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Push, Pull, Toss, Tilt, Swing: Physics for Young Children

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Allisha and Matthew are in the science area of their kindergarten room rolling balls down ramps that they constructed from cardboard tubes, a few blocks and some tape. Their explorations are punctuated by squeals of delight and brief discussions regarding their next plan of action. Other children parallel play with the same materials.

Ms. Cook, their teacher, circulates around the classroom, observing and pausing periodically to interact with the children. During large group time, Ms. Cook asks questions that encourage the children to reflect upon their activities. In addition, she introduces the word "ramp." During recess she initiates a discussion comparing the playground slide to their ramps. Allisha suggests rolling a ball down the slide. Other children begin to look for different examples of ramps. Later, Ms. Cook reads a book about ramps and encourages the children to bring examples or pictures of ramps to school.

The following day, Matthew brings in a picture of a parking ramp. He and other children build a circular ramp with cardboard tubes. Then they roll balls and cars down the circular ramp. The children's interest in parking ramps prompts Ms. Cook to plan a field trip so the children can observe a real parking ramp in use. Following the field work, the children continue their classroom explorations with renewed interest.

This scenario illustrates developmentally appropriate physics activities for young children. This article addresses ways teachers can use the environment to teach physics and answer the questions: "What is the value of physics for young children?," "What are criteria for developmentally appropriate physics activities?," "How does one integrate physics into a project or unit topic?" and "What is the teacher's role?"

The Value of Physics for the Young Child

Physics is the science of matter and energy and interactions between the two (Chaille & Britain, 1991). Young children's physics experiences usually involve the movement of objects, wherein action is primary and observation is secondary (Chaille & Britain, 1991; Kamii & Lee-Katz, 1982). According to Piaget's theory of cognitive development, children learn about physical properties in their environment "by *acting* on objects materially and mentally, and observing the objects' reactions" (Kamii & Lee-Katz, 1982, p. 171). Consequently, children learn about physical properties by engaging in physics activities.

While Allisha and Matthew cannot define physics, they can begin to make discoveries about matter and energy. Activities with balls and ramps offer children experiences with their physical world upon which they can later build more abstract physics knowledge (Woodard & Davitt, 1987). In a broader sense, the activities enhance the mental, social, emotional and physical development of the whole child. Furthermore, physics activities have the pragmatic benefit of capturing and holding children's attention because they involve manipulation, movement and action.

Physics activities stimulate children's inquiry and problem-solving skills. Through manipulation, children learn how their movements affect the movement of other objects in different ways (Woodard & Davitt, 1987). Kamii and DeVries (1993) remind us that "space and time are not mere 'containers' for objects and events. They are frameworks constructed by each subject as he tries to make sense out of changes in objects and events by putting them into spatiotemporal relationships" (p. 23). As children engage in physics activities, they observe movements and coordinate spatial relationships from their observations. According to Piaget (1977), children's logico-knowledge develops as they construct relationships among objects.

Chaille and Britain (1991) noted similarities between how children think and learn and how scientists work. Children, like scientists, are theory builders. When children are allowed to construct knowledge by acting on their environment, they expand their understanding, which in turn contributes to their intellectual development.

In addition, physics activities provide opportunities for social and emotional development. Cooperation and collaboration with other students allow children to verbalize their ideas and validate their emerging concepts. Cooperative groups (Johnson, Johnson & Holubec, 1990) enable students to view situations and problems from perspectives other than their own. Furthermore, emotional development can be strengthened by participation in physics activities. When given the opportunity to solve problems on their own, children develop initiative and gain confidence in their ability to figure things out for themselves. Their growing self-confidence facilitates autonomy and intrinsic motivation.

Children also develop physically as they manipulate materials in, around and through places. When Allisha and Matthew play with ramps and balls, they use large and small muscles to place the ball on the ramp, add a block to change the height of the ramp and run to retrieve the ball at the end of its path.

Kamii and DeVries believe that the value of physical science for young children "is not to teach scientific concepts, principles, or explanations. It is, rather, to provide opportunities for the child to act on objects and see how objects react—to build the foundation for physics and chemistry" (1993, p. 12). Allisha's and Matthew's ramp and ball explorations are valuable because they provide opportunities for developmentally appropriate intellectual, emotional, social and physical growth. Experimentation and active participation in their environment encouraged intellectual development. Ms. Cook further encouraged such development by providing the children with opportunities to reflect on their explorations and connect them to everyday life. The children's social and emotional development was refined through collaboration and cooperation. Concomitantly, their physical development was enhanced as they manipulated the balls and ramps. While the ball and ramp activity did not specifically address the content of physics, Allisha and Matthew were engaged in a rich foundation of experiences upon which more formal science knowledge could later be constructed.

