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Teaching with Toys:
Scientific Inquiry through Play

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abstract

Toys are designed to be fun and playful and are highly motivating for both children and adults. Commercial toys and child-designed toys can be used both in the classroom and at home to encourage creativity and to teach science concepts. Much of what children can do with toys involves tinkering, defined by Merriam Webster as “to repair, adjust, or work with something in an unskilled or experimental manner: fiddle.” Children (and adults) can tinker as they take toys apart, experiment with them, and design toys for themselves. This paper is inspired by workshops the authors conducted at the International Toy Research Association (ITRA) conference in Bursa, Turkey, 2011, and the IPA World conference in Istanbul, Turkey, 2014 as well as activities we used in our classes.

In the United States, No Child Left Behind, Race to the Top, and subsequent iterations of school improvement have focused on standardized testing, almost entirely removing play and playfulness from the school day for many American students. In a test-driven culture, play is often viewed as a waste of time. By 2008, the school districts surveyed by the Center on Education Policy (McMurrer, 2008) had cut time for social studies, science, art, music, physical education, recess, or lunch to allow more time for tested subjects, with 53% of the districts cutting at least 75 minutes from science per week. Unfortunately, the decades-long focus on high stakes testing, exacerbated by No Child Left Behind, has been accompanied by a decrease in playful classroom activities typically associated with innovative thinking, social collaboration, and creativity.

An entire generation of students, especially students in poverty, has had little opportunity at school for "playing around" with construction materials and science toys or hands-on experience with science and the arts. The National Science Teachers Association (NSTA) Position Statement on learning science in informal environments (NSTA, 2012) stresses the value of informal experiences provided by family and friends. However, the children who are learning the least science in school are likely the same students whose families cannot afford such things as home workshops, microscopes, LEGO robotics, and museum visits. Also, although there is a current focus on STEM education, and teachers are encouraged to engage in engineering design projects with their student, many teachers have little interest or expertise in science, perhaps because of the lack of hands-on science and inventive projects in their own elementary school and life experiences (Bulunuz & Jarrett, 2010; Jarrett, 1999). However, playfulness is critical for the development of creativity. Einstein's famous saying, "Creativity is intelligence having fun" illustrates a creditable relationship between playfulness, having fun, and innovation. The significant relationships between play and learning and play, creativity, and innovation have been discussed in several recent books (Bateson & Martin, 2013; Brockman, 2004; Gray, 2013; Honey & Kanter, 2013; Singer, Goinkoff, & Hirsh-Pasek, 2006; Wagner, 2012).

Play is important for the development of life-long interest in science (Bulunuz & Jarrett, 2015, Jarrett & Jafri, 2019). A serendipitous study of new middle school students (seventh graders), who thought their required science class was an elective, found that 96% of students who experienced fun, hands-on science (SCIIS) in elementary school signed up to take more science in middle school, compared to 4% of those students who had studied science only from textbooks (Sprague & Wolf, 1983). Teachers who are taught in a fun, playful way may encourage a next generation of students to become interested in science if they implement the methods they are taught (Bulunuz, 20 12a, 2012b; Jarrett, 1998, 1999). And children who were allowed to play with and investigate materials daily, showed interest, creativity, and initiative they had not shown in their other schoolwork (Jarrett & Jafri, 2019). Also those children who were able to tinker daily in addition to their science lessons raised their science test scores above children in other classes at the same school whose science lessons were textbook based (Jarrett & Jafri, 2019). This observation and a study with kindergarten students in Turkey (Bulunuz, 2013) strongly suggest that elementary school science experience plays an important role in developing interest in science. Classroom research in both the U.S.A. and Turkey shows a positive motivational effect of hands-on science (Bulunuz & Jarrett, 2015).

