Using Toys to Teach Science

Yau Che Ming & Wong Voon Ping Johnson
Natural Science and Science Education Academic Group
National Institute of Education,
Nanyang Technological University

Abstract
This paper is on the use of toys to aid in science education and to share various issues and implications relating the use of toys in teaching. The rationale of using toys for education; the relations and impact of using toys to teach; the advantages of using toys; the classifications of toys and descriptions of how toys are being used are depicted in this article. To date, a collection of more than 300 toys has been compiled. In this paper, five selected toys are featured, namely: 1) Drinking Bird, 2) Floating Pen, 3) Pecking Chickens, 4) Cross-Joint, and 5) Mirror Mirage. For each toy, coloured photographs and diagrams are illustrated with explicit explanations on the functionality of the toy, theories involved, topics of interests and some questions for further investigations. In conclusion, we advocate that the use of toys have enormous potentials in education and can be integrated in various subject disciplines in different levels of school science education.

What Are "Toys" In Science Teaching?

> *"Toys as a tool of the human child; used to train them in physical skills, help them to develop imagination, and to stimulate thinking"*
> Encyclopaedia Americana (Grolier, 2004)

A toy is any object or thing that is used or manipulated in order to amuse, educate, or otherwise encourage playfulness. Play and toys are simply inseparable. Through playing with toys, the learner is able to tap motivational qualities such as enthusiasm, spontaneity, imagination, divergent thinking and independence. Educators and psychologists, beginning with Friedrich Wilhelm August Froebel and Maria Montessori (Barbara A. C. and George A. V., 1993), have stressed the role of toys in the mental, emotional, social, and physical development of children.

There are many different types of toys available in market, some of which can even be homemade. The wide range of toys can be grouped according to many different criterions. An interesting way of grouping toys as proposed by Mack (1997) is to put the different types of toys under the following five main categories. Examples of the specific kind of toys under each category are listed below.

- **Active Play** - Push and Pull Toys, Ride-On Toys, Outdoor and Gym Kit
- **Make-Believe Play** – Dolls, Stuffed Toys, Puppets, Role Play Materials, Play Scene
- **Creative Play** - Musical Instruments, Art and Craft Materials, Audio-Visual Kit
- **Learning Play** – Mathematical or Quiz Games, Specific Skill Development Toys
- **Manipulative Play** - Construction Toys, Pattern-Making Toys, Manipulative Toys, Dressing, Lacing and Stringing Toys, Sand and Water Play Toys

The above listed classifications are a brief summary of the common practices by academics and toy manufacturers. In this paper, we will focus on a more 'education inclined' categorization of toys in terms of learning, and in particular, science teaching. Among the large variety of toys available, some are no doubt more suitable for use in the teaching of science as compared to others. Some factors to be considered in the selection of toys for effective science teaching are discussed as follows. It is recommended that they possess all the characteristics in one piece.

Simple

A good toy for the teaching of science should consist of only a few movable parts that are simple enough for students to manipulate on their own with little hassle or confusion. It should be possible to disassemble the toy easily, so that students can explore the working mechanism of the toy. It is most advantageous if the toy is transparent or translucent, then its working mechanisms can be examined more readily. In addition, the principles behind the mechanism should be within the students' comprehension level so that the students can appreciate the use of the toy to relate certain science theories. An added advantage of a simple toy is that it tends to be more reasonably priced, thus students can afford to purchase it.

Science related

The toys should involve directly or imply some science topics. It should not be a simple demonstration type, or else, that becomes a teaching aid for the purpose of teaching alone. On the contrary, the toys should have scientific appearance. For example, it could be related to "Light and Optics" such as toys with mirrors, light bulbs and pinhole cameras. Also, it can be related to "Mechanics and Structures" such as toy cars, turnabout tables, bridge structure and LEGO. With the development of the latest technology in the field of electronics, many toys also incorporate IC chips, sound buzzers, electromagnets and even some remote-controlled items related to radio and infrared waves.