Criteria for Physics Activities

In order to enhance the mental, emotional, physical and social development of young children, physics activities must build on their natural curiosity and desire to make sense of their surroundings. The activities must be easy to manipulate, and consist of an action and an immediate reaction. In addition to these criteria, an educator planning physics activities should understand how children learn about the movement of objects.

Physics activities for young children that have immediate action and reaction include rolling, pushing, blowing, tilting, throwing, balancing, dropping, sliding, projecting and swinging objects such as balls, cubes, beanbags, tubing, dowels, pulleys, hooks, blocks, planks, boxes and containers of all shapes and sizes. These objects may be manipulated down ramps, through the air, on water and over rough and smooth surfaces. Each of these activities meets the following criteria suggested for appropriate physics activities for young children (Kamii and DeVries, 1993):

1. Children must be able to produce the movement by their own action. Whereas rolling a ball is direct action activity, moving a nail with a magnet would not be considered a direct action because the magnetic attraction is primarily responsible for the nail's movement.

2. Children must be able to vary their action. Children playing pool may be able to adjust their action accordingly, but a pinball-type game allows very little variation. Woodard and Davitt (1987) believe that capacity for varying actions is necessary because children at different developmental levels would be better accommodated.

3. The reaction of the object must be observable. Unless children can observe the reaction, they will have no way of knowing what effect an action has on an object. Therefore, it is not developmentally appropriate to use reactions such as gravity or magnetism.

4. The reaction of the object must be immediate. If a long time elapses between the action and reaction, the child may not establish a relationship between the two. Children can raise and lower an object with a rope pulley, for example, with immediate results. Observing the weights of a cuckoo clock, however, would not be appropriate because the reaction is much slower and is not produced by the children's actions.

When planning physics activities it is important to consider the progression of how children begin to understand their action on objects. Chaille and Britain (1991) suggest that the first step is to design activities that allow children to move an object, such as Allisha and Matthew rolling the ball down the ramp. The next step is to develop activities that allow the object's movement to be directed. During this step, Allisha and Matthew aimed the ramp and ball at blocks placed on the floor. In the final step, the connection between the object's movement and the child's action should be found. The representation of the object's movement is important. Allisha and Matthew might learn where to place the blocks, ramp and/or ball in order to knock the blocks over. These categories are helpful to keep

Physics activities stimulate children's inquiry and problem-solving skills.

in mind when designing movement activities, but can, of course, be modified.

Forman and Kuschner (1984) added another dimension in the movement of objects: facilitating transformational thinking, or the process by which an object moves from point A to point B. Transformational activities emphasize ways to represent motion in order to help children focus on the path traveled. When Allisha and Matthew rolled the ball down the ramp they observed it at point A, the beginning point of the ball, and at point B, the ending point of the ball. To represent more clearly the ball's path, Allisha and Matthew could first roll the ball in paint; the paint marks would represent the ball's movement. Such a representation will focus the children's attention on the ball's path, including the beginning and ending points. Children could then create a mental image and therefore help achieve Chaille and Britain's (1991) third level of understanding: how action affected the reaction of the object.

To summarize, physics activities should produce observable, variable action, and an immediate, observable reaction. Although commercial items such as Hula-Hoops™, bowling and basketball sets, water wheels, marble games, pendulums and ring toss are appropriate for physics activities, creating materials is often the best approach. Boxes, containers, cardboard tubes and other items are readily available, inexpensive and make wonderful materials for children's exploration activities. Extra materials should be available so that children can test their ideas. Furthermore, when common, everyday materials are used, children may be motivated to replicate an activity at home.

Physics Integration

Developmentally appropriate physics activities and exploration are imperative for children. The exploration by itself, however, does not always guarantee children will move to a higher level of understanding about a concept. Knowledge is a result of mental activity that varies according to level of development. What goes on in children's heads is more important than what they do with their hands (Chaille & Britain, 1991). In order to give children an opportunity to expand their understanding and make meaningful connections, physics activities should be part of a larger project (Katz & Chard, 1989) or topic, which can be initiated by either the teacher or the children and should be carried out collaboratively.

