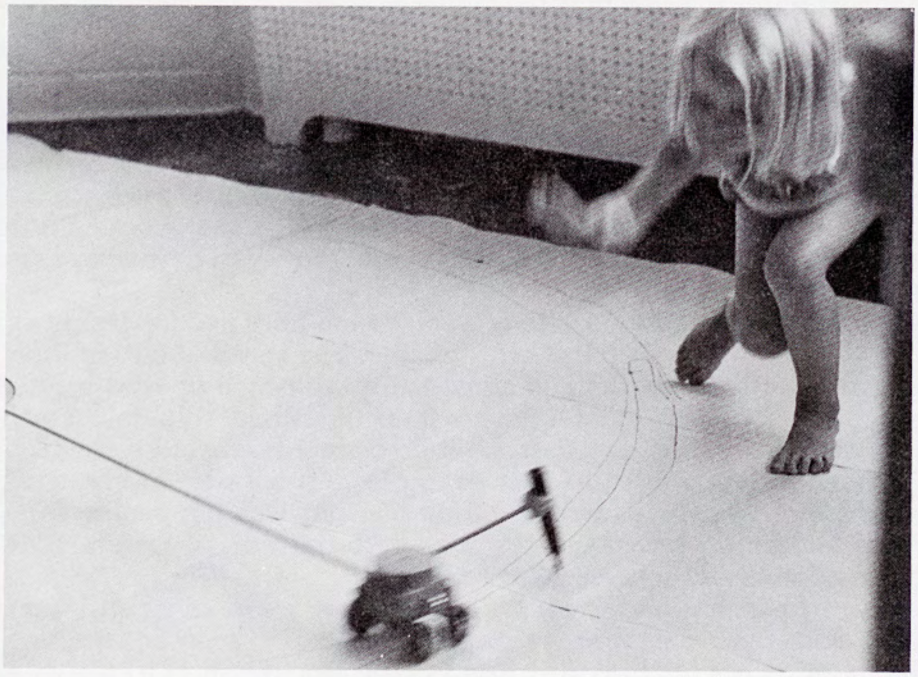
Chapter Four



Representing Motion

ENCOUNTERS WITH REPRESENTING MOTION

In Chapter One we explained how the form of a motion tells us a great deal. Consider this example: An insurance investigator goes to the scene of an automobile accident. His client has wrecked an expensive car. He looks at the tire tracks left on the pavement. These tracks show that the driver began to brake about 100 feet before the car hit a telephone pole. The tracks also show an abnormally sharp curve. Was this the curve the tires made when the driver tried to avoid hitting a dog, as he says? The investigator reasons that the evidence supports his client's claim. The tire tracks tell the tale.

Many times, the way an object has moved can tell us why things have happened or why things are now the way they are. A tree in the forest is leaning over to the point of falling down. We see a dried-up creek bed and deduce that there must have been great erosion around the base of this tree, loosening its grip on the earth. The creek bed is a trace of the motion of the water, which was the force that caused the tree to lean. These traces of motion are indices of the procedures by which things happen. As we stated in Chapter One, *procedures* are of primary concern for children between the ages of 2 and 5.

Things often happen too fast or took place too long ago for young children to easily figure them out. A pencil falls off the table. The speed of falling is so fast that the child cannot really study the half somersault the pencil does as it falls. A set of wheels on an axle, with one wheel larger than the other, rolls in an arc. But the shape of this arc is so momentary that the child cannot figure out just why he missed his target. If the motions in these two examples left a trace, as the tires did, the children could improve their understanding of what was happening in each case. The activities that follow have been designed with this objective in mind—to freeze the motion of an object with some sort of trace.

We have frozen motion for our children in two ways: in a continuous path or in a discontinuous path. The first we simply call *freezing motion,* meaning that the trace of the motion does not have any breaks. The Morton Salt girl leaves a continuous trail of her walk in the rain as long as the salt in her leaking box is not depleted. The second we call *unitizing motion,* because the movement is broken up into discontinuous units. We do not believe that the child sees these segments as equal units, but she may see them as discontinuous parts of the same continuous motion. For example, the child probably understands that the dashes on the sidewalk made from a wet spot on her tricycle wheel come from the continuous ride of her tricycle across the sidewalk. The dashes on the sidewalk break up a continuous motion into parts, and this event is not too different from what is done in measuring a distance. Unitizing motion is a precursor to measurement. We will touch on other reasons to freeze and unitize motion in the activities that follow.

FREEZING MOTION

SWINGING SAND

Preparing the Environment

For some weeks the children at the School for Constructive Play had been "bowling" with a tether ball attached to the ceiling. (This activity was described completely in the previous chapter as Pendulum Bowling.) We noticed that the children were having difficulty correcting themselves after a miss. They would release the ball, it would miss the pins, and they would grasp it and release it from the same position again. We reasoned that, if they had a better indication of where the ball had traveled on their first attempt, they could correct themselves better. For these reasons the Swinging Sand was invented.

We replaced the tether ball with a plastic ketchup bottle. The bottle had a screw-off cap with a nozzle. The children could take off the top, fill the bottle with sand, replace the top, and swing the bottle on the rope hanging from the ceiling. To facilitate transfer of learning from Pendulum Bowling to this new version, we cut a large hole in a toy plastic bowling ball. We inserted the body of the ketchup bottle into the bowling ball, so the nozzle protruded from the bottom of the ball. Now the game looked a lot like Pendulum Bowling.

Each time the children released the bottle it drained dry sand onto the paper below. If they missed the bowling pin, they could literally see on which side of it the bottle had passed. We hoped that the children would study the "frozen" form of the motion, figure out how that form had been created, and correct their actions in order to make a more accurate release. Although these objectives were somewhat beyond our 2- to 4-year-olds, the game did lead to some useful learning encounters. Six-year-olds would probably be able to see the sand trace as information that has relevance to how one bowls.

Our 2- to 4-year-olds (we had no 5-year-olds at that time) were more interested in the leaking sand than in bowling over the pin. They usually either held the bottle and let the sand drain onto the paper or swung the bottle to see the sand drain out, ignoring the bowling pin. If they did try to knock down the pin, they did not seem to concurrently attend to the sand leaking out of the bottle. Perhaps it was too many things for them to think about at once. Nevertheless, the game was interesting to them, so we set about to modify it in order to maximize the types of encounters the children naturally selected.

We discovered that after five or six passes of the swinging bottle the surface below got so covered with sand that it was difficult to discern individual traces. So we invented a quick and easy way to "erase" the surface. We took two large pieces of ¼-inch plywood, 4 feet by 4 feet. We hinged them together at one end and left them doubled over. We then placed the hinged plywood under the swinging bottle and flat onto one of the 15-inch-high platforms we have in our classroom. After the child had released the swinging bottle for five or six passes, he and the teacher would simply lift the unhinged edge of the top panel upward, making an angle sufficient to cause the sand to slide off the lower end (see Figure 4.1).

The double-panel construction made it easier for the teacher and child to tilt the top panel without its falling off the platform. The sand slid into a trough made out of a cardboard tube split down the middle. This trough could be picked up after it had received the sliding sand and then dumped into a pail for recycling into the ketchup bottle. We also placed runners along the top panel's right and left edges to assure that the sand would not slide off the sides when the panel was tilted. The "ecological cycle" of the sand, passing from ketchup bottle to plywood panel to trough to pail and back to bottle through a funnel, was itself a learning encounter with a closed system of relations.

Entry

Swinging Sand did attract the attention of two to three children at a time. The motion of the swinging bottle itself was interesting, because here was an object that, when pushed away, would come back. The younger children wanted to squeeze the bottle between their two hands, watching the sand drain and pile up below. The older children showed interest in the shape of the paths that the draining sand made. They varied the way they tossed the bottle and watched the change in the pattern of sand traces. The younger children had a tendency to throw the bottle, rather than release it. They seemed to feel the need to impart force to the bottle directly. The older children understood that the weight of the bottle itself would cause it to swing. They held it in one place and released it.

The more direct approach of the younger children, both in terms of squeezing the bottle to make it drain sand and pushing it to make it swing, seems to be part of

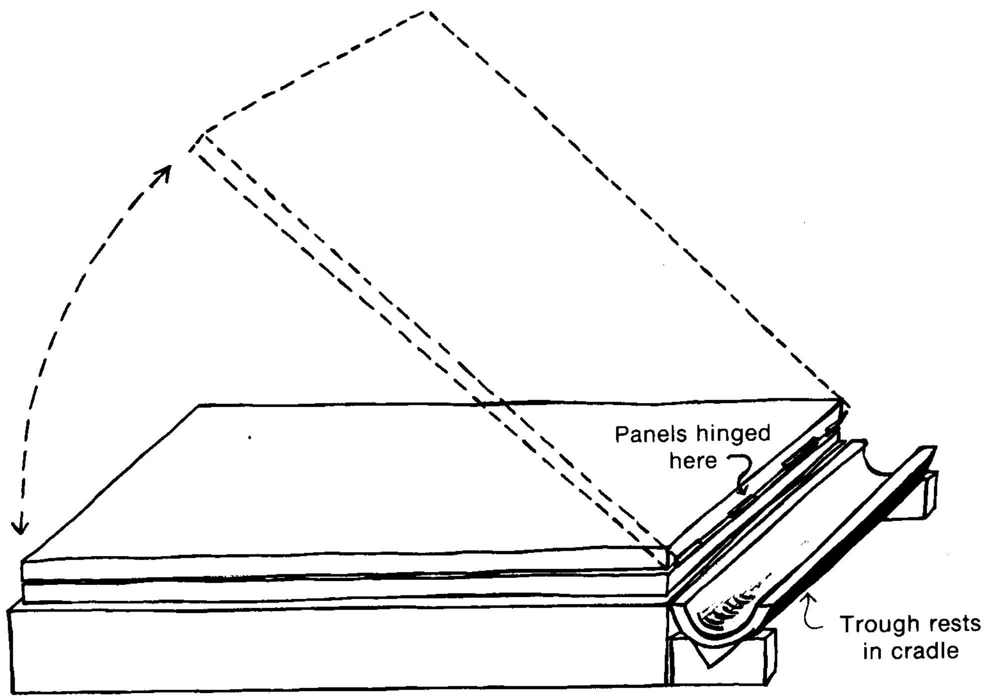


FIGURE 4.1 Hinged panel for the Swinging Sand.

the egocentrism of the younger years. They assume that an object moves because of the actions that they themselves impart to it. The notion of "natural motion"—that is, what adults call gravity—is not well formed at this age. To understand that objects sometimes move of their own accord requires a type of decentering from an egocentric view of the world.

Younger Children

Jimmy grasps the bottle in both hands. It slips out and he notices the sand spilling onto the surface below. He recaptures the bottle and holds it about chest high, letting the sand drain between his feet. As it is making a pile, Aaron looks on. Beverly, the teacher, also watches. Jimmy holds the bottle in his hands until all the sand drains out. He holds the translucent bottle up to the window light and sees that there is no more sand in it. He, with slight assistance from Beverly, unscrews the bottle cap and proceeds to funnel in another load of sand.

This turns out to be a favorite activity for Jimmy. Drain and fill, drain and fill. On one round of draining he begins to drain the sand onto the toe of his shoe. The sand splashes down over the shoe onto the plywood surface. When he moves his foot a few minutes later, he is surprised to see a stencil of his foot there in the sand pile. Beverly is quick to expand this learning encounter. She places other objects under the draining sand as Jimmy holds it. After he drains out all of the sand, he or Beverly removes the object to see what sort of "hole" it has made in the spread of sand.

Other children enjoyed this game, too. Some of them drained the sand only on the top surface of the stencil object. They did not quite understand that the hole in the spread would result only if they passed the sand over the outside edges of the object. Consequently, their approach did not leave a clearly defined vacant space in the sand. For these children the game was one of getting the sand to fall on the object.

For Jimmy the game was one of getting the sand to define the outline of the object when the object is removed. Jimmy was, in effect, thinking about the "not-object," the vacant space. At a minimum, he was thinking about where the sand was not going to be. He would deliberately remove the object covered with sand, picking it up gently so as not to scatter the sand that defined the outline of the object. Perhaps this behavior indicated that Jimmy knew, at least in terms of appropriate actions, that the stencil hole was the negation of the sand. Recall our discussion in Chapter One about the level of opposition, in which the child first begins to see one thing as *not* something else.

The nice thing about this whole activity was the way that it evolved. The game had been prepared to let children study the sand trace of the swinging bottle. The teacher, however, did not force that objective on Jimmy. By watching him closely, the teacher expanded the learning encounter that Jimmy set as his own goal. The accident of stenciling his own shoe was expanded into a delightful game for Jimmy and for a lot of children thereafter. Beverly demonstrated good principles of teaching in the way she expanded and facilitated the self-regulated play of the children.

Older Children

The older children did get involved with the shape of the sand trace. In one of our earlier setups, Kevin is holding the bottle in one hand. He then flings it across the black paper that is taped to the floor (see Photo 4.1). Fleet then sweeps the sand away to the side of the paper so that Kevin can try another push and notice the design that it makes.

The setup seen in Photo 4.1 was hard to keep going, because the sweeping took too much time and the sand could not be recycled into the ketchup bottle. That is why we invented the panel of plywood that could be tilted to quickly "erase" the surface. On several occasions we did use a third setup. The sand bottle was suspended over a round table about 5 feet in diameter. With this setup the older children stood around the table and took turns pushing the bottle. Because the string from the ceiling was now shorter, their pushes made very interesting concentric spirals.

The children were used to studying designs on table tops; many of their crafts activities were done there. It seemed that their attention to the sand pattern was heightened when it was left on the table top. No doubt it is a general fact of education that the type of space that supports an activity—be it the floor, a 15-inch platform, or a 3-foot-high table—determines in large measure the quality and form of that activity.

Children up to 4 did not get involved with trying to predict exactly where the sand would be laid down. Nor did they look at the sand trace to figure out where the swinging object had been. They did seem to understand that a straight push would cause straight traces and a wiggle added to a push would cause a scalloped design. They could, in other words, make the correspondence between *their* action and the resultant pattern. They did not show evidence of making a correspondence between the *bottle's* action and the resultant pattern or vice versa.

Some of the very young children would not even move the bottle back and forth. So we decided to see what would happen if we moved the surface under their stationary bottle of draining sand. This idea led to the next activity, the Spinning Sand.

THE SPINNING SAND

Preparing the Environment

At first we tried to put a 3-foot lazy Susan under the swinging bottle of sand. As the bottle made passes back and forth, the children could turn the lazy Susan. The resultant pattern was then the multiplication of the two motions, swinging and spinning. This was too much for our children. They got involved either with the swinging or the spinning, but not both.