Motion related

Toys that have some moving parts tend to capture the attention of students easily. Kids like moving objects. They will be less attentive to stationary objects. In the children's mindset, they are fond of playing with animals and human as they are more interactive and responsive. Hence, they might treat moving objects as some sort of "living creatures". As for teenagers, they are matured enough to recognise that the toy is just a non-living object. At the same time, they start to wonder how the toy moves or spin about. They will be eager to find out what is the reason, phenomenon and the possible mechanism involved. Thus, toys should include components that spin or rotate about one or more axes; float in one or several medium; move in circular or sequential motion, or move in random directions. Running lights are also considered motion.

Cultural aspects

Toys act as a universal language for playing in different levels of learning and cultural backgrounds. However, toys originating from different countries possess quite unique cultural and historical features. They are likely to appeal to people of other countries and cultural background. For example, a "Chinese Toothpick Selection Box" will appear to be rather fantastic for American kids. And, a "Japanese Prosperous Cat waving model" is cute and unique to non-Asian students. As Singapore is a multi-cultural society, the use of toys from various racial groups can obviously help foster greater understanding and appreciation of the culture and way of life of each race. Hence, a variety of toys should be selected for playing from each ethnic group to promote racial harmony.

Two Research Studies

Many studies have shown that the use of manipulatives, such as toys, is an effective method of introducing or reinforcing abstract scientific concepts. As pointed out by Berk (1999) in her paper "Hands-On Science: Using Manipulatives in the Classroom" a survey with 2,000 American teachers about their use of various types of instructional materials indicated that the teachers' use of manipulatives ranked only second in frequency to the use of textbooks. In addition, 55% of the teachers surveyed felt that manipulatives are "highly effective" teaching tool, as compared to 25% for textbooks. Hence, it seems that the incorporation of the use of manipulatives in classroom teaching has gained popularity among teachers.

According to Berk, students learn by using their senses to "discover and digest" scientific principles for themselves. The learning of science, or any other subject, requires students to make connections between the new information and their prior knowledge and skills. This can be achieved, as proposed by Berk, by incorporating new knowledge into learning activities that involve the use of manipulatives among small groups of students. Students' understanding of science concepts can be reinforced through the use of manipulatives, which acts as an additional avenue whereby knowledge is passed on to the students. In another paper "Toywise: Celebrating the Art and Science of Teaching with Toys", Klag (1996) suggested that after observing how a toy operates under certain circumstances, students can then decide which ideas are most useful for making sense of things around them - such as explaining how the toy operates. While students are manipulating the toys, the teacher should encourage them to observe many different things about the toys, as well as search systematically for patterns and relationships between various variables embedded in the toys.

Both Berk and Klag expressed that the benefits of using toys and manipulatives to teach a subject are numerous. The use of toys adds variety to the teaching method and generates much enthusiasm from the students who are usually excited by the use of manipulatives. Toys help bring science alive by making abstract principles concrete and relevant to the student's lives. Also, as the working principles of a toy are often assembled from a variety of subject areas, teaching with toys also help students to make connections in learning, particularly among different subject matters. Not only are students able to build a wide repertoire of essential process skills while using toys, the manipulation of toys in a group setting also encourages social interaction and gives rise to positive social development among the students.

Why Do Some Teachers Use Toys For Science Teaching?

When we talk about toys, naturally, play comes to our mind. The components of play corresponding to the skills and talent required for good learning are: sense of inquisitiveness, enjoyment, open-mindedness, intentionality, involvement, repetition and practice, relaxed attentiveness. Play helps to develop skills and attitudes that are important to effective thinking and swift decision-making abilities. Playfulness fosters openness and awareness. Play enhances the development of creativeness, flexibility, and motivation among students. These skills are much required in providing solutions for scientific and life-related problems. Therefore, students who are given opportunities to play and explore objects exhibit characteristics that promote motivation and a positive attitude about learning.

