type of action required to make each one work. After they had conducted discussions within their teams, I charted their collective findings, shown in Table 4-2.

We defined a switch as something that turns an electric device on or off. It is a control that regulates electric flow.

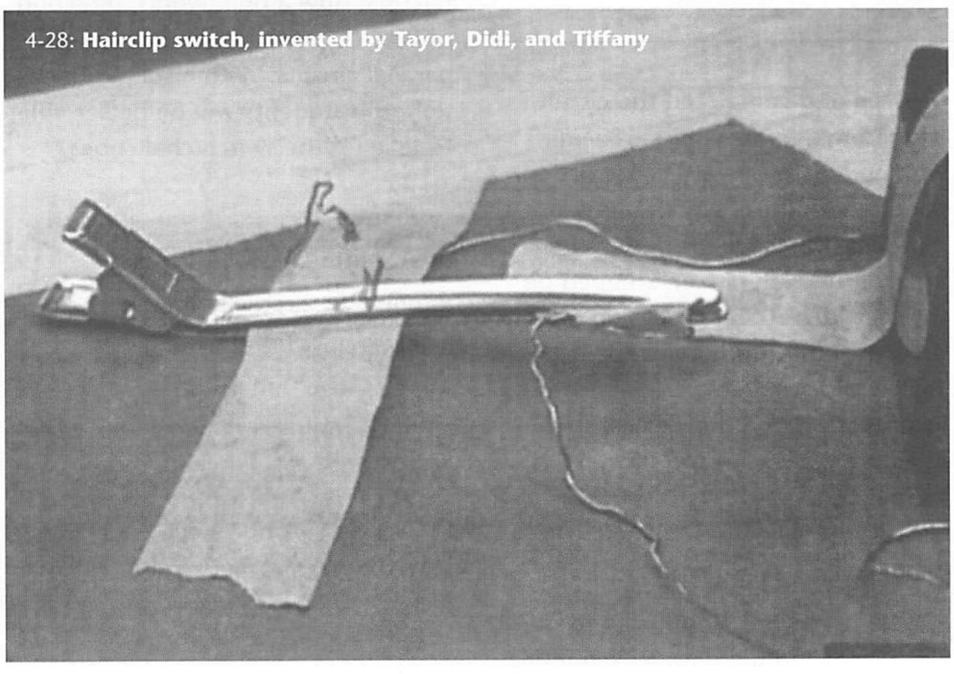
December 1

Brandon's team invented a switch by simply putting a metal paper fastener between a non-conducting part of the battery and the battery holder. As he pressed down on the fastener, the terminal of the battery separated from the metal on the battery holder and turned the bulb off. Quite clever!

December 2

Sophia asked, "What materials are inside the pull-string switch in the garden area? Wouldn't the inside of the switch burn with all that electricity and heat?"

I responded that those are important factors that must be considered in inventing switches. She could open the switches to see the materials they actually used to prevent overheating and fires.


4-28: **Hairclip switch, invented by Tayor, Didi, and Tiffany**

December 7

The fifth-graders explored various switches. They also began to design circuits involving switches that they would have to invent themselves. I provided each group with a box of the supplies needed to make four complete battery-and-bulb circuits. Each box also contained the following: fasteners, paper clips, and index cards. These are materials they could use to invent simple switches, possibly with a few hints from me.

I let them know that they could bring in any materials they wanted, and that they could also give me a list of things they might need. Because they have already analyzed commonly found switches, some students feel confident enough to begin trying to invent their own switches. I suggested that they might think about designing flashlights or light circuits for a model home. They could also make exploded drawings of an appliance, highlighting the switch controls and explaining how they work.

December 8

The fifth-graders had only 40 minutes with me today, so I let them work on drawing up plans for their team projects. Table 4-3 shows a summary of the plans so far.

The class appears to be very excited about these projects. I will provide periodic research time during which they can explore books on electricity in my library corner. I strongly recommended the use of the CD-ROM and book, T*he Way Things Work*. They can copy sections of the books that are relevant to their work. Those who need more time can come up during lunch to work on their projects.