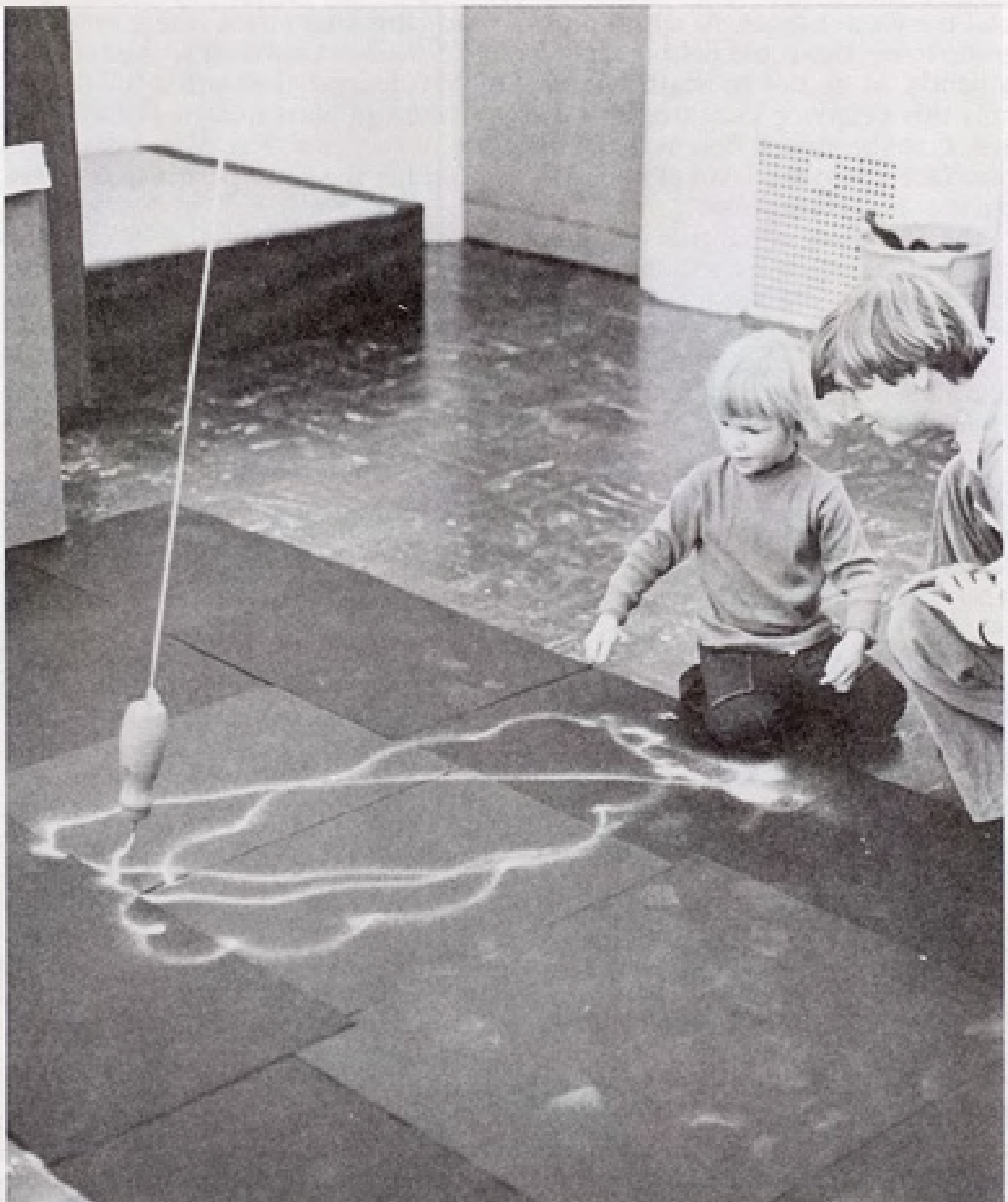


PHOTO 4.1 Kevin slaps the Swinging Sand bottle and watches the scalloped patterns of the draining sand.

So we eliminated the string and just gave the children the ketchup bottle filled with dry sand. Now they could hold the bottle stationary, as many of the younger children did anyway, and spin the lazy Susan. The draining sand left circular traces on the flat surface. But the lazy Susan soon filled up with sand, and additional sand that was drained onto the filled surface was completely camouflaged.

Then we noticed that some of the onlookers who did not have ketchup bottles would stick their finger into the layer of sand spinning around. This observation led to the final version of the activity, called the Spinning Sand. We simply filled the lazy Susan with dry sand and let the children make etchings in it by spinning it and putting finger, brush, or some other object to the surface. In Photo 4.2 Juliette slants the scraper so that the edge does not gouge into the sand as she makes a clean etching.

PHOTO 4.2 Juliette turns the lazy Susan with one hand and makes etchings with the other.

Entry

The children were attracted to this activity, as they were to any container filled with sand. The fact that this container turned only increased their interest. Some of the younger children liked to place toy animals in the sand and spin the lazy Susan around. They let it make a few revolutions and then took the animal off. Sometimes, a teacher or another child placed another toy animal on the sand. No matter how long the two animals "chased" each other, they never got closer. An animal placed in the center of the lazy Susan looked as if it were turning around, rather than chasing around. Animals placed on different radii from the center elicited different comments from the children.

The younger children dug in the sand and spun the space as separate acts. Some of them did spin the space and, while it was still spinning, stuck a finger into the sand. Their focus seemed to be more on how the sand would pile up in front of their finger as the lazy Susan turned. The older children liked to vary the diameter of circles and to erase previous etching by smoothing the spinning sand.

Juliette, almost 4, is sitting with Peter, a teacher. Marika sits nearby, looking on. Juliette spins the sand. Peter enters with this question: "Can you make a smaller circle?" Juliette does not understand Peter's question. Some seconds later, when Juliette has her finger in the sand, Peter spins the space. Juliette then begins to see more clearly that the tracks in the sand make a circle. When Peter once again asks Juliette to make a smaller circle, she places her finger in toward the center. She could on most occasions thereafter make a big or a small circle on request. The position of her stationary finger determined the size of the circle.

Tristan brings a fork to the spinning space. He experiments with the different types of marks he can make with it. "I'm making roads!" he exclaims as he looks over the traces in the sand. Peter takes a spatula, presses it into the spinning sand and says "I'm making wide roads." Different objects make different traces as the space moves beneath. Four fingers spread out make a different trace than four fingers close together. The movement of the spinning sand accentuates these differences. Time is added and frozen in the long etches of four fingertips.

Marika joins the game. She is more interested in smoothing the spinning sand down. Tristan makes a mark, and Marika uses her hand to smooth it down. It is not clear that Marika is aware that Tristan might see her actions as undoing his creations. She just likes to smooth down the spinning sand. "Stop it, M'rika," Tristan says. She does stop but probably does not understand why Tristan is upset.

As it turned out, the Spinning Sand was best played with no more than two children; even then, the activity required teacher supervision. With more than two children it was too difficult for a child to keep track, so to speak, of his creations. But then, how many adults would want to work with others on the same potter's wheel? Because the Spinning Sand was so easily constructed, we could have made five or six for individual children. All you need is a Rubbermaid lazy Susan and a larger board of some type glued to it. As long as the board is centered for balance, the surface can be up to 3 feet in diameter. We found other uses for the Rubbermaid lazy Susans, as you will see in the next activity.

THE DRAWING DRIVER

Preparing the Environment

For this activity the floor is covered with white butcher paper. In Photo 4.3 Sydney is bending over to grasp a felt-tip pen attached to a little car. The car itself is attached to a 4-foot wooden dowel that is stuck into a cardboard drum. The drum is attached to a Rubbermaid lazy Susan.

Photo 4.4 is a close-up of the little car, which is actually a single-unit block. We drilled a hole in its side slightly larger than the long wooden dowel, so that the car could slide up and down along the length of the dowel. Wheels were attached to the bottom of the block. A rotating turret was attached to the top of the car, from which extends an 8-inch wooden dowel. The pen is attached to the end of this short dowel by means of a Tinker Toy hub, sectioned slightly and wrapped with duct tape.

The Drawing Driver involves three independent movements: the rotation of the 4-foot dowel around the cardboard drum, the rotation of the 8-inch dowel around the turret on the block, and the back-and-forth excursion of the car along the longer dowel. This means that the child can drive the car to any spot within the largest circumference of the 4-foot dowel and make many embellishing movements with the 8-inch dowel on the turret. As long as the felt-tip pen is moist and the pen maintains a slight pressure on the paper, every move that the car makes will leave a trace of ink. Inside the cardboard drum we placed moist sand in a plastic bag. This gave the drum enough weight to keep the whole setup stabilized. Without the weight in the drum any motion of the car would have caused the lazy Susan to move, thereby destroying the pivot point for marks being made by the pen.

On different days we added different realistic props to the game. Gas station pumps were quite successful, as were little plastic Weebles (which look like people). The children could use these props to create imaginary trips to the gas station or, as one child suggested, a trip to New Hampshire.

Entry

This toy was so novel that it did not attract the children's attention immediately. Usually, a teacher would free-play with the Drawing Driver by herself. One or two children in the large classroom would notice the teacher having fun and come over, asking for a turn. The younger children usually pushed the felt-tip pen itself. The older children invented other ways to make the little car move. They either pushed the long dowel or went to the center and turned the cardboard drum

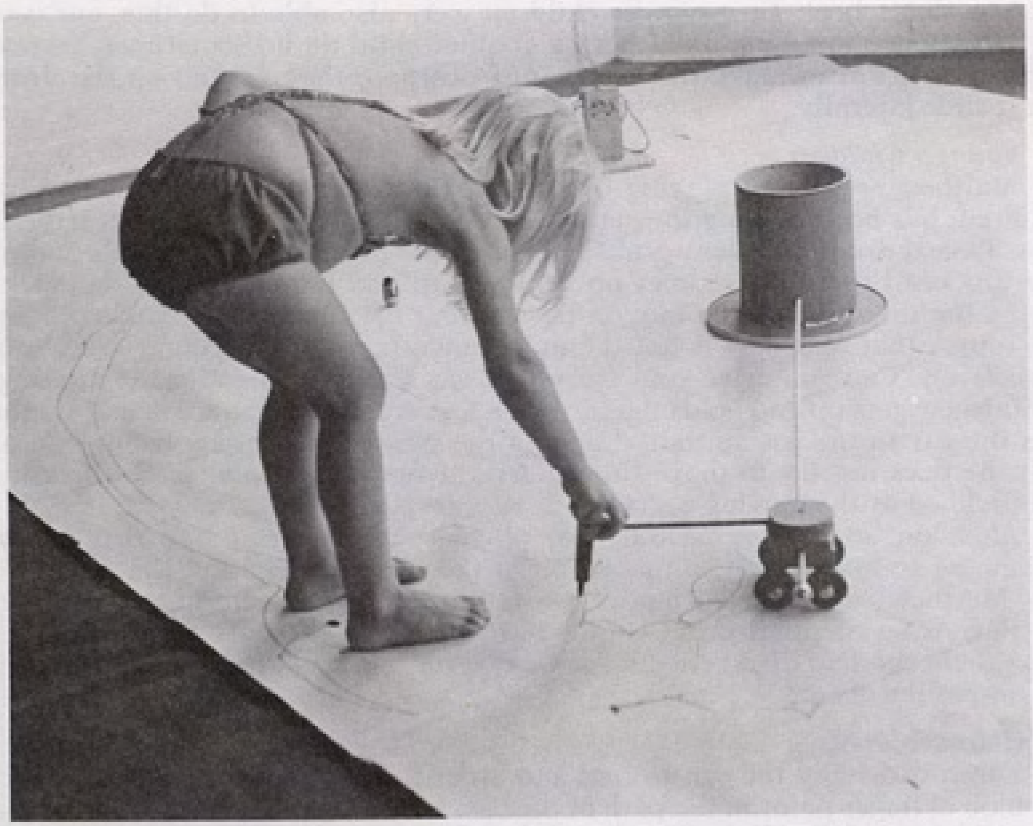


PHOTO 4.3 Sydney tests the felt-tip pen on the Drawing Driver car.

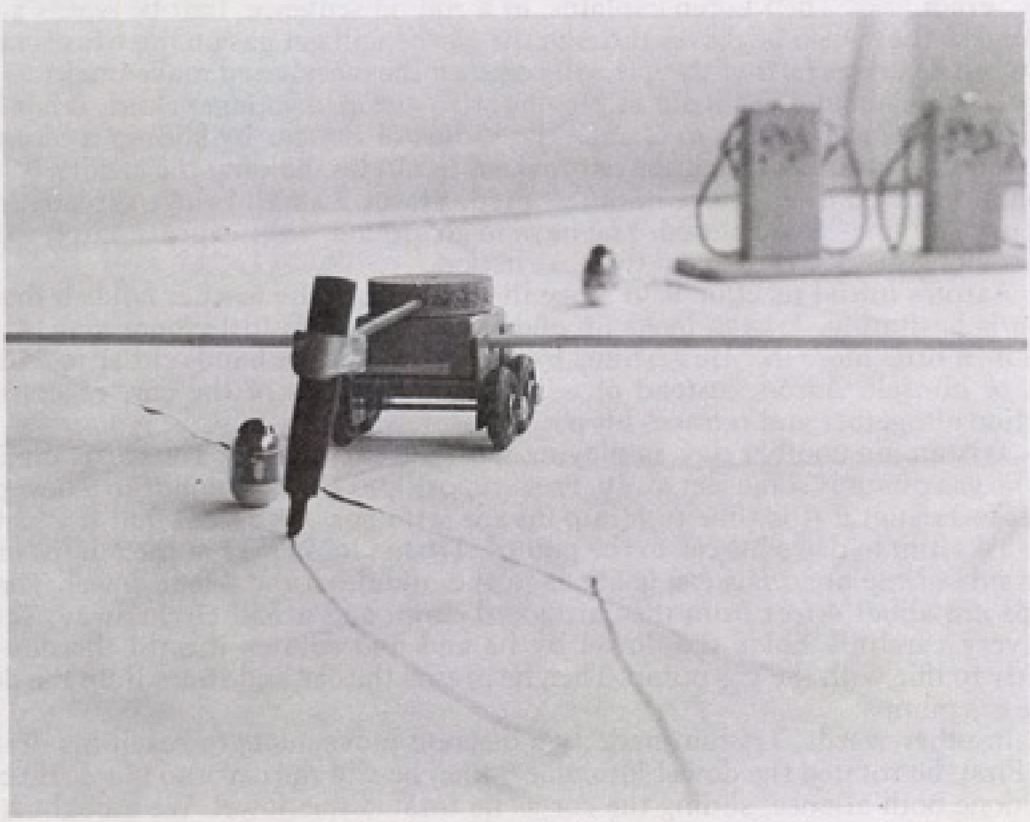


PHOTO 4.4 The car passes a Weeble (person) on the paper.

like a steering wheel. The younger children were also able to do this, but usually only in response to seeing a teacher or another child do it. Sometimes, instead of rotating the drum to make the car change position, they yanked on the drum to make it slide laterally.

Younger Children

Matthew sees Fredi playing by herself. He comes over to her and wants to play. Fredi has been moving the car on the end of the long dowel by steering from the cardboard drum. Matthew grabs the rim of the drum and turns it. He continues to do this until the dowel comes up behind him and bumps him in the back. He reverses the direction of the motion by rotating the drum in the other direction. Fredi senses that Matthew is not taking his own body into account (self-to-object perspective). "Can you drive your car to the gas station?" she asks. At this suggestion Matthew gets up and holds the car itself, leaving the cardboard drum. He sort of walks the car to the gas station, dragging the whole setup along behind. In other words, he does not try to move the car within the constraints of the three movements defined by the moving parts.

Alex, on another occasion, also played with steering the drum. Unlike Matthew he seemed to notice the action of the car on the end of the dowel 4 feet away. Matthew concentrated more on rotating the drum than on steering the car from afar. As we mentioned in Chapter Two, young children are more interested in proximal effects than distal effects. Alex, however, did seem to be looking at the car as he moved the drum.

Older Children

Loren is driving the car around and around, holding the car itself. Fredi has put a blob of finger paint in the path of the car. Loren says "We got gas in the road." He drives his car through the "gas," and the wheels make tracks on the other side of the "puddle." Loren wants to put more gas in the road. "Why do you want to do that?" Fredi asks. Then Loren explains, in a run-on sentence, that he wants gas on the road so that when he drives through the gas he will get gas on the wheels and so that when he drives farther the gas will come off the wheels and make tracks.

Tristan, about 4 years old, is playing with Aaron, a younger child. Tristan has previously discovered how to change the radius of the car by sliding it along the large dowel. Aaron is driving the car around in circles, holding the car itself. After Aaron has played a few more minutes, Fredi places a small bridge directly in his car's path, saying "Road closed. You have to go around." She expects Aaron to slide the car along the dowel to avoid the obstruction.

Aaron's initial reaction is to move the bridge, but the teacher holds it firm. As Aaron is hesitating, Tristan looks up and says "Make it a little more long. A little more in, a little more in." He gestures by slowly moving his hands closer together in front of himself. Aaron, instead of adjusting the radius of the car, reverses the direction altogether and retraces his path.

Tristan, on another day, is playing with the car himself. The car is on a trip and the gas pump is some feet away. Fredi repositions the gas pumps to a new place and asks Tristan if it is time to fill up his car with gas. He agrees that it is, and so Fredi asks him to drive his car to the pumps. Tristan looks over at the pumps on the other side of the area. His car is about in the middle of the 4-foot dowel. The gas pumps are about 4 feet from the cardboard drum and a half circle away. Tristan then very carefully holds the dowel by its end and rotates it until the dowel is directly in line with the gas pump. Then he grasps the car and slides it up the dowel to the gas pumps.

In other words, Tristan made two discrete movements to reach his destination. First, he rotated the dowel into place; then he slid the car into place. He could have done both at once, sliding the car as he rotated the dowel. We thought it was interesting that Tristan did not use that more advanced strategy.

These encounters gave us some indication that the Drawing Driver did offer some interesting problems for the children to solve. The different combinations of motions made several types of detours possible. The felt-tip pen left an indication of the choice of detours that a child might make. After a child made detours or reached his destination, he could see his choice in the lines on the paper. With children still older than our own you should be able to play more advanced games, such as How Did I Make This Mark? For example, one child called the back and forth wags made by the turret a "rainbow." Other children might want to make more rainbows and could try to figure out how that design was made. You should take your cue from the children and then expand the play gradually.