Some reasons for playing with toys to aid learning are:

- Toys invigorate the body, mind and spirit. (Klag, P., 1996).
- Toys can integrate the use of logic and intuition.
- Toys can be simple yet elegant to be used as analogies for real world phenomena which is the salient point in demonstrating associations of 'parables of science'.
- Toys promote the manipulation of variables.
- Toys encourage understanding of everyday technology applications.
- Toys to arouse students to organize their thoughts, interpret the world, understand and solve problems, and provide the channel from which good learning can carry on.

In addition, some salient characteristics of toys employed at teaching science are:

Attention-grabbing and improvisation of toys

Science is a subject that is commonly associated with experiments and theories. Interesting toys or even magic shows can demonstrate simple theories and working principles in a fun way to draw attention. These toys stir interest for learners to participate in the science experiments and theoretical explanations. Playing toys fascinates the learner and helps to sustain the concentration level. Activity-based toys promote involvement of learners in the classroom environment allowing teachers to focus on the subject than classroom management issues. The use of improvised toys enables all learners to have the opportunity to appreciate toys as a means to their learning process. Making improvised toys by students provides a better appreciation of science theories. Simple toys can be easily modified.

Arouse curiosity and inventiveness

Science is a remarkable subject for all levels of learners. Toys can be used to arouse interest and invoke the thinking hat of inquisitiveness. Toys are suitable for all levels of learners: for weaker students, toys help them to comprehend science in a more fascinating way, thus equipping them with the foundation of the subject knowledge. For the average students, using toys builds confidence in the learning process. For the 'gifted' ones, using toys in science education is a mean to challenge and excel their learning capacity and creativeness in acquiring knowledge. The inventiveness processes helps build wonder, connect thoughts and ideas and translate them into action. Invention is an act of creation for all students.

Apart from the stating the rationale for using toys, an evident research project was carried out on the use of 'Electronic Toy bricks' at several secondary schools by Yau (2002). The aim of the research conducted was to explore and assess the motivation of students in learning electronics (a sub-component in the curricula of Design & Technology) with the use of these toys for both students and teachers. The findings of the research clearly demonstrate a tremendous interest in learning science through playing these toys. Majority of the participants expressed that the use of the 'Electronic toy bricks' invokes great appreciation of the fundamentals of Electronics and promotes development in creativity in building and designing simple circuits. The 'playing' activities provide a means to 'self-discovery learning, problem solving skills, analytic skills and resourcefulness. As such, toys provide linkages to content areas, principles and facts.

How to use some toys for teaching?

There are many ways in which a toy can aid the learning of science. The most common of which is to use the toy as an attention grabber at the beginning of a lesson. This can also serve as an interesting introduction or a trigger activity to a topic related to one of the working principles of the toy. In the journey of science teaching, a toy may also be used to demonstrate a related topic so as to help students make connection between an abstract concept or theory and its application as seen in the operation of a concrete object. As such, students may be more inclined to ask interesting questions. At the end of the lessons, some toys may also be used to initiate a project work whereby students proceed to investigate and verify the working principles behind a toy. In addition, students can also be encouraged to redesign or improve on the toy, perhaps to enhance its functionàlity or make it more fun to play with.

Out of a collection of some 300 interesting toys (*A collection by one author Yau.),* five toys are selected for use in the teaching and learning of science in secondary 2 and 3 in Singapore schools. The experience is briefly described and shared below as a reference for discussion.

Example 1: Drinking Bird

Photo taken at NIE, Drinking Bird made in Taiwa

Description:

The Drinking Bird (Howstuffworks, 2004) consists of two hollow glass bulbs i.e. its head and base, connected by a glass tube, which extends into the base. To operate the Drinking Bird, its head must be wet. The liquid is observed to move up the tube towards the head. The Bird then dips forward, and the liquid flows back into the base, causing the bird to tilt backwards and restore its upright position. The cycle repeats and the Bird continuously dips its beak into the water and flips back upright in an oscillating motion without assistance. The motion may last for 1 week in an open-air environment.

