

Playing with Electricity: Exploring electric circuits through open ended play

Mary Leighton, Panos Oikonomou and Keith Vanderlinde

Both children and adults typically have misconceptions about how basic electric circuits work (Grotzer et al. 2006). These can be so ingrained that in one study the majority of college students enrolled in a physics class were unable to light a bulb using battery and three wires (Fredette and Lochhead, 1980). In this project we aimed to introduce a basic understanding of simple electric circuits through a fun and non-intimidating exhibit which allows children to learn through engaging in open-ended experimentation.

Basis premise

We designed and prototyped a hands-on exhibit for young children (under 12 years old) which will be stationed at SciTech. The exhibit is based around building simple electric circuits using wires, a battery, and elementary electrical 'units'. These units are small blocks with banana plug connectors and either a light, a buzzer or a fan. Children are invited to experiment and connect these components to each other so they form a functioning circuit.



*Image 1: Child playing with the prototypes.
Photo: P. Oikonomou*

This exhibit works in as clear and visual a way as possible, with no components being hidden. To facilitate the visitor's experience and understanding, we actively avoided circuit boards which are more commonly used in circuit exhibits. That no part of the process is hidden is essential for the exhibit rather than an aesthetic statement. Our goal is to visually communicate that all components have to be connected to each other and to the power source in order for an electric circuit to work.

To make the exhibit easy to use, another crucial part of the design is that all connectors are colour coded.

This makes the process of starting to connect components more intuitive, without any prior knowledge or need to read labels. Once this is achieved the goal is obvious: to make the bulbs light up, the buzzers buzz, and the motors turn.

The simplicity of the concept and the clarity of the design allows for a very high level of imaginative participation. The open-endedness of the exhibit presents the children with a creative task that puts their problem solving skills to use. The idea of learning through 'play', and of having to make, rather than just observe, something is central to many theories of child learning:

“For young children, "looking at something" means touching it. Actually moving and handling objects is much more important than watching them on television, no matter how educational the program may be. Similarly, watching little figures do something on a computer screen is not nearly as valuable as manipulating the objects themselves. By nature, young children are constantly in movement and need the opportunity to express their ever deepening relationship to day-to-day life through their play.” (Baldwin Dancy, 2005)

Our aim in this exhibit is to counter the common mystification of the topic, where electric devices are seen as black boxes. As such we are not concerned with imparting an in-depth knowledge of electronics – instead we aim to avoid installing any accidental misconceptions. Even if children do not leave this exhibit knowing exactly how a circuit works, they hopefully will have a basic understanding of how to build one, and an interest that will remain with them till the next time they approach this topic, possibly in school. They will also have a basic understanding that all electric devices need to be connected together in a circuit and to a power source, in order to function.



*Image 2: Prototypes with illustrated instructions.
Photo: P. Oikonomou*

Description of the exhibit

The exhibit is laid out on a table, with approximately four sets of units and batteries. The units we prototyped are shown in image 2. They consist of a box with a light, buzzer, or fan and four banana plug receivers, colour-coded black and red. The colour-coding of the banana plugs is of particular importance, as we found in the evaluations that this was the first way that children realised that they should be connecting two different wires into a single unit. Our tested prototypes are made of foam board, but a permanent version will be made from acrylic and wood. Because circuits and electric devices are an area of science often perceived to be dull and intimidating, the units and the table are both bright and inviting, to make this potentially rather dry topic of interest to children of both genders.



Image 3: "Play tables" at New York Hall of Science. Photo: <http://www.nyscience.org/marvelousmolecules/>

The sets consist of three light bulb units, one buzzer unit and two fan units, along with a switch unit, a large number of wires with both a red and a black banana plug attached, and a battery with two wires firmly attached. Children are able to use the sets to make any kind of circuit they wish, hopefully starting with something simple and working up to the more complicated, either on their own or in a group.



Image 4: "Play tables" at Technopolis, Belgium. Photo: M. Leighton

Similar “play tables” have been used at the New York Hall of Science (image 3) and Technopolis in Belgium (image 4). This kind of arrangement allows for social interaction with other children around the table but also individual space – in prototyping we found that one set was not enough as many children would try to work on it at the same time disrupting each other.

The instructions are pictorial with very limited text, and serve

the purpose of either suggesting possible circuits that can be made or of providing a guide on what to do if the participant is stuck. They consist of photographs of basic circuits, some more complex than others, made from the same units used in the exhibit. The images should be of the actual units being used to make the instructions as clear and relevant as possible. Our instructions are included in appendix 1.

Evaluations

When testing out prototypes at SciTech on two separate occasions we were pleased to see that the exhibit was very popular with both boys and girls around the ages of 7-10. On average they stayed with the exhibit for approximately 5 minutes, with a number of children staying much longer (about 10-15 minutes) and having to be asked to leave to let other children have a chance. The initial reaction of the child was to try and plug everything into anything, often putting one wire into two plugs on the same unit, or connecting several units to each other rather than the battery. In general they eventually worked out that they needed to plug something into the battery, and usually managed to create a simple circuit with a bulb, two wires and the battery, sometimes with the help of the illustrations. The children seemed to find the moment where it actually worked very rewarding!