In Photo 4.5 you can see that Sydney invented a game of push and release. Instead of holding on to the car throughout, she sent it ahead with a sharp shove. The pen on the turret stick wagged behind. Because of the marks on the paper Sydney was better able to anticipate where the Drawing Driver would go when she pushed it forward.

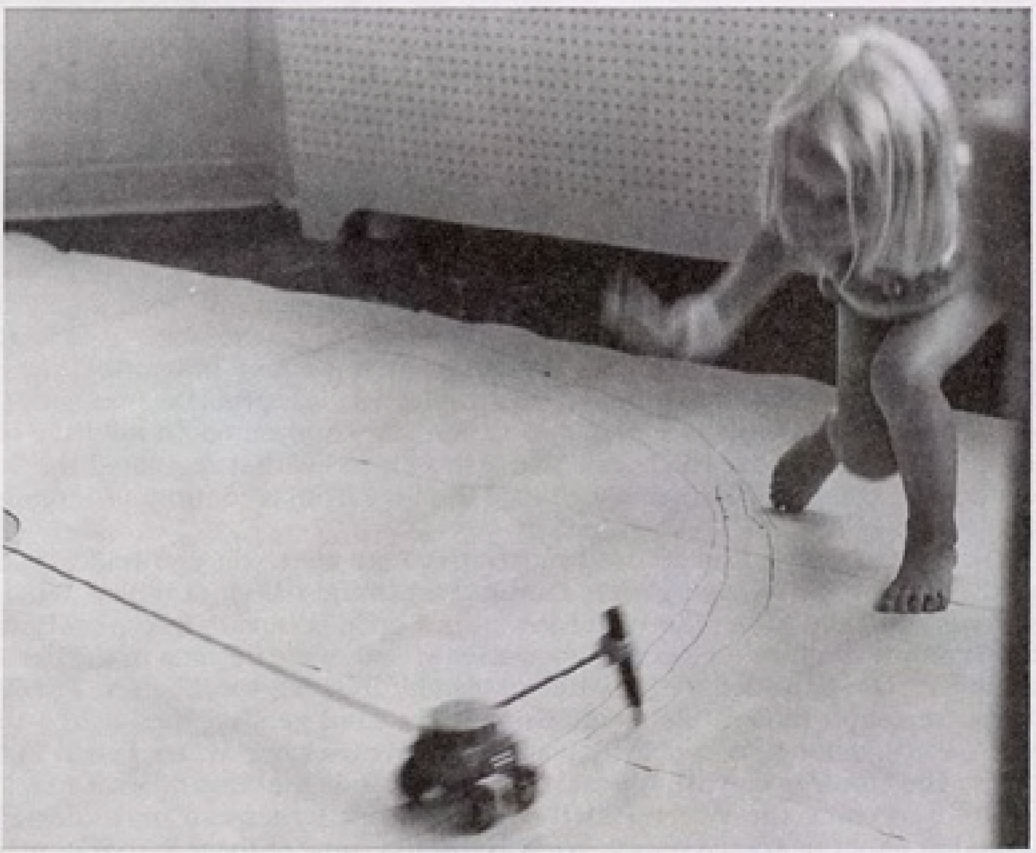


PHOTO 4.5 Sydney gives the Drawing Driver a firm push forward.

Variation—Tire-Tracking Trikes

It is interesting that the creative source of the Drawing Driver was a rain puddle on the sidewalk outside. The children, as usual, were driving their tricycles up and down the sidewalk. On this day their tires left tracks on the dry pavement after they drove through the puddle. Some of the children noticed the tracks. They zipped through the puddle and then looked over their shoulder at their tracks behind.

One 4-year-old is trying to reverse his direction. With the skill of a truck driver he turns the big bars full right, cranks his pedals backwards (passing through the puddle incidentally), whips the bars full left, and cranks his pedals forward. Wow!

He notices that one wheel has made perfect tracks showing both curves of his beautifully executed turnaround. He looks at this track and proclaims to a nearby teacher "I made the letter *Y!*" And indeed he did.

On other days we deliberately wet a spot on the sidewalk with the garden hose. The children thoroughly enjoyed making tracks and looking at how they diminished as the wetness wore off the wheels. The tracks were a fun way to freeze motion and study the shape of it. The tricycle's tracking also made such a vivid impression on the children that games played inside in miniature could draw on the real tracking outside. You may recall Loren at the Drawing Driver explaining why he had to have more "gas" that he could drive through.

THE WATER PENCIL

Preparing the Environment

During one staff meeting the teachers were remarking on the failures of the day. We had wanted our children to add water to dry paint so they could understand the transformation from dry to wet. The children dumped in huge quantities of water to the dry ingredients, making a memorable mess. We even tried tiny cups of water to slow down the transformation. Our children had used their free access to the bathroom to bring back to the easel a bucket of water. During this staff meeting someone said "We need a steady supply of a small quantity of water." Perhaps one of us thought about a leaky faucet, and then Lisa said "How about an IV [intravenous] tube from the hospital!" We instantly knew that this was the perfect solution to our problem. From then on the Water Pencil, as we christened it, has been standard equipment at the School for Constructive Play.

We got several IV tubes from the university infirmary. We took a gallon-size plastic milk carton and cut out its bottom. This was to be the water reservoir. We hung it upside down from the ceiling and inserted an IV tube in its mouth, using a rubber stopper and duct tape to make this connection leakproof. We hung the milk carton with a plant hanger (see p. 222 in CCK). The children could hold the nozzle end of the tube. Just above the nozzle was a thumb screw that regulated the flow of the water. The children could easily change the flow from a continuous stream to a steady drip to no flow at all.

The Water Pencil can be used most anywhere that you can find a place to suspend the reservoir. We use it over the sand table and the work tables. When it is placed over the sand table, the Water Pencil is a good means to freeze motion. The children can set the flow on a continuous stream and make designs in the dry sand. Food coloring can be added to the water so the children can see it better. Two Water Pencils at the sand table are enough. Sometimes sand gets trapped in the thumb screw. When this happens, a nearby teacher simply uses one Water Pencil to clean the other. The children can usually wait the few seconds that this takes.

Children using the Water Pencil over the work tables can make designs on construction paper or waxed paper. We will discuss some of these activities again in the section later in this chapter on unitizing motion. Set to drip steadily, the Water Pencil is an excellent means to break a continuous movement into parts. As the child moves his Water Pencil across waxed paper, the motion leaves a "unitized" trace in the tiny beads of water spaced at regular intervals.

Entry

When we placed the Water Pencils over the sand table, the children came to this area anyway. The teacher modeled for a few minutes, and the children quickly took the nozzle and began to drop the water stream into the sand. We started the activity with the stream very slow, so the sand would not get saturated before the focused-activity period was over. We left the usual sort of play implements in the sand table, such as a few cups, shovels, and shifters.

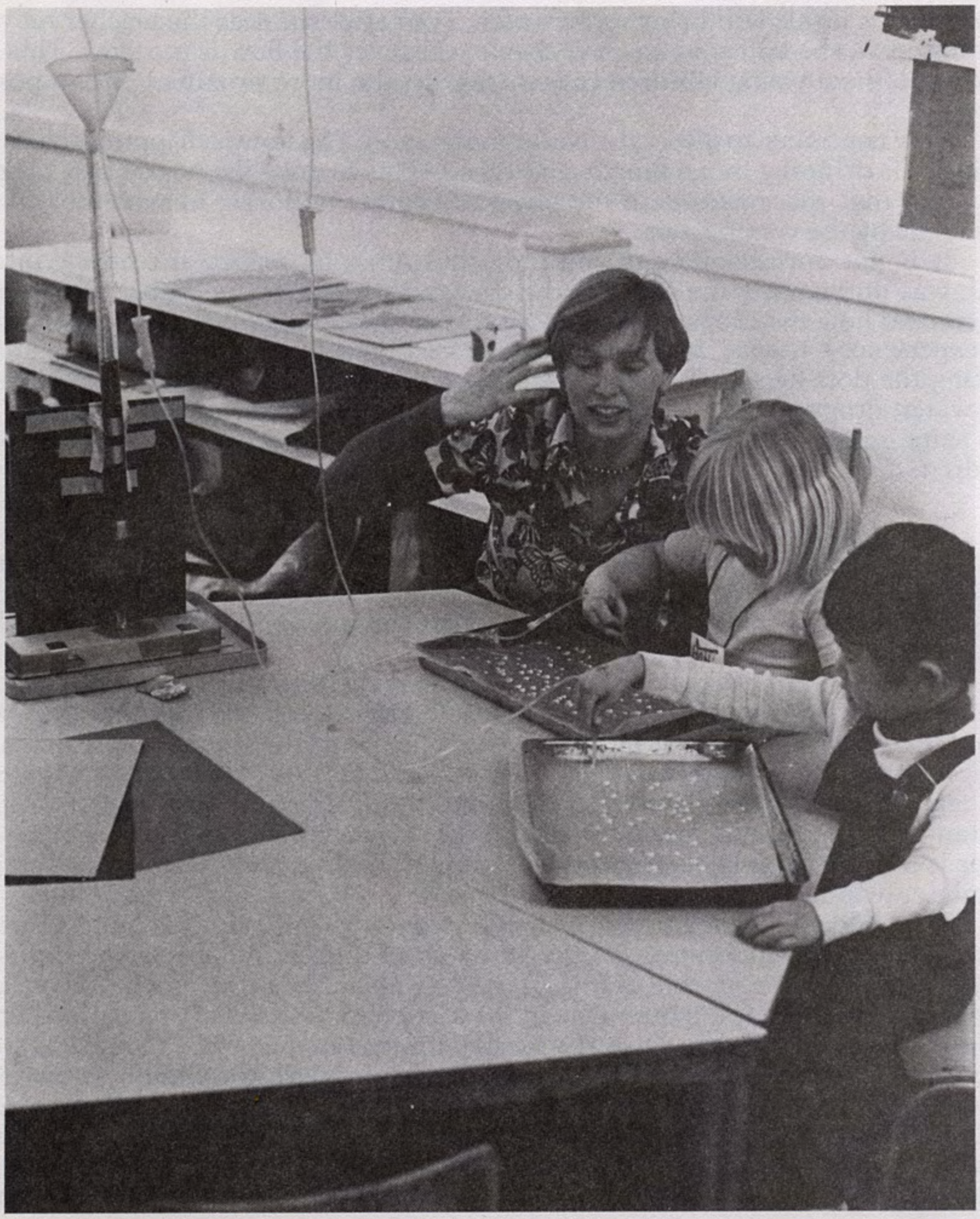


PHOTO 4.6 David and Hattie play with the Water Pencil. Water reservoir is hanging from ceiling (out of picture).

The younger children either held the stream of water in one place, making a puddle, or held it over their other hand to feel the water. The older children moved the stream of water around more. Sometimes, they made patterns; other times, they used the water stream to wash off miniature objects such as toy trucks. All children were able to see how the dry sand was gradually changing into a heavier, wetter, and more easily modeled substance. We had given the children control over the transformation in such a way that the change could be understood.

Younger Children

Amy is playing with the Water Pencil in the sand table. She directs the water back and forth from her palm to the sand. The water has slowed down to a steady drip. She wants it to flow faster, having seen it do that before. She squeezes the nozzle tip, as if this will bring more water. Even after she sees the teacher move the thumb screw, she still squeezes the nozzle whenever the flow is too slow. This is an example of how young children concentrate on the more proximal of two possible causes.

Amy continues to direct the water to the sand. The flow is dripping again. Amy studies this dripping momentarily and then begins to poke the nozzle into the sand. The holes that she makes with the physical contact of nozzle to sand look like the dots made by the water drops.

It is not unreasonable to conclude that Amy, by poking the nozzle into the sand, was duplicating the effect of the drops of water. She, perhaps, was trying to understand how the drops make the dots in the sand. She did this by "concretizing" the experience—that is, by using a more direct, proximal, and physical method of making the dots herself. Perhaps then she could assimilate the action and effect of the water drops to her own direct action of poking the sand. We noticed that this same scheme of poking was used on innumerable occasions by many of the children.

Older Children

Jenny is making long, slow passes with the Water Pencil over the dry sand in the table. The water leaves a clear, dark trace in the sand. Jenny first smoothes down an area, making a "tablet" to write on. Then she makes loops and curls with the Water Pencil.

Tristan's Water Pencil is shut off. He opens the thumb screw all the way. The teacher asks "Can you make it go half as fast?" Tristan gets the idea that the teacher wants the water to come out more slowly, so he closes the thumb screw down. But he overshoots the halfway point, and now the stream has been cut off altogether. The teacher says "Oops. Now it's not going at all. Can you open it just a little?" Tristan rolls the thumb screw forward until it reaches its physical terminus. The water is flowing at its fastest again. Most of our children had difficulty stopping the thumb screw midway.

The child's tendency to make changes go to their full limit is quite general at this age. They want to empty all the water from a glass, all the sand from a container. They want the marble to roll all the way down the ramp, not halfway. Recall the example we used in Chapter One in the section of the level of opposition. Tristan could not push the marble down the ramp with just enough force to make it stop in the middle portion of the ramp. We see here again, with the thumb screw on the Water Pencil, that Tristan is having difficulty with the concept of *degrees* (see Chapter One's discussion of discrete degrees). However, it was Tristan who said about the Drawing Driver "Make it a little more long, a little more in." In some activities, evidently, he could think about degrees of change, not just the opposite extremes of a change.

The Water Pencil can also be placed near the easel so children can trickle water down the paper. Colored water on white or yellow construction paper works nicely. We used paint powder and dusted the moistened surface of our huge Plexiglas easel. Then the children trickled and dripped the water to see how the powder would change to liquid paint. (Recall that this was the origin of the idea for the Water Pencil.)

We even used the Water Pencil with play dough. We put the dough inside an empty water table, and the children could make channels of water and lakes, sculpting the pretend terrain as they liked. Unfortunately, the play dough crumbled or dissolved after a period of time. Potter's clay or modeling clay would have worked better. Wherever we needed a steady and easily controlled supply of water, we used the Water Pencil.

THE REVOLVING EASELS

Preparing the Environment

This activity was a natural extension of the Spinning Sand, in which the child can keep her brush stationary and turn the lazy Susan to make marks in the sand. At a Revolving Easel the child can again hold her brush stationary and make marks on the paper as it turns under the brush. Using large cardboard drums, we constructed both a horizontal and a vertical Revolving Easel.

In Photo 4.7 Marya is making the papered drum revolve away from her while she holds a felt-tip pen to the paper. In Photo 4.8 Fleet helps Marya undo the paper from the drum so they can look at her marks flattened out. This horizontal version takes about an hour to make. Just cut two pieces of plywood the size of the drum's diameter and screw them into the ends. Bore a hole in the center of each end piece, stick a large wooden dowel through both holes to create an axle, and then mount the ends of the axle on some type of scaffolding. We used two shelf braces screwed into a plywood base.

The vertical version can be made in about five minutes. Take a cardboard drum and duct-tape the bottom end onto a lazy Susan (see Figure 4.2). The drum is heavy enough as it is to resist the lateral pressure children make on the sides when they make marks. You can attach sheets of construction paper to the outside surface with clothespins.

Entry

On the vertical drum the children began by making vertical marks with their felt-tip pens and crayons. The tallness of the drum may have suggested the vertical strokes. Also, by making a vertical stroke the children did not have to cope with the curved surface. They made a few marks, turned the drum, and made a few more marks. Only after several days of experience with the vertical drum did they begin to make horizontal strokes. When they did this, the teacher slowly turned the drum to give them the idea that they could make even longer marks without getting up from their seats.

Lilly and Jessica played a game at the vertical Revolving Easel. Lilly made a mark and turned the easel. Jessica laughed as she saw the marks that Lilly had made. The game was cut short by a distraction in the room, but it could have a lot of potential for future days. The Revolving Easel makes it very easy for children to exchange spaces, add marks to each other's work, and create a cooperative composite.

The horizontal easel did not lend itself as well to these cooperative games. But it was the preferred easel for freezing motion. The children could make all sorts of zigzag lines on the freely spinning drum by simply moving their pen back and forth from left to right. They seemed amazed that simple actions led to such interesting patterns on the flattened sheet taken off of the drum.

We also put black and white paper on these easels, half and half. A black crayon would make marks on the white paper but not the black half; a white crayon (or chalk) would make marks on the black paper but not the white half. The children liked to experiment with these opposites by turning the drum to different positions.