Theory behind this toy:

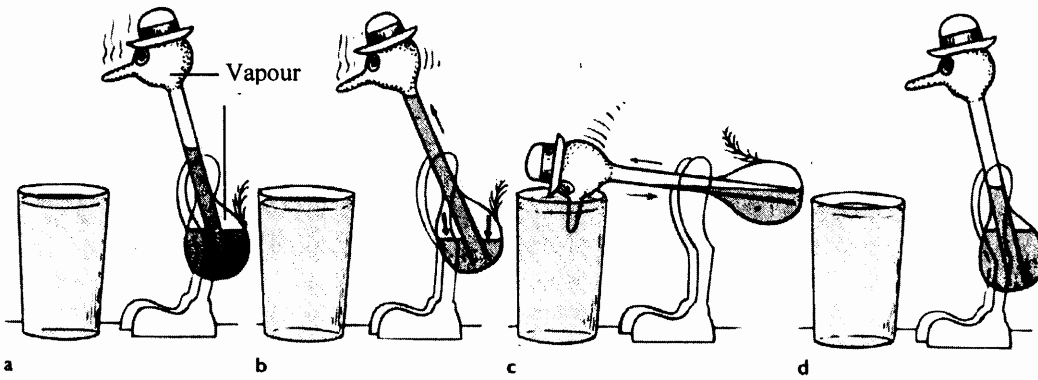


Diagram extracted from Conceptual Physics. (Hewett, 2002)

The Drinking Bird (Walker, 1975) operates by the evaporation of the liquid inside the base and the evaporation of water from the felt-covered beak and head. The liquid has a boiling point near room temperature. It evaporates rapidly at room temperature and forms a vapour above the liquid in the base as well as in the rest of the tube and the head, as indicated in **(a)**. These two pockets of vapour are not connected. As water evaporates from the felt covering the head, heat is removed from the head and cools the head and the vapour inside it. The decrease in temperature results in a lowering of the pressure of the vapour in the head. Hence, there is higher pressure in the vapour pocket in the base than that in the head and the liquid is pushed up the tube as shown in **(b)**. The centre of gravity of the Bird shifts closer to its head until it the Bird is in unstable equilibrium and tilts forward, dipping its beak into the water. Just when the Bird is horizontal, as in **(c)**, the liquid flows into the head. The end of the tube in the base is no longer completely submerged in the liquid and the two pockets of vapour are thus connected. The vapour pressure thus equalises and the liquid is free to flow between two compartments of the body of the bird. The Bird is designed such that most of the liquid flows into its lower half of the compartment. Its centre of gravity thus shifts closer to the base, causing the Bird to tilt back to its upright position as shown in **(d)**. The process will repeat itself as long as the felt remains wet.

Topics of interests:

There are a lot of suggested topics related to the playing of this toy. They are likely: Mechanics; Perpetual Motion Machines; Heat theory; Evaporation concept; Saturated and non-saturated vapour pressure; Ideal gas laws; Phase change of liquid; Latent heat upon evaporation; Types of equilibrium; Pivot function in lever system; Centre of gravity, Heat conduction, Boiling point of liquid and others.

For different levels (primary, secondary, junior college) and ability streams (gifted, special, express and normal) classes, a good choice of appropriate questions to initiate students' thinking:

- What is the liquid inside the bird? Why is it red in colour?
- What is the other liquid in the glass? Is that the same as liquid inside bird? Why is it red also?
- Does the Drinking Bird really drink water from the cup?
- If not, where has the water in the glass gone after some days?
- Can you explain why the bird moves up and down without stopping?
- Why the bird is made of glass? Any special reason(s)?
- Can the Drinking Bird be made to oscillate without getting its beak wet?
- Can you make something similar with the same theory and mechanism?
- What is the creative application of the Drinking Bird in science?
- Can we fabricate a larger model of the Drinking Bird (say *10 meters tall*), install it by seaside or river and let it drive some machinery so as to provide us with energy?