Table 4-2

SWITCHES THAT ANGEL'S CLASS FOUND

Name of switch	Place found	Action required
Button	Computer	Pushing down
Flicker	Wall	Flick down or up
Game button	Play Station	Pressing
Turner	TV	Twisting right or left
Remote	Cable box	Pressing
Chain switch	Lamp	Pulling
Sound-sensitive	Gorilla doll	Loud-noise making
Slider	Flashlight	Sliding
Motion detector	Faucet	Hand motion

Table 4-3

PLAN SUMMARIES

Team	Ideas
Charmaine's	Blow dryer dissection and own invention
Shantale's	Lighting system for home
Taylor's	Burglar alarm
Santiago's	Fan
Hakim's	Exploded drawing of singing parrot doll
Dashaye's	Lighting system for castle
Sara's	Drawings of trackball; joystick invention
Christine's	"Squeeze Breeze" dissection
Sapphire's	Alarm system

December 15

Today, Eric and Ankaser invented a switch using aluminum foil, a paper clip, and a small card. Pressing down on the raised paper clip brought it into contact with the aluminum foil, completing the circuit and turning a motor on. They proudly shared their work.

December 21

Taylor's team invented a burglar alarm. They used a hair clip and a raised paper clip. When the paper clip was pressed, it touched the hair clip and completed the circuit, triggering a buzzer-alarm. The girls worked creatively with construction paper and hid the switch under a mat near the teacher's desk. When an unsuspecting person stepped on the mat, the buzzer would go off and draw attention to the intruder. Taylor, Didi, and Tiffany, the proud inventors, shared this device, shown in Figure 4-28, with the class.

Clearly, many of Angel's students became knowledgeable about electrical controls. They saw the analogy between electricity and fluid flow, looked inside a variety of appliances and switches to see how they worked, and found out how to interrupt the flow of electricity using a control device. They used this knowledge to build useful devices. At the same time, Angel felt that some of his students had been left behind. In retrospect, he felt that he should have preceded this activity with a science unit on electricity.

While some students were successful and had an easy time inventing their own switches, a good number were having difficulty and became frustrated in setting up complete circuits using light bulbs. It became apparent that they were not grounded enough in basic electricity concepts such as the flow of electricity, conductors/non-conductors, etc.

I therefore decided to spend the next month or two (January and February) introducing lessons from a science curriculum unit on electricity. The skills and concepts include simple circuits, conductors/nonconductors, how a bulb works, direction of flow of electricity, and series and parallel circuits. With a solid foundation, the students will be better able to take up the switch challenges.

During the next two months, Angel's fifth-grade science class went through the electricity unit that had been provided by the District. In March, Angel and his fifth-graders returned to the work with electrical controls. He came up with a project that combines the study of switches with another ***Stuff That Works!*** topic, *Signs, Symbols and Codes.*

He began with a problem that is very real for his class: the frequent interruptions from the main office or from elsewhere in the school. Could an electric code-sender be used to send messages between rooms, and thereby cut down on the number of interruptions? The students would not only have to design and test the devices for sending and receiving messages, but also develop the codes that would be used. Their inventions could actually be tested between rooms, and put in place if the Principal agreed.

The Challenge

Each student will design an encoder with a signaling switch, and show and explain the design in his/her journal. Each student will share ideas with the rest of the team, and the team will adopt one plan to implement. Then the teams will gather the necessary materials, and proceed to build and test the design.

March 1

I gave the fifth-graders the Encoder Challenge and most were excited about it. They drew their designs and wrote up their plans in their journals. They have to share their designs and adopt one as a team. Immediately, some began to develop codes to use with their systems. I suggested that they could use either bulbs or buzzers to convey the signals. I also said that they could divide up the work within the teams. Some could work on the encoder, while others worked on the codes and their meanings.

Lauren shared her team's idea using the overhead projector:

"We'll get that wire that goes from the office. Our Principal can put this button on her desk and it goes to every classroom in the Family Academy.

- If it lights two times, we got school sing;
- If it lights three times, fire drill; and
- If it lights four times, the principal wants to have a meeting."

Samantha presented this design, shown in Figure 4-29, from her team:

"There will be a buzzer with a button and a bulb. It will be connected to a battery, a big one. Then there will be three wires, one to the battery, one to the bulb, and one to the buzzer. The wires will be connected to all the rooms in the school. If the bulb lights up, that's for emergencies like fire drills. You press down on the buzzer and it sends to the office. One buzz is any announcement. Two beeps is 'Come pick up this child.' Three beeps is emergency, and if it's a fire drill, the office will have a light bulb. It will send to our room and then we will know."

During lunch hour, Brittney came upstairs with her teammates, Charmaine and Antemia, to finish and test out their buzzer encoder. They added longer wires and succeeded in sending their coded messages. The next day they shared their work with the entire class.

This account confirms the soundness of Angel's decision to develop the students' background on circuits before proceeding further with electrical controls. It is clear from this account that the students felt confident about circuits, and were able to use their knowledge to solve practical problems.

4-29: **Samantha's sketch of the electric code-sender system**