Power Puppet: Science and Technology Education through Puppet Building

Firaz Peer
Georgia Institute of Technology
Atlanta, GA 30332
firazpeer@gatech.edu

Michael Nitsche
Georgia Institute of Technology
Atlanta, GA 30332
michael.nitsche@lmc.gatech.edu

Lauren (La) Schaffer
Georgia Institute of Technology
Atlanta, GA 30332
la.schaffer@gatech.edu

ABSTRACT
In this paper, we describe our approach to designing electronic puppet-building workshops for middle to early high school students. Power Puppet uses traditional puppet building materials - paper and cloth as the main resources, together with simple circuits elements such as LED's, batteries and magnets. We document our process of designing puppet-building workshops that include STEM education criteria. We collaborated with the Center for Puppetry Arts to design these workshops in such a way that part of the making will include basic electronic input and output components. We aim to open this tradition up for larger audiences to enhance hardware CS education in STEM fields.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *prototyping* K.3.2 [**Computers and Education**]: Computer and Information Science Education – *computer science education*

General Terms
Design, Documentation, Performance.

Keywords
Electronic Puppets, Workshops, Puppet Making, Conductive Materials, Basic Electronics, STEM Education, Curriculum

1. INTRODUCTION
Puppetry as an expressive art form is over 4000 years old and - just like any other artistic format - has adapted to various technologies and practices. As a result, it provides a wide range of designs and technologies to build and control puppets. It has been used in scientific research to tackle control mechanisms in advanced robotics [14], interface design [15], and network optimization [12], among other areas. But it also has been applied to digital media and design through storytelling, improvisation, and public engagement [2], to describe the relationship between user and avatar [23], and in educational projects [13]. At the same time, traditional puppetry has started to explore and theorize its relation to the digital, gradually building frameworks to include it better [22].

IDC'14, June 17–20, 2014, Aarhus, Denmark.

http://dx.doi.org/10.1145/2593968.2610457

The Power Puppet project builds on this convening field. Its goal is to teach middle school to early high school students basic circuit building in the setting of a puppet building workshop. As students build their puppets, including control mechanisms (like rods and strings) and expressive elements (like joints and materials), they also create basic circuits that operate in combination with the puppet that houses them. This does not break with puppetry tradition, as the inclusion of digital control components have been applied to puppet design and revolutionary input devices such as the Waldo were co-designed by puppeteers like Jim Henson. This paper reports on the first stage of the project: designing and preparing the workshops.

2. WHY ELECTRONIC PUPPETS?
There are a range of successful projects in Computer Science for software related STEM education (ALICE, Scratch, countless game-based projects). However the list of hardware-related projects is much shorter [4], [20]. This stands in contrast with the growing needs to educate a new generation into the age of ubiquitous computing, where hardware construction of computational devices is becoming as relevant as their software programming.

Atlanta is an international center for puppetry; it not only hosts the world-renowned Center for Puppetry Arts but is also home to a number of puppeteering troupes and performers. Many of these artists also provide educational programs in their performances as part of their puppet making. Puppets as educational tools are in use in formal as well as informal education settings in Atlanta. For example, each young audience show at the Center for Puppetry Arts includes a Make-Your-Own-Puppet workshop. These workshops offer basic puppet building opportunities to its visitors. Different workshops are offered to different audiences: short basic construction workshops encourage younger audiences to build mainly paper puppets that relate to the current stage productions; more elaborate courses are directed at older K12 students and include different materials (foam) and practices (hot glue guns); finally, specialized workshops on puppet building and control are provided to mainly adults and often cover specialized areas (such as marionette control or shadow puppetry). The craft of puppet design and construction is a lifelong learning process and offers many entry points to engage students and involve them in new design experiences.

Puppet making, thus, is a typical art and craft practice and well supported in Atlanta. Notably, it is a practice embraced across genders, age groups, and educational backgrounds. It offers a gateway to reach precisely those new audiences interested in creative making but deterred by a purely CS-technological perspective.

3. RELATED WORK

Since Froebel established the first kindergarten in 1837, and developed a set of toys with the explicit goal of helping young children in learning concepts such as number, size, shape, and color, other educators, such as Maria Montessori, have created a wide range of manipulative materials that engage children in learning through playful explorations [3].