Example 2: Floating Pen

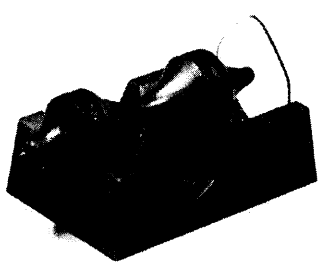


Photo taken at NIE, Floating Pen made in China

<u>Description:</u>

The Floating Pen is a 'display item' that consists of a 'Dumbbell-shaped' pen (axle) levitating on a 'cross-wells' platform (base assembly). A piece of acrylic is inserted at one end to align the pen and to produce this 'hovering' effect. The Pen simply floats if properly aligned. When the 'Pen' is being rotated, it will spin about its longitudinal axis in a near-frictionless state for a prolonged period of time.

<u>Theory behind this toy:</u>

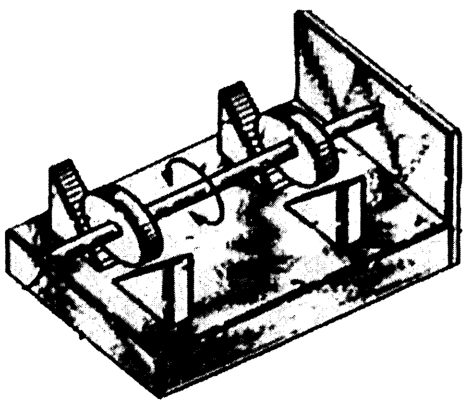


Figure 1 (taken from Ritts, 1993)

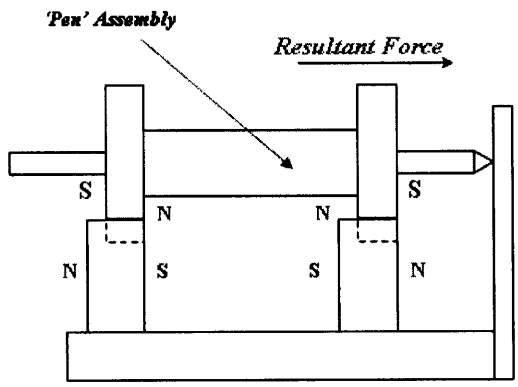


Figure 2 Simplified diagram of one possible working principle of the Floating Pen.

A simplified 'skeleton' structure of the 'Floating Pen' is show in ***Figure 1*** (Ritts, 1993). The base assembly consists of a combination of base magnets that are spaced apart along a platform. An acrylic wall attached to the platform forms the 'Pen' support at one end. ***Figure 2*** shows the polarity of the disc-shaped magnets in the 'Pen' assembly in relation to the polarity of the base magnets. The polarity configurations of the magnets in the 'Pen' and the base magnets are repulsive to one another. This permits 'free floating' levitation of the 'Pen' above the base. Also, a longitudinal lateral force is generated, which is sufficient to keep the pointed end of the 'Pen' in contact with the erected axle support.

Topics of interests:

There are some suggested topics related to the playing of this toy. They are likely: Different kinds and shapes of magnets, magnetic force, magnetic matrix or combined fields, Combination and resolution of forces, Different types of Equilibriums, Linear motor, Rotational inertia, Angular momentum and others.

For different levels and ability, a good choice of appropriate questions to initiate students' thinking:

- Why does the pen float? Can the pen be replaced by something else?
- Can we change the pen's direction? If not, why?
- Can we spin the pen and how long does it take stop? Why not?
- In what kind of equilibrium is the pen floating? Stable or unstable?
- What happens if we add weight to the pen at different locations?
- Is there another mode of magnet design for this "magical" show or motion?
- Can we make something similar with the same theory and mechanism?
- What is the creative application of this 'Floating Pen' in science or for shop display?
- Is this toy related to a linear motor mechanism or perpetual motion machine if we have a change of electromagnets instead?