Why should children be encouraged to experiment? Piaget says, “A student who achieves a certain knowledge through free investigation and spontaneous effort will later be able to retain it; he [and she] will have acquired a methodology that can serve him for the rest of his life…” (Piaget, 1979, p. 93). Why use toys to teach scientific inquiry? Toys have special meaning across the lifespan (Erikson, 1977) and are an important part of culture (Sutton-Smith, 1986). Classic toys are meaningful both to teachers and to the children they teach. Most teachers are familiar with simple toys such as Slinkys, spinning tops, balloons, balls, paper airplanes, balancing birds and butterflies, kaleidoscopes, wind-up toys, and pull-back cars. They can easily learn ways to engage children in inquiry through these toys. Teaching science through toys, both commercial toys and toys children design themselves, is an effective and inexpensive way to introduce children to scientific inquiry (Jarrett and Jafri, 2019). In fact, recent studies from many countries , including Turkey (Ekin, Cagiltay, & Karasu, 2018; Kabapinar & Incegul, 2017; Karaer & Tezel, 2017; Tezel & Karaer, 2017), Portugal (Cardoso, Correia, Rodrigues, Felizardo, & Lopes, 2016), Finland (Ihamaki & Heljakka, 2018), Sweden (Samuelson, 2018), and Thailand (Thananuwong, 2015), have examined the use of toys for teaching science. Thailand has even been testing a textbook on *Science of Toys* for 7th – 9th graders.

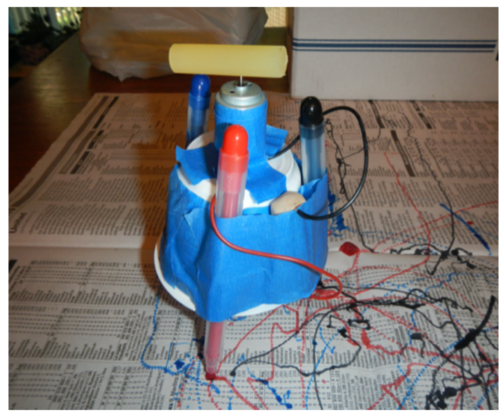
Investigating toys has elements of both work and play. As children play with the toys, they can also engage in measurement and scientific or engineering design. According to a study by Mihaly Csikszentmihalyi (Scherer, 2002), children are able to identify things they are doing as work, play, work and play, or neither. Examining the activities children identified as work and play, Csikszentmihalyi concluded that the best learning situation is when students perceive what they are doing as both work and play. A productive area of research would be to replicate Csikszentmihalyi's study with schools that include tinkering, investigation of toys, and even maker spaces to determine how children rate these activities as work, play, work and play, or neither.

Methods of teaching/learning with toys

There are several ways in which toys can be used in learning science concepts and scientific inquiry. Children (and also adults) can: (a) tinker with materials to design and adapt their own toys, (b) investigate toys (sometimes by taking them apart, to learn science concepts, and (c) pose hypotheses about the behavior of toys and collect data to test those hypotheses. All of these ways can stimulate understanding of science and interest in science, both among children and among their parents, teachers, and caregivers. These ways are discussed below.

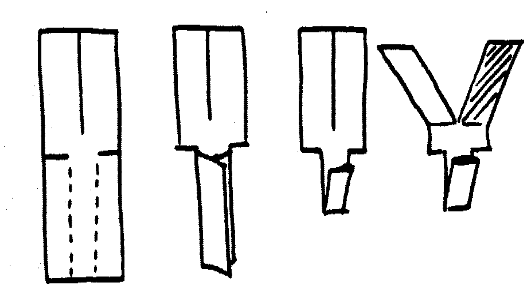
Tinker with materials to design and adapt toys. The possibilities here are limitless. Several recent books explore the philosophy of tinkering and share ideas for tinkering with people of all ages (Doorley, 2014; Gabrielson, 2015; Honey & Kanter, 2013; Martinez & Stager, 2013; Wilkinson & Petrich, 2013). Give children materials and they are likely to design things they can play with. We will include a few activities we have used with teacher workshops and with groups of children.

- **Make a scribbling machine** with a cup or berry box, out of balance small motor, and felt tip pens. See a scribbling machine below. For instructionshttps://www.exploratorium.edu/tinkering/projects/scribbling-machines

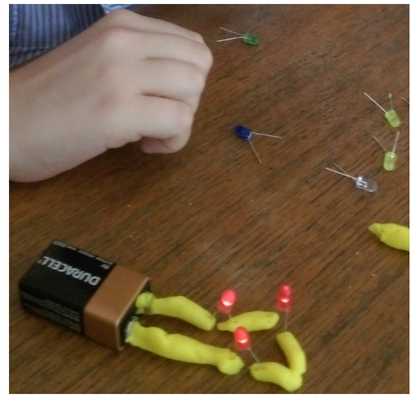


- **Home-made spinning tops.** Lay an old CD on cardstock or even printer paper. Draw around a CD and cut it out, including the hole in the center. Draw a design on the paper. Try out spirals and blocks of all the colors of the rainbow. Glue a marble into the center of the CD with the larger part up. When the glue is dry, fit the paper over the hole and spin. What happens to the patterns when spinning?