Image 5: Children playing as a group with the prototypes. Photo: P. Oikonomou

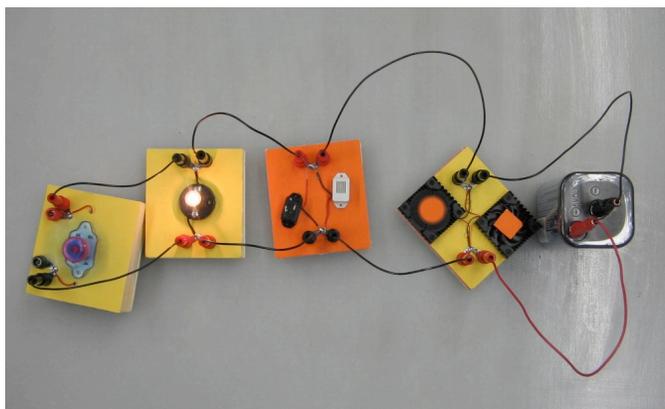


Image 6: Prototypes in parallel. Photo: P. Oikonomou

The concept of connecting two units in parallel seemed to come relatively naturally and children often began to do this without any prompting. When we tried to encourage them to connect two units in series, however, this proved much more difficult to explain and much less intuitive to the child.

Our initial attempt to distinguish between a LED and an incandescent light bulb was similarly unsuccessful, as the children could not distinguish between the two. We realised that explaining the concept of polarity would be too complicated, and that therefore those units which required connecting in a specific direction, such as the fan, the LED (which we later decided not to use at all), and the buzzers, would have to be either rewired or doubled up. When a child had connected a circuit correctly except for the polarity they would be disappointed if it did not work and, being unable yet to understand the concept of polarity, assume that their assembly was incorrect. We resolved this by putting either two buzzers or two fans on the same unit, wired up so that either one or the other would work depending on the polarity of the circuit created. This meant that the child would still get a result either way, and would only wonder about the reason why only one or other of the buzzers/fans would come on if they were interested. This fit in with our aim of not hiding any of the processes, and of allowing room for further experimentation and later investigation depending on the child's interest.



Image 7: Double units. Photo: P. Oikonomou

Proposed design

Four sets can be laid out around a round table, with the instructions stuck flat on the table top and the various units and wires in baskets. Each set will have its own power source, cable set and the basic ‘units’. A panel showing the connection between this exhibit and electric circuits in children's lives should also be included.

More durable sets can be made from acrylic plastic and wood, rather than foam board. The plastic can be



Prototype made from wood and plastic. Photo: P. Oikonomou

see-through so that nothing is hidden, or coloured if this is found to be too confusing.

Costs and safety issues

Safety concerns we came across in this exhibit include:

- Making sure the electric current is low enough to not cause any harm but high enough to work well. For prototyping we used a 6 volts heavy duty battery. However, to reduce cost in the long run, we suggest that the battery is replaced by a mock-up battery connected to the outlet. An appropriate transformer can be used to bring down the voltage to 6VDC.
- Securing all small pieces so that they will not be broken off.
- Using banana plugs rather than crocodile clips or open wires. Banana plugs are more aesthetically pleasing than larger radio plugs, and also fit better onto the purposefully small units, but may need to be replaced frequently.

Our estimated costs are approximately \$10-12 per unit. We suggest that each set has 6 units and the exhibit includes 4 sets. This brings the cost to around \$300 including costs for batteries, transformers, cables etc. We have not included the cost of the table.

Educational Standards

Our target age group is early elementary school, and this exhibit is in compliance with Illinois educational standards 11B, 12C, 13A.2b and 13B, covering 'inquiry and design', 'concepts and principles' and 'science, technology and society'.

11B: Know and apply the concepts, principles and processes of technological design.

12C: Know and apply concepts that describe properties of matter and energy and the interactions between them.

13A.2B: Explain why similar investigations may not produce similar results.

13B: Know and apply concepts that describe the interaction between science, technology and society.

Conclusions

Although logistical difficulties did not allow us to develop this exhibit to its final stages, our initial prototyping has been very successful and we hope that SciTech will be able to use this concept. The

reactions from the children were very positive, and the majority, even when they did not seem to know what to do when they first started, very soon able to make at least one circuit, taking away a real sense of accomplishment.

References

Baldwin Dancy, R. 2005; *Learning Through Play*

http://www.waldorfinthehome.org/learning_through_play.html

Fredette, N. and Lochhead, J. 1980; Student conceptions of simple circuits. *The Physics Teacher*, 18, 194-198.

Grotzer, T. and Perkins, D. 2005; *Causal Patterns in Simple Circuits: Lessons to Infuse into*

Electricity Units to Enable Deeper Understanding <http://www.pz.harvard.edu/ucp/curriculum/circuits/>