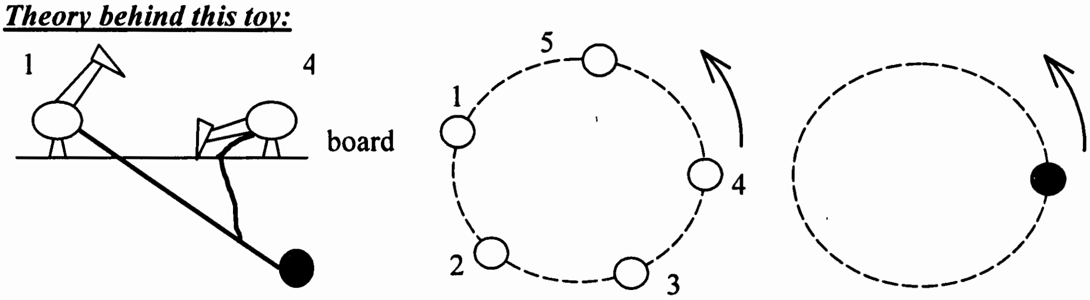
Example 3: Pecking Chickens

Photo taken at NIE, Pecking Chickens made in China.

Description:

The Pecking Chickens is a toy with five chickens arranged in a circle on a board. A string is tied to each chicken's neck and attached to a ball that hangs below the board. As the ball is swung in a circular motion, the chickens' heads drop down and rise up in turn, following the direction of motion of the ball. The overall effect is a sequential pecking motion exhibited by the chickens, with each chicken's head moving up and down in a harmonic motion so long as the ball is kept in circular motion.

__Theory behind this toy:__



Side view **Top view: (a) Chickens** **(b) Ball**

For this toy to operate, the ball must be kept in circular motion by moving the handle attached to the board. When the ball is in the position as shown in the simplified side view, the string attached to Chicken 1, (which is furthest from the ball) is pulled taut with the greatest tension. Hence the chicken's head, by the pivot and lever effect, is fully upright. On the other hand, there is no tension in the string attached to Chicken 4 (which is closest to the ball) and so the chicken's head dips down by its weight. The tension in the strings attached to the remaining chickens varies between these two extremes and the chickens' heads are up/dip to corresponding extents. The chickens' heads are dropped and raised in succession, following the direction of motion of the ball i.e. if the ball moves horizontally in an anti-clockwise direction, as shown in the top view, Chicken 1's head will move up followed by Chicken 2 and so on. Each chicken's head moves up and down periodically as the ball moves around in a circle. Hence, the circular motion of the ball translates into a harmonic motion of the head of each chicken

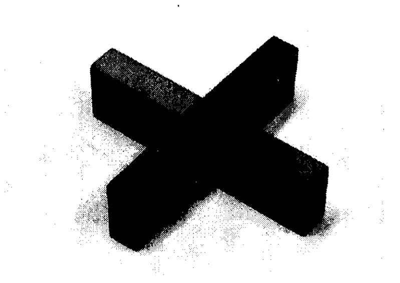
__Topics of interests:__

These are some suggested topics related to the playing of this toy. They are likely: "Village Life" in feeding chicken, tension in strings, circular motion, harmonic motion, sequential linked mechanism and motion and others.

For different levels and ability, a good choice of appropriate questions to initiate students' thinking:

- Why do the chickens peck in a certain sequence? Can the sequence be altered?
- Is the pecking of each chicken a simple harmonic motion?
- Is it true that in "Village" culture, chickens are fed in this manner? How about ducks?
- Is there any other method(s) of pulling the chicken to cause different effect?
- Can you make something similar with the same theory?
- What is the creative application of the Pecking Chickens kit in teaching other subjects?
- What determines the frequency of pecking of the chickens? Weight of ball? Length of string or else?
- How is the circular motion of the ball related to the simple harmonic motion of each chicken's pecking?