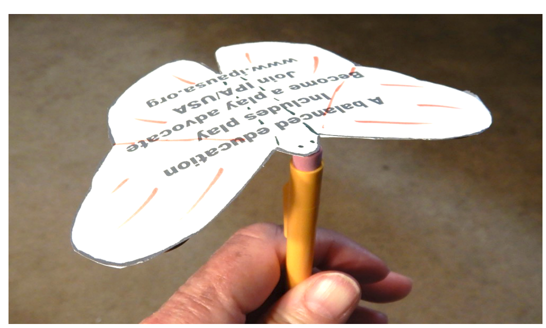
Play Doh circuits. Commercial Play Doh conducts electricity. You will need play doh, small LEDs, and a 9-volt battery (also experiment with other batteries). Make **"wires"** out of rolled-out play doh and also incorporate lights in creative sculptures. What affects the brightness of the LEDs? These photos show the creation of both a parallel and a series circuit. For ideas, see https://www.exploratorium.edu/tinkering/projects/squishy-circuits



Paper Helicopters. Make paper helicopters and drop them from as high as you can reach; e.g., off a step stool or perhaps playground equipment. A good design is made from a fourth of a sheet of paper (cut the paper in four strips across the sheet). Fold the helicopter as shown on the drawing. Paper clips can be added to experiment with how they affect the helicopter's flight.



- **Balancing butterflies/birds. Try this experiment,** Make a Balancing Butterfly – Experiment Exchange.
  Try balancing the butterfly on the end of your finger. Copy the butterfly onto cardstock, cut out, decorate it with markers, and tape pennies on the underside of the wings. Then try to balance the butterfly on your finger or the end of a pencil. The point at which it balances is the center of balance (or "center of gravity") the point at which all the mass of the butterfly is centered. Design your own butterfly and experiment with center of balance.
  Try balancing the butterfly on the end of your finger. Copy the butterfly onto cardstock, cut out, decorate it with markers, and tape pennies on the underside of the wings. Then try to balance the butterfly on your finger or the end of a pencil. The point at which it balances is the center of balance.



Investigate toys to learn science concepts. Some toys have considerable educational value. Play doctor kits generally have stethoscopes through which one can hear one's heart, and LEGO bricks allow children (and former children) to design machines, both simple and complex. Chemistry sets teach simple chemical reactions. *How Toys Work* (2010) by Lisa Greathouse gives simple explanations about how many toys operate.

Here are a few other playthings children can explore and investigate.

What is inside battery operated mechanical toys? Here is another idea from the Exploratorium tinkering studio, https://www.exploratorium.edu/tinkering/projects/toy-take-apart

What is inside balls? In the next section is an activity for collecting data from bouncing balls. If one finds differences in how high balls bounce, sawing balls in half may provide clues as to why balls behave differently.

Bubble mixtures. Compare a commercial bubble mixture with your own recipe. Start here for recipes https://draxe.com/beauty/how-to-make-homemade-bubbles/ . Have an assortment of bubble blowers: cylinders such as paper towel tubes, oatmeal containers and food cans with the tops and bottoms removed, and chenille sticks (pipe cleaners). See which bubble blower will make the biggest bubbles. Experiment with the bubble mixture. What proportion of detergent to water makes the largest bubbles; the longest lasting bubbles?