PLEXI-PAINTING

Preparing the Environment

All of the activities that follow in this section use our large Plexiglas panels. These are two ¼-inch-thick panels of Plexiglas about 5 feet by 3 feet, mounted in wooden frames. The frames are hinged together at one end. The panels can be stood up in easel-like fashion (see Figure 4.3). They can also be folded or spread out

PHOTO 4.7 Marya pushes the Revolving Easel with her right hand and makes marks on the paper with her left hand.

PHOTO 4.8 Marya and Fleet look at the marks that Marya has made.

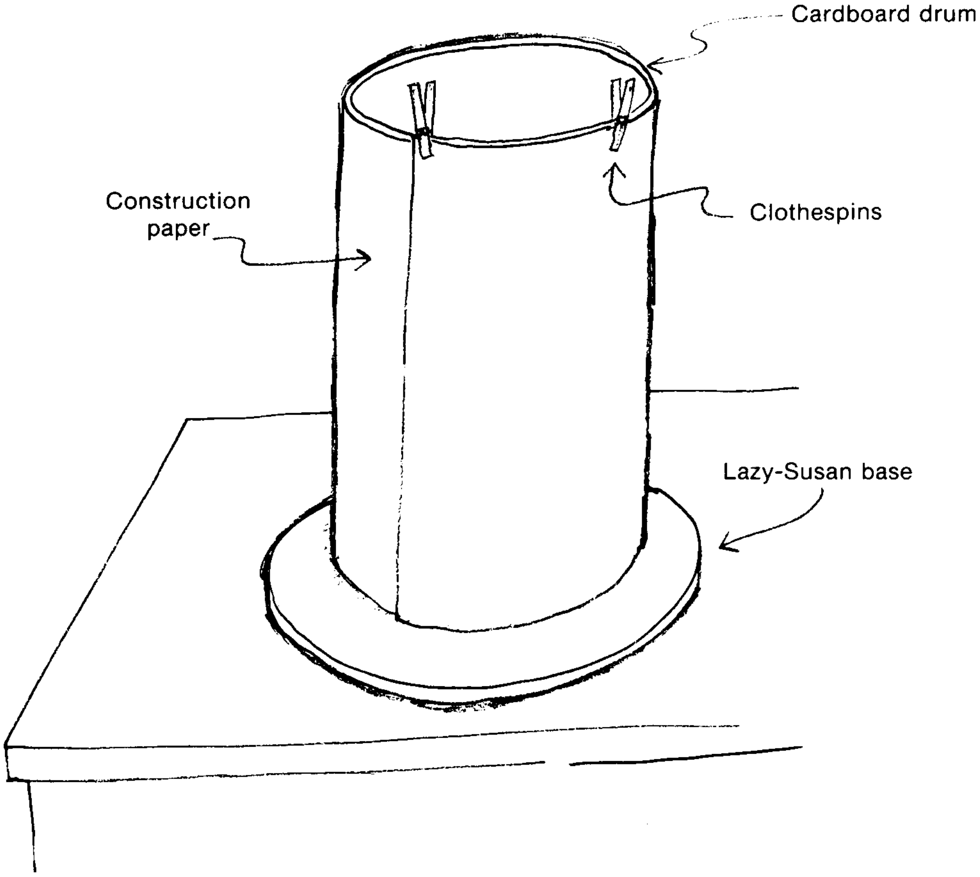


FIGURE 4.2 Vertical Revolving Easel.

horizontally and placed on saw horses; this makes a Plexiglas table. Or they can be placed on the floor in an L formation on two long sides; this makes two perfectly vertical surfaces on which children can stand and draw. Finally, they can be placed with one panel a horizontal ceiling and the other panel a vertical wall, as we did in the shadow play described in Chapter Two. In this arrangement the children can look at objects from an underneath perspective through the ceiling of Plexiglas (see p. 165 in CCK).

Plexiglas easels can also be easily made with two cardboard drums. Stand them on end, cut a vertical slit in each, and insert the right and left sides of a Plexiglas sheet into the drums. Children can stand on opposite sides and trace each other. In Photo 4.9 Hattie is painting Tom's face, beard and all. Tom is lying down in the loft of our climber, and the panel is built into its railing.

In keeping with our emphasis on movement, we decided to make things move behind a vertical Plexiglas panel. The children were given felt-tip pens (with washable ink) and asked to copy the motion of the things that moved. We called this version of Plexi-Painting *Kinetic Drawing*. In Photo 4.10 Katie has just seen Fleet pull back toward her and then release a plastic spool attached to an elastic band. The spool makes a rapid vibration at the top of the elastic before it falls straight down. The elastic is stretched taut between two points on the tiny scaffold and passes freely through a hole in the spool. In the photo you can still see the spool vibrating slightly as it descends. Katie makes her "copy" as Marya looks on. We will describe several different learning encounters with this setup.

Entry: Kinetic Drawing

The children initially drew the static features of an object. But with some encouragement they drew the motion of objects, such as the trajectory of a falling feather or the vibration of the spool on the elastic band. The slower the action and

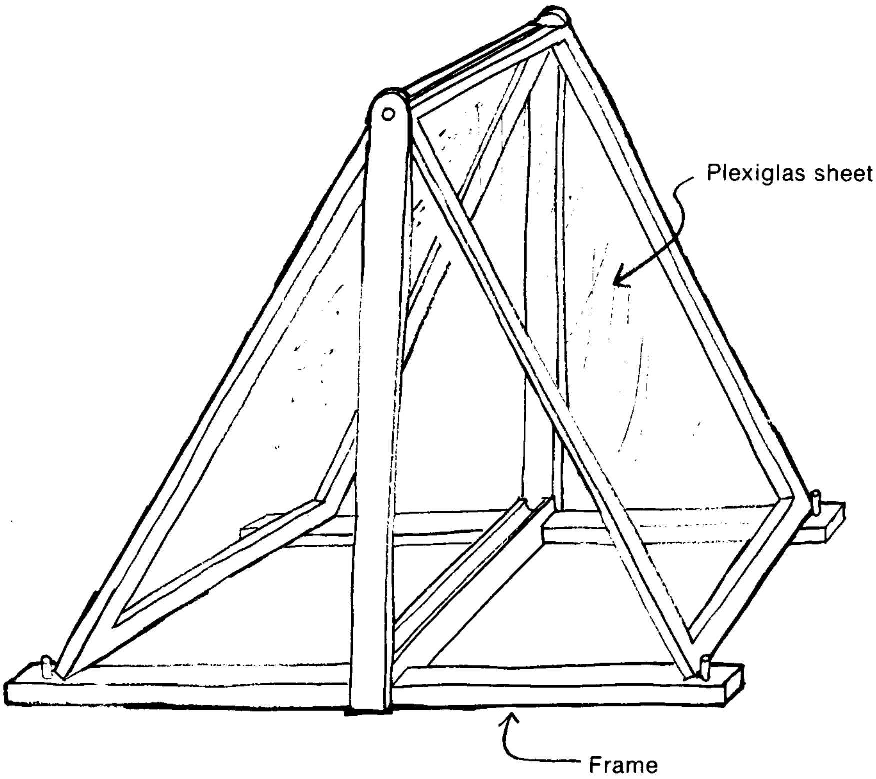


FIGURE 4.3 Plexiglas easel.

the more gracefully undulating the fall, the easier it was for the children to reconstruct the motion.

Younger Children

Katie, at 2½ years of age (she is about 4 in Photo 4.10), is watching Lisa drop a feather from about 5 feet above the table. Lisa asks "Can you draw how the feather falls?" Katie makes a 4-inch mark and crosses it with three perpendicular lines. Evidently, Katie is trying to draw the feather itself, as it looks when it is motionless. Lisa drops it again and says "Draw how it is falling." Katie again draws the static feather. On the third attempt she begins with a shaft and three perpendiculars but then draws a long trailing line downward, with abbreviated dips here and there. The trailing line looks like the trajectory of the feather's fall. Now she is thinking about the movement. The fourth time that Lisa drops the feather, Katie brings her pen down hard on the drawing surface. She smiles, looks at the feather, and crashes her pen down again.

It seemed that Katie's pen had become the embodiment of the feather. She had shifted from a graphic representation of the feather's falling to a physical (or gestural) form of representation. Perhaps the graphic representation did not express all the information that Katie wanted to represent. The pen-as-feather could express the actual contact that the feather made with the table. Young children seem to be very attentive to the point of contact between objects.

Older Children

Clayton watches Lisa drop the feather. He waits for it to fall all the way, and then he makes a single downward line on the Plexiglas. He does this several times. Lisa feels that the feather is falling too straight. So, she throws it aloft with a sharp movement of her hand. Clayton, interestingly enough, makes a sharp upward motion with his pen.

PHOTO 4.9 Hattie paints Tom's face on the Plexiglas panel in the climber/loft.

PHOTO 4.10 Katie makes lines on the Plexiglas to represent the action of the spool on the elastic band.

Clayton had apparently shifted from representing the fall of the feather to representing the sharp rise of Lisa's hand. Actually, what Clayton did seems natural, because Lisa's hand is more like Clayton's pen-holding hand than is the feather. The correspondence between his hand and Lisa's hand could be the reason he changed to making a physical (gestural) representation of action.

When Lisa drew back and released the spool on the elastic band, Clayton made a diagonal mark from top right to left and then made the mark drop straight down. His drawing indicated that he had thought about both the horizontal vibration of the spool and its subsequent drop. Or his drawing might have represented the initial position of the spool when Lisa had it drawn back, ready to release, and then the subsequent drop. He made a similar set of marks on a second trial, but the orientation of the two marks was rotated 90 degrees. Clayton was thinking about some aspects of the movements but had not quite worked out their relation to the bottom of the table. The game was brand new for Clayton, and with time he would probably think more about the motion itself.

Kinetic Drawing is quite unlike any other activities that we are familiar with as early-childhood teachers. Our culture teaches young children to draw a house, a tree, or a person. These are static objects. We teachers make the assumption that children cannot draw the shape of a motion. Yet these small successes that we had at the School for Constructive Play made us believe that Kinetic Drawing is both possible and enjoyable for young children. On top of all this, it may be good pedagogy if it serves to give the child a more dynamic world view, a view of how things change.

We thought that the kinetic aspect of objects could be more easily studied by children if they watched moving shadows. The shadow can be cast directly on paper, using the rear-projection technique that we have already described. The child can make marks directly on the moving "object." In point of fact, we should have invented Kinetic Drawing with shadows first, because it is easier than the drawing on clear Plexiglas. The following encounters describe the children playing with kinetic shadows.

Entry: Kinetic Shadow Drawing

We used two versions of Kinetic Shadow Drawing. For one version the shadows were cast on a vertical panel. The children marked on the paper on one side, and the teacher moved an object in front of a light source on the other side. Objects with slow, undulating movements elicited the most attempts to draw action. One of the best was the Wonderful Waterfuls, a commercial game that consists of small, plastic rings in an enclosed, clear-plastic reservoir of water. By pressing a button that created a water jet inside the reservoir, the teacher could make the little rings shoot upward in the water and gracefully float and tumble down. The rings made the most captivating shadows seen from the child's side of the papered Plexiglas panel. Marika, for example, would make long, comma-type marks inside the shadow of the reservoir. When the teacher removed the Wonderful Waterfuls from the light source, Marika could clearly see her marks. The marks had frozen the motion or, at least, Marika's understanding of the motion.

For a second version of Kinetic Shadow Drawing we placed the Plexiglas panels horizontal on saw horses. The children could trace moving shadows or a moving light on paper. We found that small penlights worked better than regular flashlights. They were easier to move around, and the children did not have the tendency to color in the surface area of light. With a small point of light the children got more involved with movement. They kept their crayon on the point of light wherever it went. When the teacher turned off the light, the children could look at their marks. The marks were, as one child said, "where the light went."

All of the activities in this section have dealt with freezing motion. Children eventually construct the relation between the object in motion and the trace left behind. Once they construct that correspondence, the traces present information about motion that is otherwise lost with the passage of time. We now shift to freezing motion in a different way. The trace left behind is a discontinuous representation of a continuous action. The motion is broken into "units."

UNITIZING MOTION

In the activities on unitizing motion we take an action with continuous motion that the child can easily see, such as a rolling ball, and add to this some trace of the action. But the trace is discontinuous. Through these activities, we hope, young children will get the idea that a continuous motion can be broken up into parts, or segments. Many skills, such as telling time from a clock, measuring off a distance, and calculating the rate of rise or fall of a moving object—all things that the child will do at an older age—involve the simple notion that a single motion can be broken into segments. We have no illusion that our children will regard these segments as equal or not equal, but we do sense that they are intrigued with the discontinuity of the traces within the continuity of the motion.

The discontinuity is not always frozen in a trace. Sometimes, we use the physical starting and stopping of the moving object itself, such as a spool rolling down an incline and hitting speed bumps every 12 inches or so. The continuous downward motion of the spool is unitized by the punctuation of the bumps as the spool rolls. The child, in this case, makes a mental representation of the discontinuity, rather than seeing the physical representation of a paint trace or water mark. That is, the child sees the second bumping action, relates that to the first, and gets some sense of the discontinuity of the motion. To think about the discontinuity, the child must remember the whole roll.

THE BLIP SPOOL

Preparing the Environment

The Blip Spool is so named because, as it rolls down a papered incline, it leaves a spot of paint twice every revolution. The children called these spots "blips." In Photo 4.11 Seth has just released the spool down a narrow table that we had jacked up at one end to make an incline. The spool is rolling toward a target made out of Tinker Toy parts. If Seth has aimed correctly, the spool will hit the center Tinker Toy stick and spin it on its goal post axle. The table is covered with butcher paper, which is changed after every four or five trials. The more enterprising of you might construct a holder at one end of the table so that the exchange can be a simple matter of rolling paper out and tearing the old sheet off.

The spool itself came from a recycling center. It was probably used for electrical wire. We took two little sponges and epoxied them to the center shaft of the spool, one on each side. Before each roll the teacher dabbed a little finger paint on both sponges. The paint was thick enough to leave on the paper an easily discerned spot without the splatter that thinner paint would cause.

To make the game easier for the younger children, we tacked 3-inch cardboard retaining walls on the sides of the table. The walls also discouraged waiting children from interrupting the roll of the spool.

Entry

Our children at the School for Constructive Play were quite familiar with rolling games. They enjoyed them and knew how to manage them. Even without modeling the children would place the spool at the higher end of the table and release it. The teacher did have to structure the game somewhat in order to apply the paint to the sponges. The marks on the paper were a new experience. It seemed

PHOTO 4.11 Seth releases the Blip Spool toward the target. The spool leaves traces of paint as it rolls down the incline.

that the onlooking children noticed the blips before the child who had released the spool noticed them. But after a few runs—particularly after a few misses—the child who had released the spool would look at the blips.

On a larger table the teacher can reposition the target. Her role is to create a slightly different problem for the child. A whole variety of challenges can be posed by changing the position of the target, changing the slant of the incline, and changing the number of sponges moistened with paint. If the table is unevenly elevated at one end, with one leg higher than the other, the sponges make glancing blows to the paper as the spool both rolls and slides. (This last variation depends on the friction of the paper to the spool and does not always work.) The aim of the activity, as always, is to start the children off but then fade out and see how they begin to explore the possible changes.

We wanted to invent a spool on which the position of the sponges could be changed. This would be more in keeping with our emphasis on *change without exchange.* The blip marks would then be closer together or farther apart depending on how the child spaced the sponges on the circumference of the spool. In general, a spool works better than a ball. Balls roll in so many different ways that the sponge infrequently comes into contact with the paper.

If the children do not comment on the marks, do not force their attention to it. Casual comments every now and then should be enough. At first, the children will be much more involved in the rolling than the marks. They begin to notice the marks incidentally at first, but more deliberately later. As we said, the marks are a novel experience, and it may take some time before the children assimilate the marks as relevant to the motion.

HOLELY STROKES

Preparing the Environment

In Photo 4.12 Hattie has been painting at our Plexiglas easel. We had prepared the easel beforehand by duct-taping four rubber sheets, filled with holes, onto the panel. The children could make brush strokes across the sheets—thus the name of this activity. Then, when they lifted one, as the teacher is doing in Photo 4.12, the children could see that they had made circles on the Plexiglas. The rubber sheets came from a recycling center in Boston, the duct tape came from the hardware store, and the idea came from our objective of unitizing motion. The continuous movement of the paintbrush is broken into parts, the separate circles made on the Plexiglas panel.