Example 4: Cross-Joint

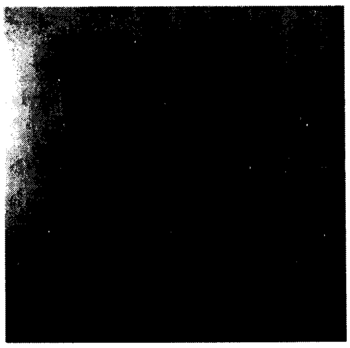


Description:

The Cross-Joint comprises of two identical wooden pieces, each with a through hole and two locating pins loosely inserted in 2 blind holes. When locked, either pin from each wooden piece will be slotted through the hole randomly in the other wooden piece. It is so difficult to unlock it unless you spin the whole cross.

Photo taken at NIE, Cross-Joint made in Singapore.

Theory behind this toy:



Side view

Internal drawing

The above diagram on the right shows the cross-section view of one of the wooden pieces when the joint is locked. All holes are identical in diameter. Each locating pin moves smoothly in and out from its locating hole. The Cross-Joint can only be possibly unlocked by having all four pins away from the hole in the middle of the piece. It cannot be achieved by tilting the cross to one side or other. Hence, to unlock this it can only be done by spinning it in either direction for a few rounds. By the principle of the circular, the "centrifugal force" will "push" the pins towards either ends and far away from the middle hole. And, to reassemble the joint, the pins are pushed back, with the square halving orientated properly in a cross. The joint is jiggled slightly to lock it.

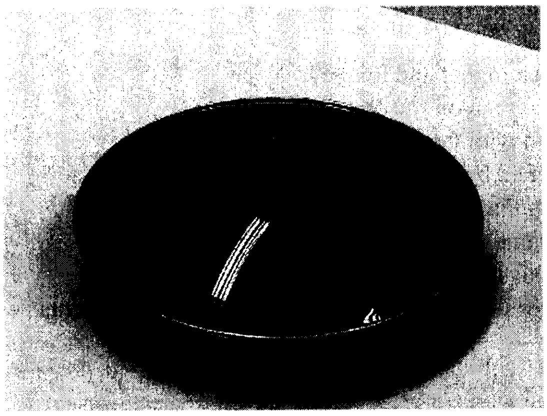
Topics of interests:

There are some suggested topics related to the playing of this toy. They are likely: Circular motion; Centripetal force; Joint design for wood and metal; Safety lock design and else.

For different levels and ability streams classes, a good choice of appropriate questions to initiate students' thinking:

- How can the joint be unlocked easily? Is there any magical trick? Think creatively and try.
- What is the design of the joint? How is it possibly made?
- Should all the holes be of the same size? If not, why not?
- Is spinning the only way to unlock the cross? Any other possible solution?
- What is the difference between centrifugal and centripetal force as shown in this example?
- Can the cross be spun in various directions to unlock the joint?
- Can you make something similar with the same theory and mechanism?
- How can we modify the joint to a 3-D lock for a creative application?

Example 5: Mirror Mirage



Description:

The Mirror Mirage produces a three-dimensional (3D) hologram-like image of a small object placed inside the kit. The real image seems to be standing on the top of the setup. The image is in colour and appears in 3D reality.

Photos taken at NIE, Mirror Mirage made in United States

Theory behind this toy:

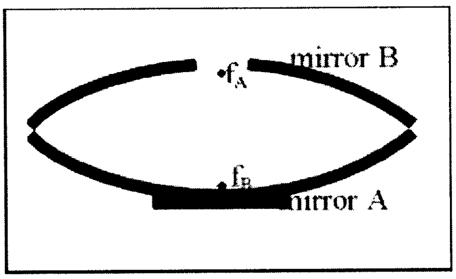


Figure 1

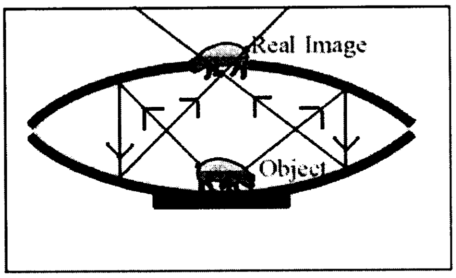


Figure 2

Figure 1 &2 extracted from Physics Demonstration Resource (Josh, Andrea & Shawana, 2004)

The Mirage Mirror (Josh, Andrea & Shawana, 2004) comprises of two "spherical" mirror-coated plastic bowls of identical shapes. One (mirror A) lays face-up on the table while the other (mirror B), which has a hole in the centre, lays face-down on the mirror A.