The teacher may initially create interest in a project by introducing activities that show "how things move." Ms. Cook's classroom included the ramp and ball activities as well as other materials that children could push, pull, balance, slide, project or swing. "Debriefing" time (Wassermann, 1988, p. 232) after play allows children to explain a discovery or observation to the class. Debriefing may mean recording all the ideas on chart paper during a class discussion, or asking each child to write or draw his or her exploration reflections and share them with the class.

Through these class discussion or individual narratives, the teacher can assess the children's knowledge, experiences, interests and misconceptions. Ms. Cook may discover that Allisha and Matthew have had numerous prior experiences with ramps and balls and now need to be challenged with new materials and activities. Ideas discussed during debriefing may lead to expanded investigations with the same or new materials, or may take the project in a totally new direction. Questions that may evolve from a discussion on movement are: "How do our bodies move?," "How do animals move?," "How do cars, trucks, planes or boats move?," "How do toys move?" or "How do things appear to move without anyone touching them?" All of these questions include physics concepts and could become a project topic.

In addition to classroom activities, field work (Katz & Chard, 1989) gives children new firsthand experiences and the opportunity to collect resources and record observations. Ms. Cook encouraged Allisha and Matthew to reflect on their classroom explorations during recess. A comparison of the playground slide to the classroom ramp led to an extension of the classroom activities, and helped Allisha and Matthew connect their classroom experiences to the real world. Furthermore, Matthew accepted Ms. Cook's invitation to bring in artifacts and pictures of ramps. His picture of a parking ramp raised the children's interest to a level that warranted a field trip to a real parking ramp. The trip led to further classroom explorations with toy cars and more elaborate ramps made of blocks and boards. The children even added ticket takers, cashiers and "automatic" ticket machines to their parking ramp in the dramatic play center.

As children investigate and explore a physics activity, they will also be developing skills in language arts, mathematics, social studies, science and the fine arts. Mathematics, for example, has a natural connection with physics activities. Allisha and Matthew demonstrate logico-mathematical knowledge when they act on the ramp and ball without actually touching it. For example, they may have an idea of what is going to happen to the ball before it moves down the ramp. They begin to classify the placement of the ramp in relation to how fast and far the ball moves. In addition to such logico-mathematical knowledge, Allisha and Matthew create spatial relationships as they observe and anticipate the movement of the ball on the ramp. They also structure time as they vary the height of the ramp and observe the ball moving faster or slower. Put simply, space and time are constructed as each child tries to make sense out of changes in objects as they move. Logico-mathematical knowledge and spatiotemporal relationships are mental activities that are only possible if children have prior experiences with physical manipulation (Kamii & DeVries, 1993).

Children can create art with physics activities by rolling marbles and spools in paint or swinging pendulums carrying colored sand onto a piece of construction paper dabbed with glue. Blow painting with a straw and squeeze-bottle painting are other options. Mobiles and wood sculptures are other creative art activities that enhance balance and spatial experiences.

Teachers can reinforce physics concepts with children's literature. *Choo Choo: The Runaway Engine* (Burton, 1937) could be used to expand the ball and ramp play into dramatic play with railroad tracks and trains. Would the train go faster if the box cars were full or empty? Set up two ramps to represent the drawbridge that Choo Choo crossed to see if it is possible to jump the gap and land on the other side. Do balls move farther and faster than trains? Why or why not? Other books can be related to physics. In *Mr. Grumpy's Motor Car* (Burningham, 1973), an automobile gets stuck in the mud. The class could discuss how Mr. Grumpy gets his car out and whether a ramp would help. In *The Snowy Day* (Keats, 1962), Peter represents movement by dragging a stick through the snow, leaving a track on the ground. Ask the children questions such as, "What other ways do we leave tracks?" and "What other tracks have you seen?"

After children have investigated a topic, they should share their findings with others. As a culmination of their new experiences and knowledge, Allisha and Matthew could display that knowledge by developing a toy or game with ramps, constructing a model of a parking ramp, making a mural of a playground or writing a book (Katz & Chard, 1989). However they choose to present their newfound knowledge about physics, they will retain that knowledge because it was meaningful. Allisha and Matthew will remember what they learned about ramps because they constructed it themselves.

Similarities exist between how children think and learn and how scientists work.

Role of the Teachers

When teaching physics to young children, a teacher's role is multifaceted. He or she must begin by planning and creating appropriate physics topics, as well as integration activities. Chaille and Britain (1991) elaborated on other roles a teacher must consider when using the classroom environment to teach physics. They described the teacher as a presenter, an observer, a question asker, a problem poser and an environment organizer.