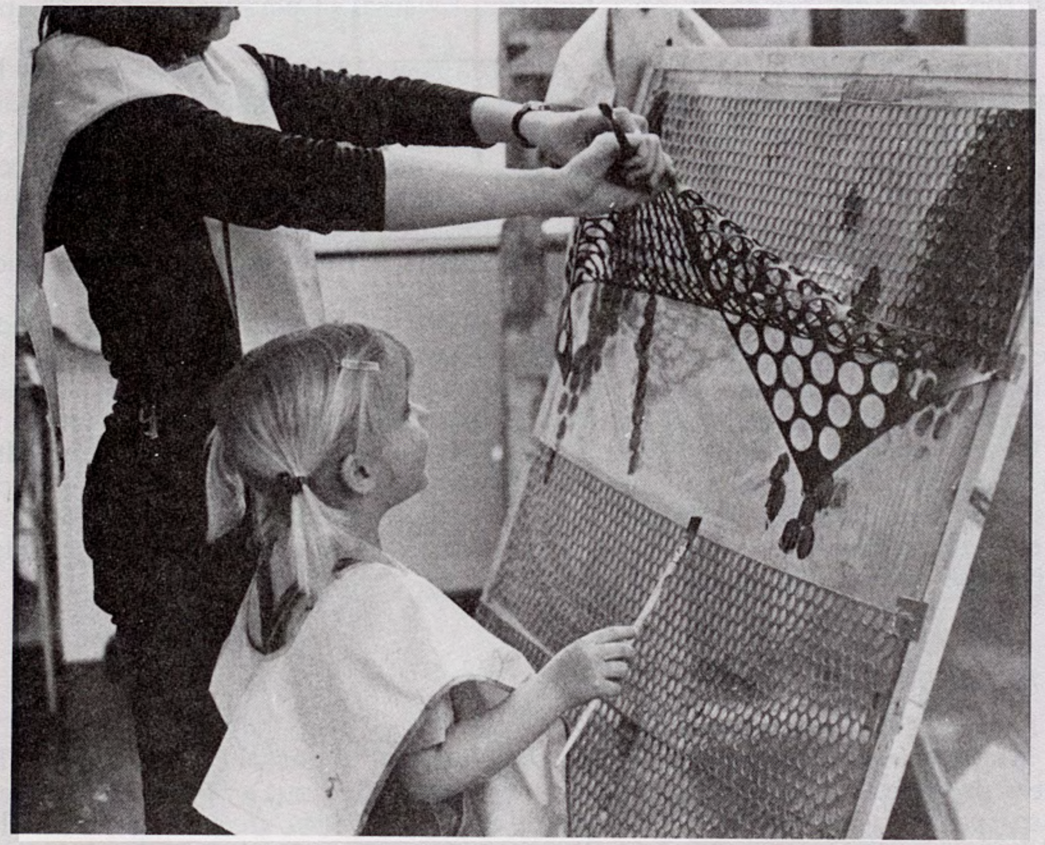


PHOTO 4.12 Hattie looks at the discontinuous circles left under the rubber sheet.

Entry

The younger children liked to fill in each individual hole one at a time. The older children, with a wide-bristled brush, made a single swath across a row of holes and then looked at the pattern left underneath the rubber sheet. With the sheet of larger holes, however, even the older children enjoyed filling in individual holes with paint. The large holes seemed to suggest individual spaces that should be filled.

Younger Children

Matthew stands at the easel, holding the brush almost all the way up the back of the handle. He repeatedly jabs paint into the rubber holes and twists the brush. After he has filled several adjacent holes, a whole area appears blacked out. At this point a teacher raises the rubber sheet. Matthew looks at the same area now. It no longer appears blacked out. He has made some globby circles, some connected because of the excess of paint he used to fill in the holes. He laughs at this and, when the teacher lowers the sheet, he begins to paint again in the same manner. He begins to anticipate that the teacher will, after a while, raise the rubber sheet. Now he uses less paint per hole and shifts to a new hole more frequently. Perhaps he is thinking about how the blacked out-area (continuous color) will look when the rubber sheet is raised (discontinuous color).

Older Children

Eva is painting over the rubber holes. Aaron is on the inside of the easel with a paintbrush. Wherever Eva makes a circle of paint by painting across the holes, Aaron adds a dot over it from the inside. "I'm painting yours," Aaron says to Eva. Eva doesn't say anything. About five minutes later, after Aaron has left, Eva gets inside the easel. She starts to paint the other side of the circles she has made, just as Aaron painted her circles. From the underside of the easel it appears that the circles are on top of the rubber sheet, an interesting reversal of perspective (see Chapter Three).

Hattie is making swaths of paint across a row of holes. She knows to dip her brush deep into the paint in order to have enough to cover more than a few holes. When the teacher lifts the rubber sheet, Hattie laughs. Before the teacher lowers the sheet, Hattie dips her brush into the paint again and connects the individual circles with a single stroke. This behavior could indicate that Hattie has assimilated the row of separate holes to the scheme she used to create them, a single stroke of the brush. She has converted, in effect, the discontinuous circles back into a continuous swath of paint!

After we watched children explore the rubber stencils at the easel, we decided to use them on the overhead projector. The effects were enlarged on the projector. Children found this variation quite exciting, except that the younger ones had difficulty making the correspondence between the painting surface and the image on the wall. We also used finger paint by itself on the overhead projector. Here the children could both freeze continuous motion or unitize motion, depending on the implements they used. The swirls and texture of the finger paint projected on the walls were extremely beautiful. We also liked the fact that the dynamic aspect of finger painting, the motion, was so conspicuous.

ROLLED-OUT PLAY DOUGH

Preparing the Environment

We described the preparations for this activity, in part, in Chapter Two. The teachers prepared a large batch of play dough and rolled out a ¼-inch layer over a large surface of the table. The children could use this layer as an etching tablet. They could freeze continuous motion by rolling a toy car over the dough. Or they could freeze motion with a discontinuous trace by using a sprocketed wheel such as a pizza cutter or a plastic gear. In Photo 4.13 Lauren is rolling a plastic gear through

PHOTO 4.13 Lauren rotates the plastic gear through the play dough and leaves a unitized representation of her motion.

the play dough. Look closely, and you will see the track that the gear leaves in the dough—a discontinuous row of teeth marks.

Some implements work better than others to make these unitized traces of motion. The difficulty with a plastic gear is that the child cannot make its marks go any farther than a half revolution before her hand gets in the way. The pizza cutter works better. It is on an axle, which is attached to a handle. The cutter wheel turns as the child extends her arm across the play dough.

The pizza cutter, however, has very small sprockets. It does not leave in the dough marks that are clearly separate. So we made our own pie cutter with Tinker Toy parts. Two wheels on an axle, with the axle on a handle, turned out to be the ideal implement for unitizing the forward motion of the cutter. We placed shortened dowels in the holes around the rim, as you can see in Figure 4.4. The children could change the pattern of the teeth prints in the dough by adding or subtracting teeth or by simply twisting one of the wheels on the axle without twisting the other.

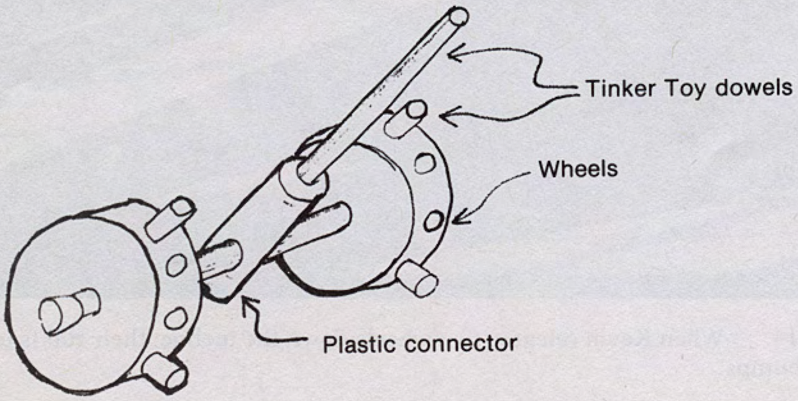


FIGURE 4.4 Wheels for unitizing motion in play dough.

Entry

The children named these little prints everything from "the broken wheel" to "footprints in the snow." The younger children sometimes tried to gouge up the play dough with the sprocketed wheel. The older ones were quite fascinated with the row of holes that the wheel left behind. For these older children, we might venture to say, this encounter was a precursory experience with measurement. After all, measurement involves marking off a total distance into parts. In fact, something quite like our sprocketed wheel is used to measure athletic fields. We will not push this analogy too far, but we do think the children are at least intrigued with the discontinuity (the row of holes) within continuity (the smooth action they use to make the holes).

SPEED BUMPS

Preparing the Environment

In the next few activities the child encounters a motion that is punctuated by a bump or a jerk. There is no trace left behind, but the child can change the motion back and forth between smooth and jerky, smooth and bumpy. In this fashion he may begin to understand that one continuous motion can be divided into units. In Photo 4.14 Kevin is rolling two cardboard wheels down an incline. The teacher has placed three cardboard rods across it. As the wheels hit the rods, they bump in a rhythm determined by the spacing of the rods. Kevin can either change the spacing of the rods or remove them altogether.

The wheels are "pipe sections" sawed from a larger cardboard tube. The

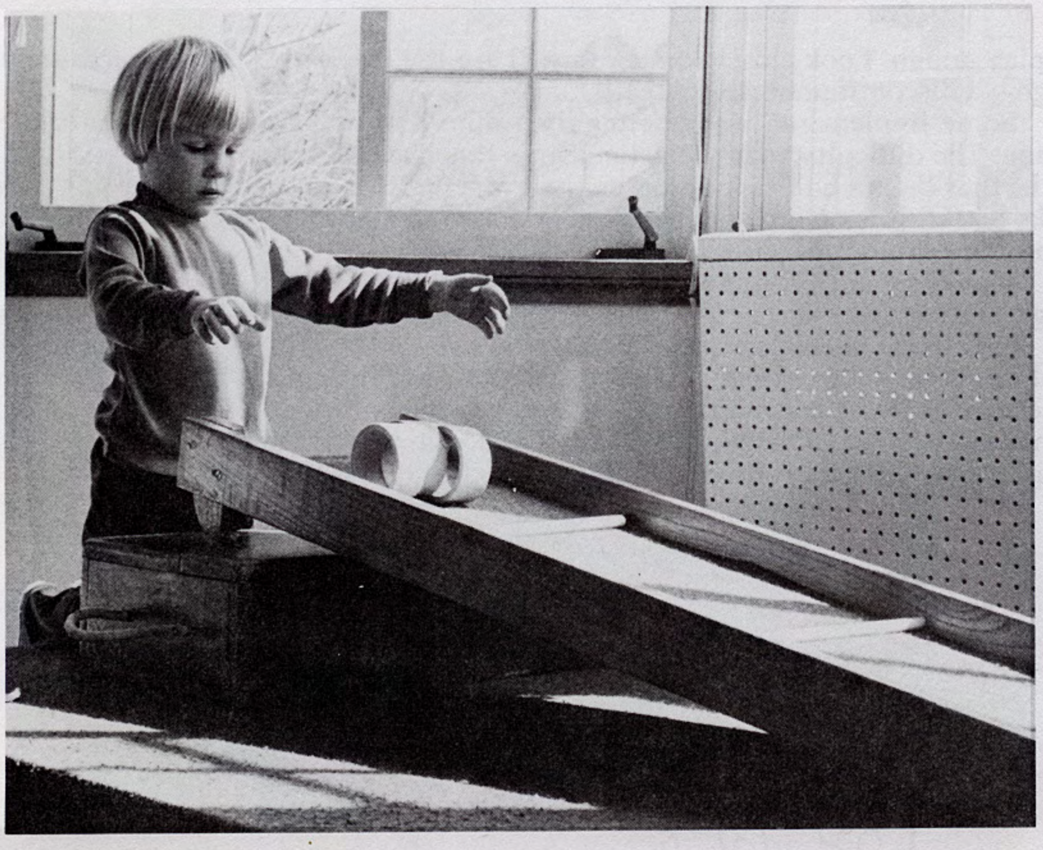


PHOTO 4.14 When Kevin releases two wheels down the incline, their roll is unitized by the speed bumps.

incline is actually a slide from an indoor climbing gym. We propped it up on one end with a wooden step-block. The "speed bumps" are cardboard tubing taken from coat hangers. They can be cut to specification, so that they will stay firm between the edges of the slide but can also be moved to make the wheel bump in different rhythms.

Entry

The teacher does little more than facilitate the children's explorations and help them take turns. At times, a speed bump will bend beyond repair, and the teacher can give the child a replacement. The speed bumps do not always stay in place, and a teacher can help cut them to improve their fit. If your school has the resources, you can improve this activity by routing out grooves along the side walls of the incline within which the cardboard rods can slide but not lift up.

The younger children have a tendency to push the wheels down the incline. The older children, as you see Kevin doing in the photo, place and release the wheels. The release works better, of course, because a vigorous shove is likely to cause the wheels to skip and even fall out of the alley.

We constructed a more advanced variation of the Speed Bumps by using a plastic spool. The spool was of the same type used in the Blip Spool activity. In this instance we cut a notch in both sides of the spool, as you see in Figure 4.5. The notches were cut deep enough so that, whenever they rolled directly over a speed

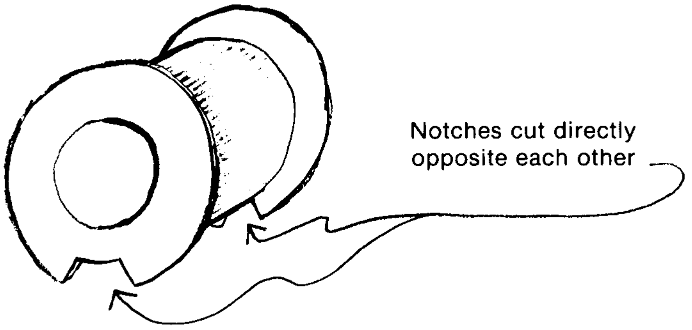


FIGURE 4.5 Notched spool for Speed Bumps.

bump, the spool would not bump. There was an arrangement of the speed bumps that made it possible to roll the spool down the incline without a single bump! The speed bumps were stationed apart at intervals equal to the circumference of the wheel's rim. It was then simply a matter of starting the release with the notches placed on the first speed bump. Our children did notice the differences in the way the spool behaved, sometimes bumping, sometimes not. But none of our 4- or 5-year-olds could figure out how the bumpless rolls occurred.

Part of the problem was mechanical. The construction of the speed bumps made exploration of their various positions difficult. The cardboard rods would either bend or fail to stick properly. The teacher had to help too often. Part of the problem also could have been the child's level of understanding about a motion within a motion. To understand the bumpless roll, the child would have had to think about the rotation of the notch around the center axis of the wheel (one motion) and at the same time think about the forward motion of the spool down the incline (another motion). As we have discussed before, children between 2 and 5 have difficulty thinking about two simultaneous functions (two within one). This more advanced version of the speed bumps, however, might be an interesting problem for 6- and 7-year-olds to solve.

SLATTED ROLLWAY

Preparing the Environment

We solved most of the "human-factor" problems of the Speed Bumps by using some long boards and hardwood blocks to make the Slatted Rollway. First we placed a saw horse on one of our 15-inch platforms. On it we propped two parallel 10-foot seesaws, resting their opposite ends on another saw horse on the floor.