Continuing in this tradition of playful explorations, Leah Buechley and other researchers at the High-Low Tech group at the MIT Media Lab have conducted workshops that teach participants to design circuits on paper, producing a small set of interactive projects [16]. In Pulp based computing [7] the authors describe a series of techniques for embedding electro-active inks, conductive threads and smart materials directly into paper during the papermaking process, thereby creating seamless composites that are capable of supporting new and unexpected application domains in ubiquitous and pervasive computing at affordable costs. In [10] the authors describe ways to produce electronic origami using thermochromic and conductive ink that changes color when electricity is applied. Saul et al. [21] describe a family of interactive devices like paper robots, paper speakers and paper lamps made from paper and simple electronics.

With a Kit of No Parts [18], Perner-Wilson describes an approach to building electronics from a diverse palette of craft materials, which the author argues are more personal, understandable and accessible than the construction of technology from a kit of pre-determined parts. "Personal materials" like these have proven their value in research workshops that use the intimacy of such materials to the student as "new technologies can be taught in ways that open students to the potentialities for self-empowerment and playful exploration of taboos or serious issues within contexts that are creative and artful" [1]. Furthermore, projects like these have proven effective for the engagement of new student groups, particularly women and girls, in hardware prototyping technology through craft [6].

4. OUR APPROACH

A key inspiration for our approach is Buechley's combination of craft and computing [5] and related work on the use of soft circuits in education [11], [17]. Buechley's initial work was an expansion of existing techniques through new technology. In Buechley's case, this included the development of the LilyPad, a prototyping board that simplified building soft circuits in cloth, with the aim of reaching newer audiences. Challenges reaching newer audiences, such as women or underrepresented minorities remain as long as technology education aims to teach for technology's sake. STEM robotics programs are often taught without a view to the context for these technologies. Students use LEGO Mindstorms to learn about robotics - not about the underlying context and the cultural role of the mechanisms they build. Consequently, these programs reach mainly students already interested in technology but they fail to reach out further [8].

The second challenge is continued "black boxing" of many educational technological tool sets [9],[19]. Commercial kits like Mindstorms hide the underlying functionality of their parts and black boxing is in the nature of these kits as marketed to educators. Their commercial viability depends on limited access.

Each state in the US has a different set of standards and expectations when it comes to science education. To make matters worse, public, private, and charter schools within each state also have their own sets of guidelines that they enforce. To simplify our approach, we decided to use the physical science curriculum published by GeorgiaStandards.org to design our workshop exercises. We looked at the learning outcomes and performance goals mentioned in these documents, and designed our individual exercises around it. According to Georgia Performance Standards Framework for Physical Science [GeorgiaStandards.org], eighth grade students should be able to

1. Draw a diagram of a circuit that will light a bulb, given an electric wire, a battery cell and a bulb.
2. Draw a diagram of a series circuit with 2 bulbs.
3. Draw a diagram of a parallel circuit with 2 bulbs.
4. Identify an advantage of a series circuit.
5. Identify an advantage of a parallel circuit.

We used this as a guideline when deciding which electronic components to use in our exploration. With these standards in mind, we built interactive puppets and installations with paper and cloth that made use of conductive tape, conductive thread, batteries, LED's, washers and magnets. We believe such materials have a lower barrier to entry compared to electronic circuit building kits like LittleBits, Arduino LilyPad and BlinkM's in terms of cost and availability while at the same time allowing us to build a variety of simple interactive pieces.

5. PUPPET PROTOTYPES

Jean Piaget observed that children acquire knowledge by acting on the world around them. We started off by building basic series and parallel circuits with conductive tape, batteries and LED's laid out on paper. This method is included to allow students to realize abstract concepts such as polarity and flow of electricity in more concrete and tangible ways. The circuits can be put together in minutes, so students can easily make multiple test circuits for a variety of applications.

Figure 1: Series circuit with conductive tape

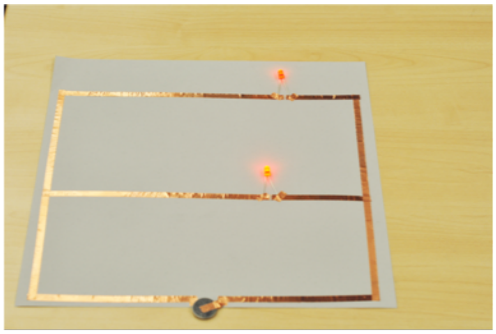

Figure 2: Parallel circuits with conductive tape

We used this as a base to add on more interactive elements to the circuit. We constructed origami puppets with two LED's for the eyes, connected in series. In order to make the connections between the conductive tape and the origami puppets, we fixed magnets onto the conductive tape as shown. By using paper clips and washers as leads in the origami puppets, we snapped connections into place.