The mirrors are designed with the focal point of one mirror lying just at the vertex of the other when the mirrors are placed on top of one another, as illustrated in the left diagram shown above. An object placed at the apex of mirror A will be at the focal point f_B of mirror B. Light rays from the object is incident on mirror B and reflects off as parallel rays. The parallel light rays then reflect off mirror A and converges to the point f_A. This forms a real image at f_A as shown in the right figure above. If the observer looks at this point, the object appears to hover at that point. However, when the observer tries to touch it, he/she will realise that the object is not at that position.

Topics of interests:

There are topics to be taught of while playing with this toy. They are likely: Reflection of light; Formation of image; Concave mirrors; Psychological science for illusionary and reality; Mirage and others.

For different levels and ability streams classes, a good choice of appropriate questions to initiate students' thinking:

- Is it a real or virtual image? How to judge an object and image?
- What is the definition of the virtual image as seen on the opening?
- What is the size and orientation as compared with the object and image?
- How is the image formed? Can it be explained by using ray diagram(s)?
- Does this resemble any natural phenomenon that you experience in daily life?
- Can you make something similar with the same theory and mechanism?
- How is it possible, in "mass scale", to use this toy for some magic show?
- What is the creative application of the Mirror Mirage in some psychological experiments of reality and illusion?

Conclusion

The writers are part of the training team for the subject Design and Technology in National Institute of Education in Singapore. Design and Technology, D&T, is a creative subject with components of design, workshop skills and technology knowledge to make artefacts in meeting unique needs. D&T is a 'well-received' and compulsory subject for all secondary 1 and 2 students in Singapore schools. We both believe that, in the growing popularity of design and innovative campaign learning in Singapore, research and design-and-make for appropriate toys to aid science teaching could be a potential area to be explored.

In our view, good toys are far better than the conventional teaching aids available in class. The advert use of technology in designing 'intelligent toys' (computer animated games, simulated games, robotics coupled with artificial intelligence, etc) and an array of sophisticated toys do not render the simple and inexpensive toys obsolete or irrelevant. On the other hand, the appeal of affordable toys will be advantageous (for the underprivileged learners who are unable to acquire those toys).

Teachers who desire to expand learning opportunities for students should seriously consider the use of toys in their instructional planning. This is especially true if they want to enhance creativity, problem solving, and inventiveness in their students. Toys can provide a tremendous viable avenue to spark imagination, encourage creativity, ignite inquisitive traits, reinforces learning skills for all learners.

Hence, we recommend that it is most advantageous to introduce toys in the learning journey as:

- Toys encourage cooperation, collaboration and communication.
- Toys extend upon 'out-of-school' experiences for students.
- Toys promote positive motivation and attitude in learning.
- Toys allow abstract principles to be translated in readily simple form.
- Toys support conceptual instruction through a wide array of teaching methods and approaches that can range from at-risk to gifted student populations.
- Toys involve both the teacher and student in the fun aspects of learning and promote elements of novelty, curiosity, and wonder.
- Toys have universal affinity to all learners. They appeal to all regardless of races, cultures and religion. This suits well with the multi-cultural and multi-racial communities in Singapore.

Finally, we strongly believe using toys in lessons is an innovative approach to providing great enhancement in the teaching of not only science but also in other subjects like mathematics, geography, etc. There is enormous potential in integrating these toys to invoke fun and creativeness in multi-disciplines and cross-subject learning. Hence, toys are definitely a viable way in aiding teaching. Lamentably, due to time constraint for the submission of this paper, we admit that it could be perfected using an additional exhaustive comparative study. In the near future, we propose to conduct a research program to further investigate and to promote the use of toys in teaching science at various levels in Singapore schools.

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