We commandeered about three dozen double-unit and six-unit blocks from the block area. We lined the double-unit blocks all along the crack between the two parallel boards, creating a "Slatted Rollway" (see Photo 4.15). The slats were held in place with six-unit blocks, placed on edge and duct-taped together to create a retaining wall for objects to be rolled down the slats. The retaining wall was itself held in place by more six-units blocks duct-taped flat to the seesaw boards. The child could

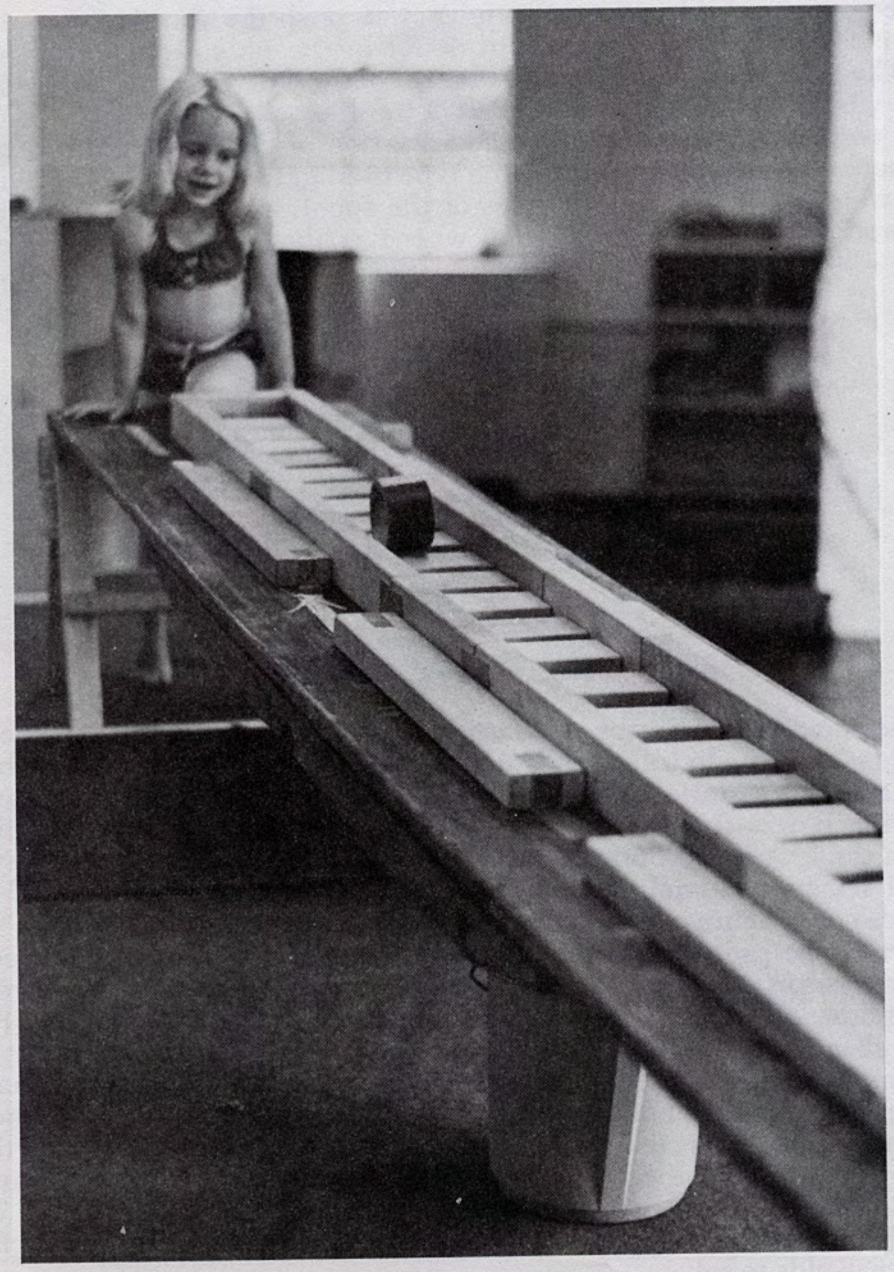


PHOTO 4.15 Sydney releases a wheel down the Slatted Rollway.

make holes and gaps anywhere along the Slatted Rollway. In Photo 4.16 a cardboard cylinder falls through the end of the rollway into a bucket below.

The whole setup was like a big xylophone. As the wheel rolled down the rollway, it would make a clackity-clack of rhythms determined by the spacing between the slats. That is, the motion of the rolling wheel could by unitized in different ways. The children had easy control over these transformations.

The children had several options for changing the Slatted Rollway. They could move individual slats (the double-unit blocks) or many at the same time. They could move the retaining wall as a unit without moving the slats. The retaining wall of six-unit blocks was securely duct-taped together as an enclosed box, 8 feet long and 1 foot wide. Finally, children could either remove or add blocks to make the rollway either less or more continuous.

We also discovered that the double-unit wooden cylinders produced interesting effects when rolled down the rollway. These cylinders would exactly fit within the sides of the retaining walls, roll down to a large gap in the slats, and come to rest on the inside edges of the parallel seesaw boards without falling through. On some occasions we substituted these wooden cylinders for most of the slats and let the children explore the functional properties of a rollway made with two or three dozen cylinders. We will also discuss other variations of this activity, which turned out to be one of our most versatile and popular games.

Entry

Most of our children, both younger and older, became fascinated with the "moving hole." By pushing the slats together, they could make one large hole in the rollway. They preferred to make the hole all the way at the bottom of the incline. This way, when they released the wheel at the top, it would roll the maximum distance before it fell through the hole into the bucket below. After whoever was playing the game had made the wheel roll the complete distance, the teacher created a small problem for the child to solve. The teacher pushed the slats and opened a hole at the middle of the rollway. Children of different ages had different strategies for solving this problem.

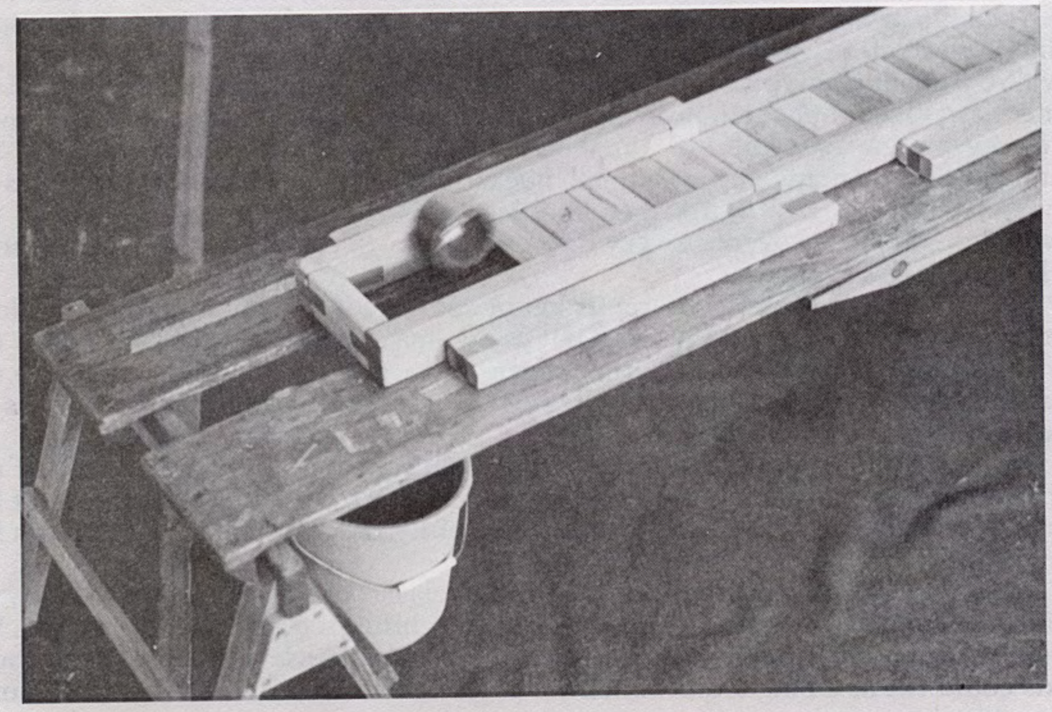


PHOTO 4.16 The wheel drops through a hole in the rollway into a bucket below.

Younger Children

Alex, a 2½-year-old, is rolling the wheel down the rollway. Gary, a student teacher, is nearby. Each time Alex rolls the wheel, it falls into the bucket. He retrieves the wheel from the bucket and returns to the top of the incline to roll it again. Just before Alex rolls the wheel, Gary changes the position of the hole, so that it is no longer over the bucket. Apparently understanding the implication of this change, Alex repositions the blocks, one at a time, until the hole is again directly over the bucket. After a few more rolls, Gary moves the bucket instead of moving the hole. Alex has a choice. He can either move the bucket back where it was (the inverse of Gary's transformation) or move the hole to be over the bucket (the reciprocal of Gary's transformation). Alex chooses to move the hole by pushing the slats down one at a time.

Although the reciprocal is usually a more difficult compensation for a child to make, in this case, perhaps, it was easier. After all, moving the slats was what Alex had done the last time the hole was not over the bucket. We did not ever see Alex move many blocks at once, which could be done by grasping and sliding a block several slats away from the current position of the hole. The younger children approached the problem with a one-at-a-time strategy.

Perhaps this strategy is another indication of the younger children's focus on the most proximal site of an effect. They could grasp and push a block that was next to the hole to move the hole over one space. But to grasp a block several slats away from the hole did not occur to them, because this latter strategy would require thinking about an effect some distance from the site of action. It would also require an understanding that pushing one block can cause other blocks, not directly touched, to move. We have seen the same thing with toy trains. A young child will pull a train by grasping the locomotive and pulling the other cars along incidentally, but he will seldom grasp the caboose and push the other cars ahead deliberately. The idea of force's being communicated through a series of connected objects does not occur to 2-year-olds as easily as it might to older children.

Older Children

Loren has been rolling several wheels down the Slatted Rollway at the same time. The hole in the slats is at the bottom of the incline. As he approaches the top of the incline holding a wheel in his hand, Gary opens a hole in the middle of the rollway by pushing many of the slats at once. When Loren gets to the top of the incline, he notices that the hole is in the middle. He walks back toward the lower end of the incline past the hole in the middle. He grabs the bottom end of the retaining-wall box made of the six-unit blocks. With a firm, steady tug he draws all of the slats inside the box together and recreates the hole at the bottom of the rollway! Loren has discovered a very interesting way (a reciprocal reversal) to undo the change that Gary made.

After several more rolls, Loren is again challenged by a hole in the middle of the rollway. This time Loren presses a flat palm on a slat about eight slats below the hole and slides that slat and the other seven upward, creating a hole closer to the bottom of the incline. He repeats this strategy one more time, and the hole opens up at the bottom of the rollway.

Not only did Loren understand that he could push many blocks ahead of the one he touched, he also knew that a hole would open up behind (not ahead) of his direction of push. He did all this with the certainty of a craftsman who knows his tools intimately.

After the Slatted Rollway had been in the classroom for about two weeks, we modified it slightly by making it possible for the children to change the incline. We did this by screwing cross-boards between the parallel seesaw boards so that both boards could tilt as a single unit. Then we placed the rollway on a single saw horse at the midpoint.

Tristan invented a new game with this setup. Placing a small doll on one of the slats, he tilts the incline so that the slats start to move down. "Give the baby a ride," he says. The doll rides down the incline on the slat. "Look, they took the baby away," Tristan comments. Gary facilitates this game by taking out more of the slats so that the doll will have a longer ride. Other children get interested and find their own objects to put on the slats. The game becomes a sort of conveyor belt. "Can you send me some coffee?" Gary asks Aaron. Aaron puts a coffee pot on one of the slats and then tilts the incline down toward Gary. The coffee pot slides down the incline on the slat.

We even added seats on each end of the rollway so that two children could make the seesaw version change inclines the way all seesaws do. We placed a mixture of double-unit blocks and double-unit cylinders in the retaining-wall box. As the children seesawed, the cylinders rolled first to one end, then to the other, creating holes at the top of each change of incline. The children were fascinated with the back-and-forth motion of these blocks. Heretofore, a seesaw had meant an up-and-down motion. Perhaps the Slatted Rollway, in this version, gave expression to a type of motion, back and forth, that the children had never considered.

Variations

The school semester ended before we could make other modifications to the Slatted Rollway. We considered many possibilities. For one, it seemed that we could not use the gaps themselves to unitize motion. The children preferred to roll the objects into a wide gap rather than across a slight gap. We plan to try different types of slats. A slat slightly higher than the others could make a speed bump that the children could easily move around. Several of these slightly raised slats could be spaced regularly among the others in order to unitize the motion of rolling objects. The rollway could even be set up so that the retaining walls converged slightly. Then the slats would have to be seriated to fit inside. The Slatted Rollway should be considered a general-purpose activity.

In the fall of 1978 we did try an activity that evolved from the Slatted Rollway but was different enough to have its own name, the Domino Row. This activity was field tested by Susan Kowal. Rectangular double-unit blocks were stood on end in the familiar row, regularly spaced so that they would knock one another down when the first was pushed over. We modified the activity to fit the ability of our 3-year-olds, who had trouble arranging the blocks in a straight line. We made a long channel by taping two 8-foot boards (2 inches by 4 inches) parallel on the floor. Each block for the row was hinged to a single-unit block with a piece of duct tape. The upright double then had a nice pedestal that would slide freely inside the long channel. All the children had to do was stand the blocks up and slide them back and forth within the channel. By reducing the need to make a straight line, we invented a unitizing-motion game within the ability of the younger children.

CASCADING WATER

Preparing the Environment

The Cascading Water was designed to give children encounters with a unitized flow. We placed the water table on one of our platforms. Then we built a set of steps up to the table, using our large step-blocks from the block area. On top of each step we placed a split section of cardboard tubing about 5 inches wide. These split tubes functioned as troughs for the water, a set of tiers down which it could cascade. The troughs were lined with tinfoil to make them waterproof (see Photo 4.17).

Entry

This activity is one of our most successful in terms of extended play by a variety of children. Both the younger and the older children enter the Cascading Water area and stay there at play for 30 minutes or more. Because they are familiar

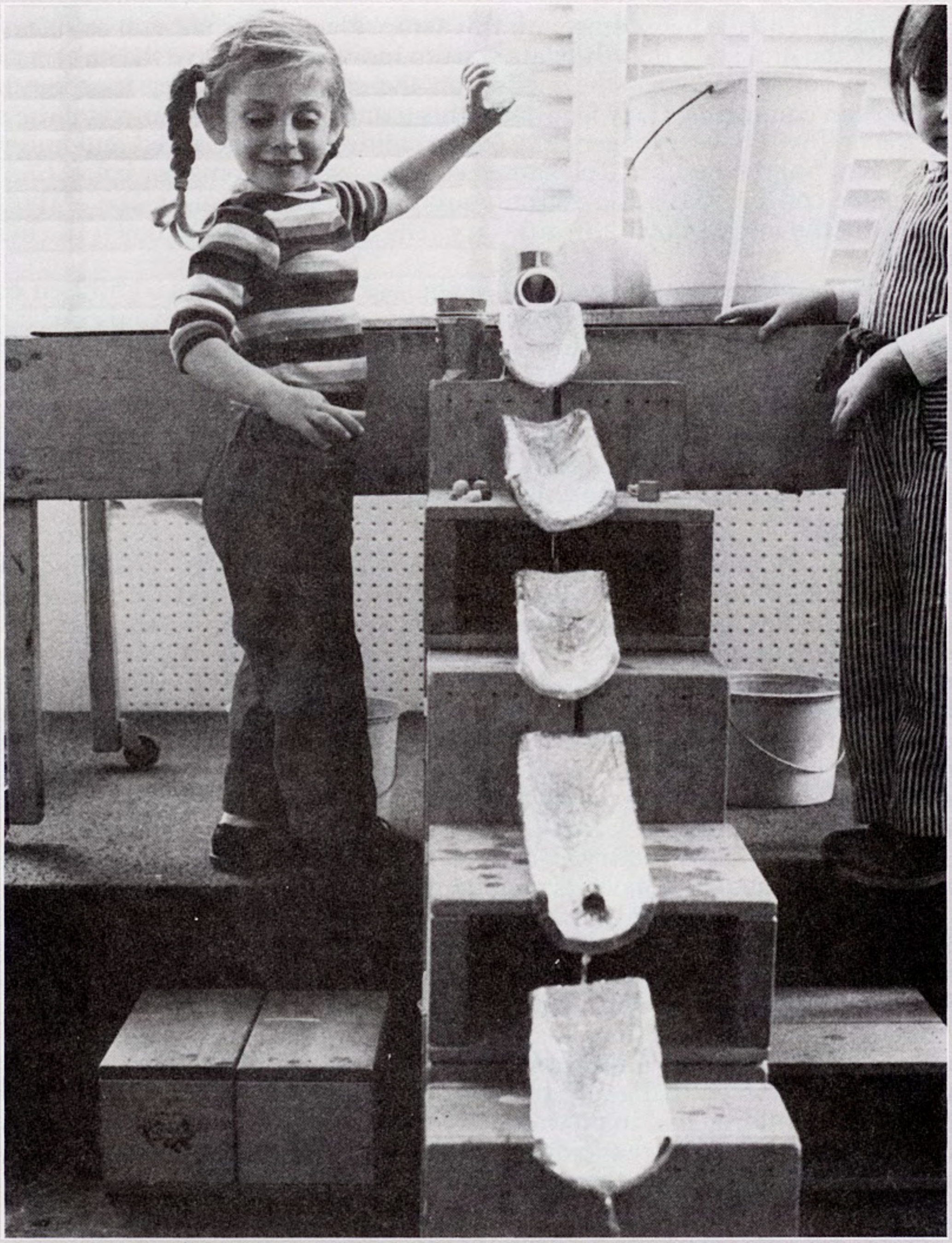


PHOTO 4.17 Jessica pours water down the Cascading Water in order to wash a bead down the tiers. A bucket is out of the picture at the bottom.

with water and because this setup gives them control over many different types of effects, the children enjoy the Cascading Water immensely.