As a presenter, the teacher may introduce a physics topic to the entire class during the large group session and provide exploration activities during play time. Questions such as: "What can you think of to do with these?," "What do you think would happen if . . .?" or "Can you . . .?" help to promote critical thinking and problem solving. Questions should include "you" in order to return the activity to the child who should generate her/his own ideas at her/his own ability level. Kamii and DeVries (1993) emphasize the importance of introducing the activity in a way that maximizes children's own initiative.

Once the physics activities have been introduced and the children are acting on objects, the teacher becomes an observer. This essential role becomes the foundation for everything else the teacher does. Observation provides information about the children's interests, offers clues to understanding their individual needs, serves as a basis for curriculum development and helps the teacher decide when and how to interact with children (Chaille & Britain, 1991).

As a natural extension of observation, teachers should ask children questions about what they are doing and perceiving. The children's explanations may help teachers understand their mental construction. Furthermore, effective questions, if based on a teacher's observation and perceived understanding, can help children maintain interest. Open-ended questions are best because they prompt children to predict outcomes, encourage problem solving, consider feelings and even introduce conflict. Examples of such open-ended questions are:

"What do you think would happen if you made the ramp higher (lower)?"

"How could you make the ball move slower?"

"How do you feel about the ball going off the side of the ramp?" and "What can you do about it?"

"What can you do with this?" (a piece of sandpaper, a toy car or another block)

"What do you think is causing the problem?"

"How else could you do it?"

Questions should be used sparingly and at the right moment so that a child's theory is extended rather than changed. Children must be encouraged to reorganize their ideas into frameworks that will aid in the construction of their knowledge (Gaffin & Tull, 1985). They should not be used solely to assess the teacher's objective.

Note that the open-ended questions focus on *what* is happening or might happen, not *why* something is happening. Young children do not fully understand causality. When they do ask for explanations, however, the answers should be within the realm of their experiences and tied to what they have observed. The child is "not even aware of *how* he produced a particular result and is not able to correctly describe the process involved" (Woodard & Davitt, 1987, p. 24).

Teachers may guide children nonverbally as well as verbally. Kamii and DeVries (1993) gave three examples of what a teacher can *do* rather than *say*: a) help the child with practical problems to facilitate experimentation and observation, b) offer materials to facilitate comparisons and c) model new possibilities. In-class interventions should be used sparingly and only after a need is observed.

Observations and questions by the teacher may reveal children's misconceptions about the science phenomena being investigated. Consequently, teachers get clues as to the nature of the child's construction of theory at the present time. These "wrong" answers should be used in planning questions and experiences that will guide children to construct more "accurate" concepts and responses.

Teachers may introduce conflict and contradiction by asking children, "Do you think a Ping-Pong™ ball or a golf ball will travel faster down Matthew's ramp?" and "Why do you think so?" The resulting argumentative exchanges have value because the children must try to convince each other of their ideas through verbal explanations. Exchanging ideas and listening to another's point of view is the objective, rather than reaching a consensus or discovering the "right answer." Scientists communicate and argue about their theories, and children, as theory builders, need to do the same.

Teachers also need to create a stimulating classroom environment that encourages risk-taking, self-direction and peer interaction. The curriculum and daily schedule must be flexible to allow children to pursue their interests. Children should be able to get their materials, rather than waiting for the teacher to pass them out. Also, the teacher must consider how children will respond to the physical activities in order to eliminate unnecessary intervention. Careful planning will give birth to an environment in which children will develop mentally, physically, socially and emotionally.

Duckworth (1987) maintained that children need opportunities to have "wonderful ideas."

> There are two aspects to providing occasions for wonderful ideas. One is being willing to accept children's ideas. The other is providing a setting that suggests wonderful ideas to children—different ideas to different children—as they are caught up in intellectual problems that are real to them. (p. 7)

Ms. Cook provided opportunities for Allisha and Matthew to have "wonderful ideas," and also helped them integrate and transfer their ideas to other areas of the curriculum and their everyday life.

Physics is a natural framework that enables teachers to provide developmentally appropriate science activities for young children that will help them construct knowledge about their world. Physics explorations in kindergarten and other early education programs will give young children a solid foundation of physical knowledge and a positive attitude toward science, subsequently resulting in greater success in formal science and mathematics.

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