Developing an interactive device for primary education of circuits, energy, and waves

Gwyneth Steel

Mentored by Chris Rogers

Science and Mathematics Academy

Introduction

As STEM careers become increasingly significant in society, it is important to evaluate how these subjects are being taught, especially at an early age. When elementary school level STEM education was evaluated, Daugherty, Swagertly, and Carter (2012) found a lack of quality curricula. The study also highlighted the importance of having students use kits and devices that demonstrate different STEM principles and topics. These devices should be interactive and allow the students to manipulate components with their hands. Using interactive physical manipulatives has been shown to improve students' understanding of STEM topics by allowing them to become more interested in the topics and make deeper connections (Zacharia & Michael, 2016). Many of these devices use individual exploratory learning, which is when students are encouraged to learn about a topic on their own which developed their interest in the information (Akınoğlu & Tandoğan, 2006). In this project, a device was developed as an interactive educational tool for fourth grade students, covering the topics of circuits, energy, and waves.

Methods and Materials

The device was designed to be a cube with interactive activities on five of the sides and a removable bottom that allows for battery access. Side 1 was designed to be a circuit that lit up an LED with a break in it. There was a piece of wire that students use to complete the circuit, which conveys that circuits only work when they are closed loops. Side 2 had a motor and a sliding potentiometer. The potentiometer adjusted the voltage going to the motor, which changed its speed, to show the relationship between increased energy and increased speed. Side 3 had three sets of up and down buttons that were used to change the RGB values of an RGB LED. These values were displayed on an LCD. This side was intended to teach the students how RGB LEDs work. Side 4 had a button that activated a buzzer and two potentiometers to manipulate the frequency and amplitude of a sound wave to show how changing these values affects the sound. Side 5 had four bars of material that would be used to create a circuit to light an incandescent bulb. This would allow students to explore the differences between conductors and insulators.

All five of the sides were prototyped using a breadboard with Arduino code and an Arduino Mega.

Autodesk Fusion 360 was used to model the cube and all of the components included in the design (Figure 1). At this stage, decisions on which parts would be used and how the components would fit together were made.

Methods and Materials (cont.)

Figure 1 (left): A 3D rendering of the cube model from Fusion. Each side of the cube is 8 inches by 8 inches. The pieces were all individually modeled and then assembled to determine how well they fit together. The sides are made of clear acrylic so the user can view the internal wiring.

After the model was completed, schematics for two circuit boards were designed in Autodesk EAGLE. The schematics were then used to develop designs for two printed circuit boards (PCBs) (Figures 2 and 3).

Figure 2 (right): The finalized EAGLE model for the motherboard, the PCB that is attached to side 4 of the cube.

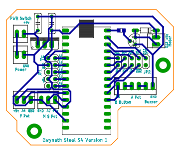
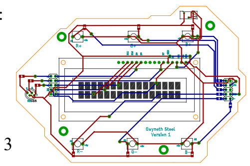


Figure 3 (right): The finalized EAGLE model for the daughterboard, the PCB that is attached to side 3 of the cube.



After the device and PCBs were designed, the parts were produced and assembled. The sides of the cube and several additional pieces were laser cut out of acrylic on a Full Spectrum Laser Hobby Series, a few pieces were 3D printed using a Cube printer, the PCBs were milled on a LPKF ProtoMat E33 and then soldered, and all of the pieces were assembled and wired. The code was uploaded to an Arduino Nano in the side 4 PCB.

Results

The side 4 PCB (Figure 4) controlled sides 2 and 4. Both of these sides functioned, so this PCB was successful. The side 3 PCB (Figure 5) controlled side 3, which did not function due to a few errors in the PCB, so this PCB was unsuccessful. Despite the PCB issue, the box was assembled with all components fitting into place as planned (Figure 6).

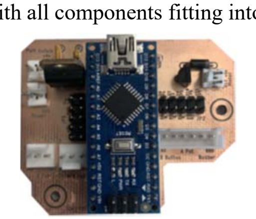


Figure 4 (above): The finished PCB for side 4 with a height of 1.95 in.

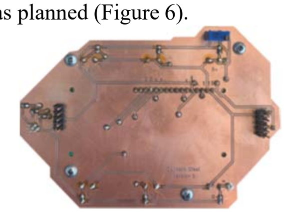


Figure 5 (above): The finished PCB for side 3 with a height of 3.5 in.

Results (cont.)

To determine the functionality of the activities, 20 subjects were given basic use instructions and then given time to interact with the box. Sides 1 and 2 were fully functional for each subject. Sides 3 was functional during box assembly, but two connectors broke before testing for functionality so this side did not work for any of the subjects. Side 4 was not functional for any subjects, presumably due to faulty connectors and errors in the PCB. Side 5 was functional for the first four subjects, then the incandescent bulb burnt out and it was no longer functional.

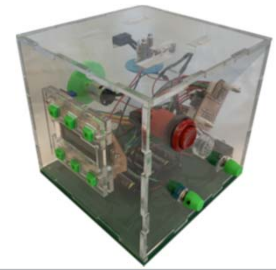


Figure 6 (left): An image of the assembled cube. The top of the cube is side 5, the side seen on the left is side 3, and the side on the right is side 4. Side 4 was mirrored in the manufacturing process. All of the lime green components were 3D printed and the clear pieces and dark green pieces for the bottom were laser cut out of acrylic.

Conclusions

While not all of the sides of the cube were fully functional, the three that were not consistently successful could be fixed. This project could be expanded by finishing the debugging process. Future research could be done in a classroom setting to test the effectiveness of the device as an educational tool for fourth grade students about energy, circuits, and waves in comparison to a traditional lecture-based method. A curriculum could be developed to accompany the cube that would promote the use of physical manipulatives and individual exploratory learning. Eventually, the device could be developed into a commercial product.

References

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