Younger Children

The younger children like to watch the effect made by pouring water down the cascade. They put their hand under the lip of one of the troughs and let the water run over it. On one occasion we had put the Water Pencil at the head of the cascade, trickling water continuously down the tiered troughs. Debby, a student teacher, added a teaspoon of blue paint powder to the top trough. The powder colored a segment of the water, which then snaked down the troughs. The effect was quite spectacular. The clear water took on life and motion that was not visible before. The younger children showed the most interest in adding the paint. Matthew would put a bit of powder in the water stream and gaze in rapt concentration as the blue trickled down each silver trough and then disappeared.

Older Children

The older children invent games using solid objects such as beads. One day, Nauman places a bead at the foot of each of the five troughs while the water is not flowing. He shouts "Ready, set, go!" and washes all of the beads down with a dump of water at the head of the cascade. If any beads pile up at one of the troughs, he dumps a glass of water directly on the bottleneck and says "Down you go."

Jessica and Tristan play a similar game. Jessica, in Photo 4.17, dumps water at the head of the cascade to wash a single bead down. Each time the bead begins to fall over the bottom edge of a trough, she says "Vrooom." As the bead drops off the last trough into the bucket, Tristan says "Splash." They repeat this game for some minutes, giving four "vroooms" and a "splash" at the appropriate points in time. We felt that Jessica and Tristan were punctuating the motion of the bead with these noises; that is, they were breaking a continuous motion into punctuated points of discontinuity.

We never, as much as we wanted to, had an outdoor version of the Cascading Water. Outdoors, we could have had more troughs, branching right and left, stopping here and there. We could also have constructed the troughs so that they swiveled, sending water to a left trough or a right branch below. Such an outdoor version could give children more variables to explore—and less concern about spilled water.

Variation—The Snake Shoot

We did use the cardboard troughs in other ways to unitize motion. In Photo 4.18 Chris has just released a ball down the Snake Shoot. One end is attached to the

PHOTO 4.18 Chris releases a tennis ball down the Snake Shoot.

railing of the loft, the other to a low table. The Snake Shoot is a series of split cardboard tubes wired together end to end. The front end of each trough is wired on top of the back end of each preceding one. This long trough can be attached in many different parts of the room. We used it in the loft, in the block area, and outside. The ball makes discontinuous bumps as it rolls down the entire length of the Snake Shoot. We did not solve the problem of how to give the children more control over the intervals between each section. Perhaps you could.

JUMPING PEAK TO PEAK

On the outdoor playground we arranged a row of step-blocks. The row alternated high, low, high, low for a distance of about 15 blocks. The children could either step on the top of each successive block or jump from "peak to peak."

We noticed that Marc began this latter strategy by jumping and making a long pause before his next jump. After some practice he was better able to anticipate each successive jump. He jumped from one block and landed on another in such a way that his transfer of weight made it easier to jump immediately to a third block. That is, Marc seemed to be thinking about his next jump at the same time that he was making his landing. This made his movement more continuous in spite of the discontinuity of the gaps between the peaks. At the level of sensorimotor schemes Marc was having an encounter with unitizing motion.

IMAGINING MOTION

In the previous two categories of transforming motion, the children could see the entire motion. Even in the activities concerned with unitizing motion, the children could see the continuous motion of the object. In the activities that follow, the motion of the object itself is discontinuous; that is, the children cannot see its entire path. The children encounter gaps in motion that they are asked to fill. They do this by imagining the segment of motion that they did not see.

These types of encounters occur many times during an average day. Seth accidentally drops a wallet-size photograph behind the bulletin board hanging on the wall. It does not fall out. He curls his fingers under the bottom of the bulletin board directly in a line below where the photo disappeared at the top. He assumes, correctly in this case, that the motion continued in a vertical and downward path, even though he did not see the motion.

Katie runs in the back entrance of the climber. Nauman, standing on the other side of the room, sees her enter. He runs to the front entrance of the climber and waits. When Katie emerges, he yells "Boo" in a mock ambush. Nauman assumes, perhaps with more certainty than was merited in this case, that Katie will continue to move in a line and out the front entrance. These were both invisible displacements, and the children imagined the path of the motion that they did not actually see.

Many of these encounters occur spontaneously without special preparation of the environment. Others—the ones that we will describe in this section—occur because some activity is planned. Sometimes these activities require that the child reconstruct a motion recently completed, such as the example of Seth's trying to find the photo behind the bulletin board. At other times the child is asked to predict the path of a motion that has not yet happened, such as trying to predict where a marble will emerge from a maze. The Confusion Box is such a marble maze.

THE CONFUSION BOX

Preparing the Environment

Clara, one of our teachers, cut holes and slits in a cracker box, as you see in Figure 4.6. With the box lid closed, the children would drop a marble into the hole in the top. The marble would hit a cardboard partition inside and roll down it. Clara

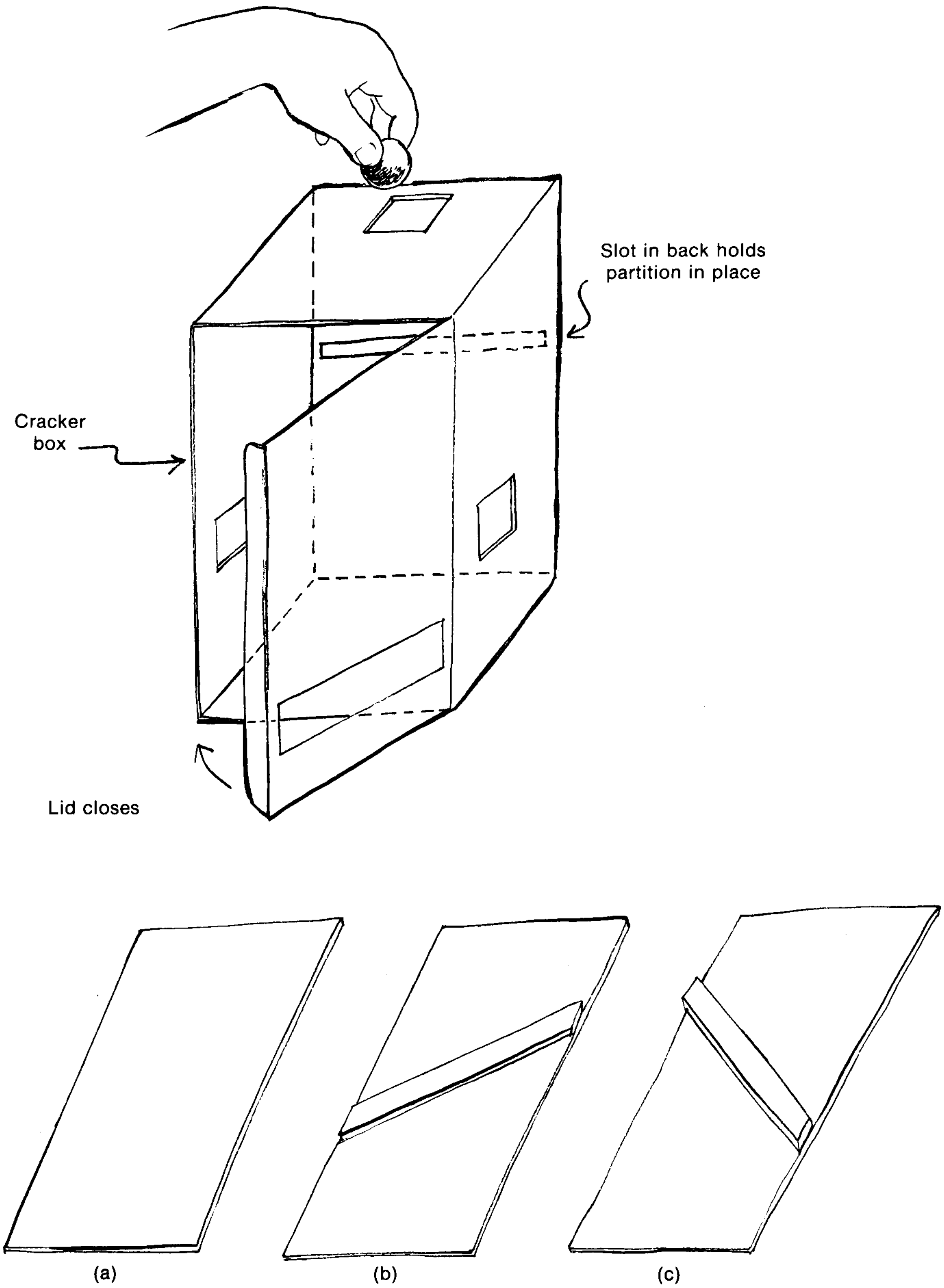


FIGURE 4.6 The Confusion Box.

had made three of these partitions, which could be exchanged. Their structure determined where the marble would come out. The plain partition caused the marble to come out the front slit. The other partitions, with raised, slanting runners, made the marble come out the holes in the sides of the box.

Entry

Clara drops the marble down the top hole, and it flies out the left side. David and Hattie see her do it and want to try. In Photo 4.19 Hattie has just released the marble through the top hole, and David has his hand ready to catch the marble on the side. (This was the hole where the marble had rolled out when Clara first modeled the game.) Both children know some aspects of the game already, but neither has had to make a prediction based on the structure of the partition inside the box.

PHOTO 4.19 Hattie drops a marble down the hole in the Confusion Box. David catches it as Clara watches.

Clara then opens the "front door" (lid) of the Confusion Box so that David and Hattie can see the partition. Clara lifts this partition out and inserts another one, which will make the marble roll out the hole in the opposite side of the box. Clara says "Look at this. I'm going to put this piece in the box. Can you figure out where the marble will go the next time we drop it down the hole?" David and Hattie look into the box, and then Clara slowly closes the door to the box. David, without saying anything, changes his position so that he can cup his hand under the hole in the opposite side of the box. Without any difficulty he has figured out where the marble will come out. Hattie drops the marble, and David's expectation is confirmed. He catches the marble, and then with one hand he drops it himself through the top hole while he cups his other hand under the exit hole.

Both the older and younger children enjoyed this little game. The younger children were not able to predict where the marble would roll out. But they did enjoy making it disappear into the box and reappear. The teachers sometimes played the game with the door open for these younger children. The older children were amazingly adept at predicting where the marble would reappear. Even when the teacher rotated the entire box just after shutting the door, they could still predict where the marble would come out.

Variations of this game can be made with tubes inside the box. With tubes the children can try to predict which color marble will come out first. This is a game of reconstructing the order. If the exit hole has a stop gate, the teacher can delay the marbles long enough for the child to recall, out loud, which color will come out first. The tubes ensure that the marbles don't get bumped out of sequence. So often the child will say that the color most recently inserted in the top hole will be the first to reappear. Note that this game should be embedded in a more naturalistic context. Perhaps the tube version could be set up as a tunnel on a miniature train track, and the marbles could be exchanged for train cars of three different colors. We leave it to your creativity to adapt these encounters with invisible motion and invisible changes to the setting of your school.

THE SHELL GAME

Preparing the Environment

This game goes back many centuries—but not, perhaps, using tennis balls and berry cartons, as we described it in Chapter One. Only a few specialized items are necessary: a small table with a hole cut directly in the center, three berry cartons, a tennis ball, and a supple pillow. Place the pillow on the floor, under the hole, before the children arrive. The child's objective is to find the tennis ball. As the child watches, the teacher covers the tennis ball with one of the cartons and then moves the cartons around. The child watches closely and makes a guess when the teacher stops moving the cartons.

Entry

Children love to find hidden objects, so the Shell Game is a natural. Finding the ball on one guess becomes their incentive to search for it again the next time. For younger children, keep the movements simple. Move one carton at a time. Let the child find the ball under a carton a few times before you pass the covered ball over the hole in the center of the table. Once you do let the ball drop, you will probably notice that the younger children look under all three berry cartons before they look under the table. The older children will understand the meaning of the hole. Once the carton that covers the tennis ball passes directly over the hole, the older child will stop looking at the movements of the cartons and will look under the table for the ball.

There is no need to conceal the hole to make this game a challenge. The hole should be clearly visible. The problem for the younger children is not their failure to *attend* to the hole; it is their failure to *understand* the hole. Be sure to mix your moves. Do not end a series of moves with the ball always under, say, the carton on the right. This would give the child a very simple way to find the ball. For older children, moving two cartons at once in opposite directions increases the challenge and interest of the game. Or the table can have several holes, all of which open into deep cloth sacks, like pool-table pockets. Any number of variations can be made to increase the challenge and interest of the game.

It is also possible that two children will pair off and play this game between them. Their method of reconstructing the rules reveals just what they understand about the order and timing of the component parts of the game. We noticed that one of our younger children would move the cartons around and then—quickly, before his playmate had a chance—grab and lift the carton hiding the tennis ball. The older children better understood the two different roles of presenter and guesser.

THE SEE-THRU NOK-OUT BENCH

Preparing the Environment

For this activity we modified a commercially available toy, the Nok-Out Bench by Playskool. This toy is a small, wooden cobbler's bench with a toy hammer. The child drives 2-inch wooden pegs into a hole in the top of the bench. The pegs go into a channel inside the bench that curves to the horizontal so that, after five pegs have been driven into the hole, one peg pops out the side of the bench. In the commercial version the children cannot see the channel inside the bench. In Figure 4.7 you can see that we have modified the Nok-Out Bench by removing the side panel of wood and replacing it with a sheet of Plexiglas. Clear acetate will do as well.

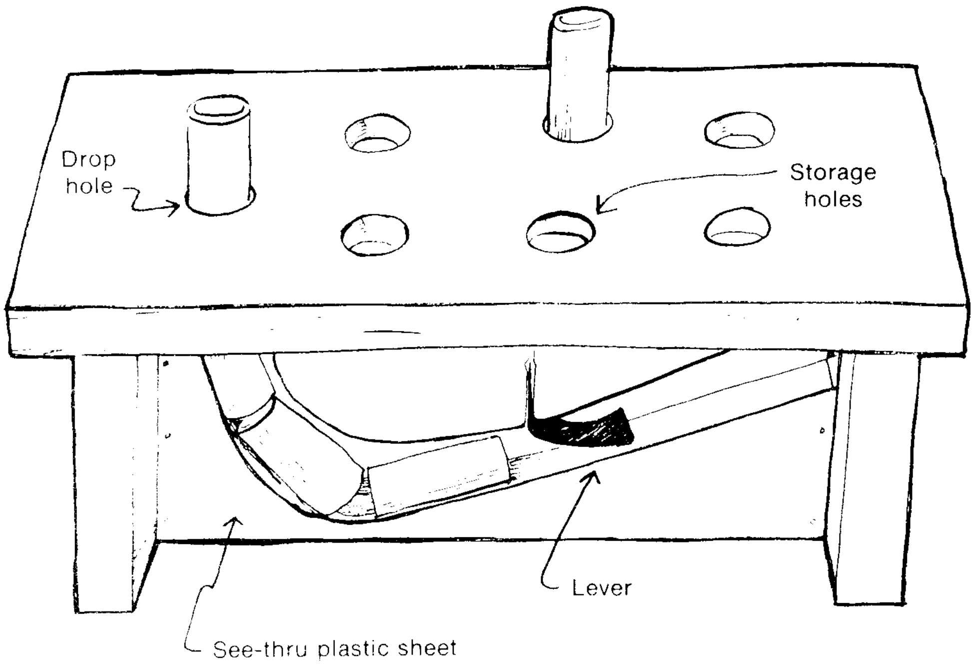


FIGURE 4.7 The See-Thru Nok-Out Bench.

There are six recessed holes on the top of the cobbler's bench. These holes were designed as storage receptacles, so that the child could have pegs easily accessible. It was amazing how many children intently hammered a peg in one of these recesses, thinking that the peg would go through.

Entry

The teacher had available one of the Nok-Out Benches with the plastic side panel and another one without this modification. We found that even with the plastic side panel children would not think to bend down and look at the channel. To increase the probability that the children would see the side of the bench, the teacher had placed a long mirror on the platform where the children were banging away.