Science from balloons. From a package of one size balloons, how big can you blow it up before it bursts? For a **balloon "rocket,"** tape a piece of drinking straw to the side of a long balloon and run a string through the straw. Tie the string tightly to two poles or posts. Blow up the balloon the let it go. How far will it run along the string? **Orbiting coin:** slip a penny into a round balloon and blow it up. Tie off the opening Measure the circumference of the balloon with a tape measure. Rotate the balloon rapidly until the coin starts orbiting inside the balloon. Time how long it orbits with a stopwatch. Repeat several times and calculate the average length of time. Then experiment with other balloon circumferences and other sized coins. IPA World Convention, Istanbul, 2014

Kaleidoscopes. Look in a kaleidoscope. How many images do you see? Is it hard to tell? Tape two mirrors together or fold a piece of mirrored paper. Draw a design on a piece of paper. Set the mirrors on it. How many images can you see? Change the angles of the mirrors and measure the angles with a protractor. What are the angles of the mirrors when you see four images? Six images? Bak (2020) discusses the science behind kaleidoscopes and other optical toys.

Pose hypotheses, collect data, and test those hypotheses using toys. A third way to study toys is to collect data on what they will do. Playing with toys allows for intelligent predictions on what toys will do. For the following investigations, all that are needed are rulers and tape measures for length and clocks with second hands or stopwatches for timing. And the ability to count!

Spinning tops. Time various tops. Which top spins longest? What do you think makes one top spin better than the other(s)? Can you make changes in tops to make them spin longer?

Pull-back cars. When one of these cars is pulled back, an internal spring is wound up tight which propels the car forward as the spring loosens. Experiment with how far back to pull it to make it run how far forward. Measure it.

Magnet Powered Cars. Make a car run by using the pushing power of a magnet. Tape a magnet on the top of a matchbox car. Using the repelling power of another magnet, make the car move forward or backward. Try racing with another car. Does it matter how far away you hold the magnet? What about the angle? What happens if you flip the magnet in your hand?

Science from Wind-up Toys. What can you learn from these toys? Here are some questions you can investigate? What is the maximum time the toy will run? What is the relationship between how many times the key is turned and how long the toy will run? How can you determine when the key has gone around once? [Hint, put an ink dot on it so you can count the turns.] How far will the toy go when it is completely wound up? How much of a slant will the toy go up? Come up with your own question. The group below at the International Toy Research Association is using a tape measure and stopwatches to measure how far wind-up toys will go and how long they continue to move.

Bouncing balls. Balls bounce different heights and different numbers of times. Experiment with various kinds of balls. Drop them from the same height. Which ball bounces highest? Does that ball also bounce the most times? Are the good bouncers and the poor bouncers made of different materials? Try dropping the balls from different heights. Does how high you start the ball affect the height of the bounce and the number of bounces?

Closing remarks and recommendations

Toys offer engaging and generally available materials for conducting scientific investigations. Through toys, children can learn to collect data using measuring sticks, stopwatches, and protractors. They can experiment with center of gravity, circuits, the attraction and repulsion forces of magnets, and angle of reflection. The fun of experimenting with toys can be highly motivating, allowing children to think of what they are doing as both work and play and fostering the enjoyment of school (Jarrett, 2020). The ideas presented in the workshops and in this paper teach science concepts while engaging students in inquiry; i.e., scientific practices. For more ideas, look into the work of Arvind Gupta of India, known for making toys from trash, toys that can effectively teach science concepts (Salian, 2017). We (first and third authors) met Mr. Gupta at the IPA World Conference in Berlin, 2005 when we attended his session on making toys from junk. He has made amazing toys to teach science to poor village children in India. Mr. Gupta's YouTube channel contains thousands of ideas that are free to anyone willing to gather up junk materials, and his

129 page book is available for free download at http://arvindguptatoys.com/arvindgupta/skillsthrills.pdf . Also recommended are two courses the first author has taken on tinkering from the Exploratorium science museum in San Francisco, https://www.coursera.org/learn/tinkering-circuits and https://www.coursera.org/learn/tinkering-motion-mechanisms.

Research is needed on what children think about investigating toys and tinkering to make their own constructions, How do they compare this playful approach with other ways of learning? Also more research is needed on how well children of various ages learn the same concepts through toys compared to other learning methods, such as reading or watching videos. Research findings showing that children learn well through play would perhaps convince teachers and administrators that such activities have an important role in the school day. What we can say from our workshops with teachers and our tinkering sessions with children is that investigating with toys is fun and highly motivational.

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