Younger Children

Amy puts a peg into the hole, hits it, and, because the channel is already full, a peg shoots out the side of the bench. She takes that peg, places it in one of the recesses, and begins to hammer it. She hammers a bit and looks out to the side, where the peg shot out a few seconds before. The teacher asks "Will it come out?" Amy nods her head and continues to hammer. "Where will it come out?" the teacher asks. "Down there," Amy says, pointing to the floor beside the bench. She continues her futile hammering on the peg in the recessed hole. "Is it working?" the teacher asks. Amy nods and says "It's going down, a little." It is interesting how young children will assimilate the physical facts to their own desires (not unlike adults, we might add).

Marya hammers a peg through the real hole. It displaces a peg into a metal dish that the teacher has placed at the side.

"How did the peg get into the dish?" the teacher asks.

"It jumped off the top," Marya answers.

Marya evidently thought that the peg that had emptied into the dish was the same one that she had been hammering. If she held this belief constant, then her answer was, in a sense, logical. She did not, of course, see the peg jump off the top, but that is the only "logical" way she could account for the invisible motion of one and the same peg. Here we see a beautiful example of how young children use inference to cope with invisible motion.

Older Children

Hattie has been hammering pegs in and watching them come out the side. She studies the channel through the Plexiglas panel. She seems delighted that a peg of one color hammered in causes a peg of another color to come out. She then points to the metal lever inside the channel: "See this? This keeps the pegs from falling out."

Somehow, Hattie knew that without this metal lever the weight of the pegs in the vertical portion of the channel would force out those pegs in the horizontal portion. She was truly seeing the pegs lined up in the channel as a system of potential movements—not, more simply, a static line of objects.

David has already hammered pegs through the channel several times, watching their displacement through the Plexiglas panel. Then he does a most inventive thing. He lines up five pegs, end to end, on the carpet of the platform riser where he is working. He takes the hammer, hits the left end of the line and watches the pegs separate!

David perhaps thought that he could duplicate the action of the pegs inside the cobbler's bench. But because he had no resistance on the last peg, analogous to the metal clip in the bench, his pegs separated uniformly. Nevertheless, David's attempt to reconstruct these effects on his own, outside the bench, bore witness to a remarkable attitude. David felt that he could more clearly understand the effects of this chain reaction if he constructed the setup himself. His attitude was not unlike that of the scientist trying to understand nature by simulating it.

Once the children had had sufficient experience with the see-through version of the cobbler's bench, the teacher asked them to consider what was happening inside the bench with the opaque panel. The questions varied from "Where is the peg now?" to "What color will come out next?" The one drawback of this particular toy was the fact that the shape and direction of the channel could not be changed. We have since constructed variations on the Nok-Out Bench in which the pegs go into flexible tubing. The children and the teacher can rearrange and redirect the tubing so that the game of guessing where a peg will come out is more challenging.

Many other variations are possible. We used cardboard tubes, marble rollways, and covered mazes to engage the children in encounters with invisible motion. They had to imagine the path of an object by studying the structure of boundaries and barriers. These games were fun for the children, and we felt that they gave them good experience in imagining motion that was not visible. Our greatest pleasure came during those moments when several children played these games independently in small groups.

LEARNING ENCOUNTERS FOR THE HOME

Certain items and situations more common to the home environment serve well the purposes of this chapter. In fact, the example of tricycles driving through water puddles as a means to freeze the motion of the tricycle is a frequent occurrence at home when Mom or Dad is washing the car on the concrete driveway. It takes just a moment to make a comment such as "I can see where you have driven your tricycle," just after the child passes through the puddle. And children are universally intrigued with making an etching in the dirt along the path that they walk. It takes only a prepared mind for a parent to say, "We can find our way home by following the marks in the dirt." These are instances of freezing motion and are embedded in the everyday experience of the child.

Home versions of the activities mentioned for the classroom setting can also be easily made. It is a simple matter to screw a lazy Susan to a three-foot-diameter wooden, circular board so that the child can experiment with the paths that crayons make when the board is papered and spun around. Even a version of the Drawing Driver can be made if you have a suitable sidewalk or driveway. Chalk can be securely fastened to wheeled toys so that they leave chalk traces of their movements here and yonder. The sidewalk soon becomes a record of traffic congestion or traffic flow and affords many opportunities for young children to read implications from these representations of past actions.

Moving shadows can be traced in the same way that we used the rear projection on papered plexiglas. Nail a large piece of homosote to a wooden frame (indoors) or a garage wall (outdoors). This provides a convenient surface to tack paper to so that your child can draw the action of shadows on it. A light passed through a fishbowl with fish makes interesting moving shadows on the paper. The child can have a great deal of fun trying to keep his or her marker on the shadow of the fish and then looking at the directions of this mark after the light is extinguished. A hanging mobile can also make interesting moving shadows and provides welcome relief to the fish. Anything that has an interesting, somewhat regular movement with moderate speed can be tracked by the child. However, tracking a shadow made by an object placed between the child's hand and the light source will make the encounter more difficult than the rear projection technique because the child will have to discount the shadow of his or her own hand. A plexiglas panel with rear projection is better, as we discussed earlier, but may not be completely necessary for the child who knows how to minimize the interference from his or her own hand. If you have an aquarium with a flat side, the rear projection system can be used by papering the front of the aquarium and shining the light through the rear, thereby casting the shadow of the moving fish on the backside of the translucent paper on which the child draws the motion. Even brief encounters like this can give the child a new appreciation of the shape of the fish's motion, sort of a time study of where the fish spends his time. If the refraction of the water presents a problem in creating a sharp-edged shadow, and empty aquarium with a moth or cricket could be used instead. An inchworm might work for the more patient child.

Home versions of unitizing motion also abound. The stoop in the front or side of the house might be an appropriate site. The child could set up three short troughs, one on each step, each at a slight incline. Then the child could either roll a tennis ball down the stoop in the troughs, as in the Snake Shoot, or flood the top trough with water as in the Cascading Water. Three steps or four steps would probably be enough and would make it easier and safer for the child to repeatedly put things at the top of this unitized incline. The neighborhood sidewalk often provides its own source of speed bumps in the form of expansion cracks or heaves. But these permanent cracks do not allow the child to experiment with the rhythm of the clickity clack of the tricycle wheels. The child cannot rearrange the distances between the cracks. But the child might at least experiment with the change in the beat of this clickity clack as he or she drives a Big Wheel more quickly or more slowly over the sidewalk cracks. A fence with missing pickets also provides another opportunity for the child to predict a rhythm when a stick is dragged along the fence on a walk. And we have all seen the joy on a young child's face when peddling a bicycle with a cardboard flap slapping repeatedly on the spokes of the wheel.

Dominoes aligned in a row, as we have already mentioned, give the child many interesting minutes of playing with unitized motion. The advantage of doing this at home rests on the somewhat greater chance of protecting the child's work from one day to the next. A child intent on making a long row to knock over can take time to do this if the space is reserved from one day to the next. But for the three- or four-year-old such long range plans are not so common. For the younger child a parent might want to attach a set of dominoes to a cloth ribbon in a manner similar to what we did in the classroom. This reduces the decisions the child has to make, yet still gives the child an opportunity to experiment with the chain reaction effect. Just staple each domino on its end to a common ribbon about an inch and a half apart. The child can still make straight and curved rows by standing up the dominoes on end. If dominoes are too small and require too much dexterity, use larger blocks with the same proportions as a domino.

An advanced game can be played in the backyard or playground with a little demonstration from the parent. The game needs to be motivated by some fantasy play, like "Don't let the alligators bite." The objective is to get from one side of the yard to the other without stepping on the grass. All the child has is two small pieces of carpet or cardboard. The child learns to place one carpet in front, step to it, turn around to lift the piece recently left, and place that piece in front. The game involves a great deal of forethought about how far to place the pieces and how each piece has the dual role of being now a place to go and now a place behind. This is truly a thinking game that leads the child to encounter concepts of unitizing motion and dealing with two purposes within one object.

SUMMARY: REPRESENTING MOTION

The overall objective of these activities was to stage encounters for the children with the shape and rhythm of motion. Our activities in this chapter involved freezing motion with a continuous trace, freezing motion with a discontinuous trace, punctuating continuous motion with bumps and pauses, and having the children imagine the motion of an object that they did not see. If a child can figure out the shape of a motion, she can often understand how an event happened. Our success for these objectives was mixed.

The younger children did not seem to grasp the correspondence between the trace of a motion and the motion of the object. For example, in the Swinging Sand the younger children were interested in how fast the sand drained from the bottle but not in how the swinging bottle could be pushed in different ways to create different effects. The older children did vary their own actions to create different patterns of sand traces, but they did not look at the sand and retrospectively figure out how the bottle had moved.

We had a little more success in the play dough. The children could look at a track in the layer of dough and figure out at least what object had made the track. But this is not the same as figuring out what particular type of movement made the track. A few of our older children, however, were able to look at a track that the teacher had made and then duplicate that track themselves. At the level of sensorimotor schemes, these children could understand the correspondence between a frozen motion and the means by which that frozen motion was produced.

In the activities involving discontinuous traces—unitized motion—the children showed varying levels of understanding. The Blip Spool was perhaps our most successful activity. The children called the spots of paint "foot marks" and would walk beside the incline, tracing with an extended finger the path that the Blip Spool had taken. The children did understand that the discontinuous paint spots were the remains of a continuous motion. The homemade version of the pizza cutter also worked quite well. The children could change the spacing of the sprockets and explore the change in the effects as they rolled the wheels across the play dough. We consider this an ideal material, because the children can make changes within an object rather than exchanging that object for a different one.

The invisible-motion activities caused the children to imagine those segments of motion that they did not see. The Confusion Box and Nok-Out Bench are good examples of small-scale games. We also had large-scale games outside, such as tunnels and sheets used to hide the movements of one child while a nearby child watched. Both types of encounter have their advantages. The small-scale encounters give the child faster and more direct control over the transformations. The large-scale encounters give the activity more interest and more personal relevance to the everyday world of getting around or—perhaps we should say—of figuring out how others have gotten around.

For the younger children we did not have too much success in staging encounters with predicting a motion before it occurred. For example, they could not look at the slats in the Confusion Box and figure out where the marble would come out. But in other ways the children were quite adept at predicting a motion, particularly if it was a continuation of something already in progress. For example, the 2- and 3-year-olds could anticipate whether a ball was on its way toward knocking over something. That portion of the trajectory from the ball to the target had not yet happened, but the younger children could imagine that portion. However, this is an encounter with a point-to-point contact and does not clearly involve the *shape* of a motion. The child could accurately predict whether a ball was about to hit a target simply by confusing line of sight with line of action. Give this child a curved path, and he would have more difficulty.

Now let us review some of the differences between the older and younger children. We do this just to help you maintain a developmental perspective on learning encounters. The strategies used by the younger children are, we think, necessary precursors to the more advanced strategies used by the older children. We ask that you protect the younger child's space and time so that these precursors can run their natural course.

DEVELOPMENTAL TRENDS

TWO WITHIN ONE

Cases where one object is both a whole and several parts:

> The younger children would try to gouge the rolled-out play dough with the Tinker Toy pizza cutter. The older children would roll it lightly to make tiny holes. This seems to represent a general tendency for the younger children to think about objects as *solid wholes,* whereas the older children can think about objects as *a system of movable parts.*

Cases where one object has two actions simultaneously:

> The younger children could perform one or another action but not two actions at once. They would, in the Spinning Sand and the Rotating Easels, move their brush *or* spin the laxy Susan, but they had great difficulty doing both. The older children had more or less difficulty depending on the nature of the two actions involved—for example, their similarity, location, and so on.

Cases where two (or more) discontinuous actions create one continuous action:

Of course, all of our games that involved unitizing motion could potentially place the child in an encounter with the continuity of one action across the discontinuity of several component actions. The Slatted Rollway, Domino Row, and Blip Spool are all good examples. We will cite one observation from the activity Jumping Peak to Peak. Younger children would jump from the first peak to the second and then pause for a few seconds to get new footing before jumping ahead to the third peak. The more advanced children could land on the second peak in such a way that they were at the same time prepared for the departure to the third peak. The two discontinuous actions of landing and departing were smoothly integrated into one continuous action.

DECENTERING FROM AN EGOCENTRIC PERSPECTIVE

Cases where the child centers on proximal versus distal effects:

With the Drawing Driver the younger children wanted to have direct contact with the felt-tip pen. The older children enjoyed making the pen move from afar by steering the cardboard drum at the center.

Cases where one point has two references in space simultaneously:

With the Drawing Driver the younger children would sometimes forget that their own body was in the way of the rotation of the wooden dowel. They could consider the relation between the dowel and the pen, but they forgot the relation between the dowel and their own body.

Cases where the body itself represents the event:

Our children, in various contexts, did things to "concretize" an event. Amy poked the tip of her Water Pencil into the sand to make holes just like the holes the water drips were making. Hattie connected the separate circles on the Plexiglas easel that she had made by brushing a single stroke of paint across the top of the stencil a few moments before. Perhaps she was "concretizing" that single stroke, now represented in the connected circles. Katie smashed her pen to the drawing surface as she saw the feather falling. She "concretized" the witnessed action of the feather by making her pen the physical embodiment of the feather. David lined up a row of pegs to reconstruct the chain reaction he had witnessed inside the See-Thru Nok-Out Bench. All of these examples seem to be the child's attempt to understand an event by reconstructing it in a more concrete form. The younger children such as Amy and Katie do this very directly, using the same object in two ways—first as a means to represent an action (marks with the pen and the Water Pencil) and then as the physical subject of the action itself (crashing the pen and poking with the Water Pencil). The older children do this in more indirect ways, such as David's using a line of objects to reconstruct the chain reaction outside the Nok-Out Bench.

Cases where the child centers on the teacher's body rather than on the object the teacher is manipulating:

Clayton seemed to imitate the action of Lisa's hand, rather than the action of the feather, during Kinetic Drawing. Making a correspondence between his hand and Lisa's hand is somewhat more egocentric than making a correspondence between his ink mark and the action of the feather. However, he did do the latter on several occasions.

SEEING THE DYNAMIC WITHIN THE STATIC

Cases where action is constrained by static structure:

> The younger children could anticipate where a moving object would go if they had seen that same action some moments before. For example, the children could predict where the Drawing Driver, Swinging Sand, and Tire-Tracking Trikes would go, based on recent experience with these objects. The older children could look at the static structure of a channel or path, as in the Confusion Box, and figure out in advance where a ball rolling down this path would end its journey. However, even the younger children, when given the opportunity to change the boundaries and barriers, showed a sensorimotor understanding of motions that had not yet occurred. Their skill, of course, depended on the complexity of the boundaries. They were much better in predicting all-or-none barriers than more subtle deflections and channelizations of motion.

FROM OPPOSITE EXTREMES TO MIDDLE DEGREES

Cases where the child has difficulty constructing the middle term:

> At times, children did not seem to be able to construct the middle condition, even when they seemed to desire it. Tristan had great difficulty making the thumb screw on the Water Pencil stop midway between fully open and fully shut. He also had difficulty making the marble roll just partway to the end of the rollway. But he could tell a friend to move the Drawing Driver "a little more in." It takes time for children to construct the notion of a continuum between two extremes, as we mentioned in Chapter One.
>
> With the Slatted Rollway the children wanted to keep the hole at the bottom of the incline. They resisted attempts to have the hole in the middle. It seems, in many contexts, that children prefer the "terminal condition." This preference may be due, in part, to the difficulty of constructing the middle term. This tendency varies with age. As children grow older, they probably see the middle condition as interesting *because* it is not at the terminal condition.

Cases where the child does not consider how one action could lead to an opposite effect:

> With the Swinging Sand the younger children wanted to cover stencils with sand. The older children understood that covering the stencils was a means to making a negative space, the hole in the sand after the stencil was removed. The negative space, of course, is opposite to the filled space. The older children were able to think about the absence of the stencil even when it was present; the younger children could not. These encounters with constructing opposites prepare the way for thinking about the variations between opposites (see Chapter One).

We have greatly generalized from a few observations. But our familiarity with the research literature (see CCK, Chapter Four) makes us believe that these observations are consonant with general principles of cognitive development. Therefore, we feel comfortable that teachers might use these summary statements to guide their own observations of children. When a teacher has a few anchor points, such as these summary statements, it becomes easier to interpret the developmental significance of a child's free play. And the ability to see the significance of a child's free play helps the teacher to facilitate free play.