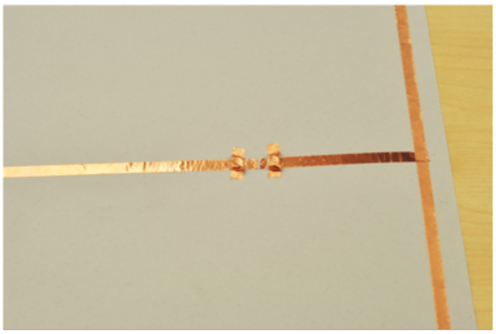

Figure 3: Fixing magnets on the conductive tape

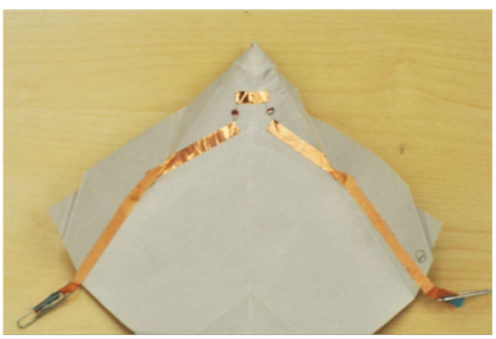

Figure 4: Internals of the origami puppet

Figure 5: Placing the origami puppet on the circuit

Our next task was to incorporate these basic electronic components into more elaborate paper and cloth puppets. We attended workshops at the Center for Puppetry Arts to learn puppet making from the experts. The materials included 1" foam sheets, non-stretch fabric, plastics dowels, cardstock, felt, various craft pieces for decoration (buttons, yarn, eyes, etc.), craft glue, hot glue, a bowl of water in case of burns, scissors, and markers. The puppet-building process was simple enough for our target age group to accomplish, though the hot glue will require some supervision. These puppets came together in a way that allowed for easy access for inclusion of technology, and they are durable and complex enough to offer many options for applications of students' ideas.

Figure 6: Making cloth puppets at the Center for Puppetry Arts

Once we had a better understanding of how the puppets were made, we took them back to the lab to wire them up with LED's and conductive thread to embed possible electronic circuits. To encourage collaborative play, we experiment with distributing the circuit across two puppets by putting the battery in one, and the LED's onto the other so that they light up only when the two puppets come in contact with each other to complete the circuit.

The final part of the design process was to invite the puppetry workshop organizers over to our lab so they could give us feedback on our concepts and to check the kinds of interactions that are permissible for children attending the puppet building workshops. Although they appreciated our use of technology to improve puppet interaction, they were concerned about our concept of collaborative play. Our design had conductive materials in the mouth of one puppet and the hand of the other, so the circuit is complete when one puppet bites the other on the arm. We were informed about how the center tries to consciously avoid interactions like biting, punching, pushing and poking while designing their plays for younger audiences. It would therefore, behoove us to follow similar guidelines when including technology in our puppet interactions.

6. FUTURE WORK

Going forward, our aim is to use the paper and cloth puppets designed at the center as a base for us to build our technological exploration upon. This approach has the two-fold advantage of

1. Leaving puppet building in the hands of the experts, while we concentrate on the technical aspects of the workshop
2. Allowing us to more easily integrate our electronics workshop with the puppet building one, so students can learn it as a whole and not two distinct parts.

We will continue to work with our current collaborators at the Center for Puppetry Arts to organize a final workshop for evaluation. This evaluation will consist of retrospective pre and post test attitudes surveys and pre / post content knowledge assessments. It will use pre / post surveys to assess attitudes towards computing and self-efficacy.

7. CONCLUSION

Our goal behind building these Power Puppets is to design a series of workshops that will introduce students to the concept of building interactive paper and cloth puppets. The workshops are not a goal in and of themselves, but the means to an end, namely enabling students to take control and solve problems, and build creative working hardware prototypes. Given how pervasive technology has become, it is vital that we prepare children to not only use technology but to be reflective about how it works on the hardware level as well. We hope these exercises and workshops give children the necessary hands on experience to equip them with the basics of puppet building and electronic circuits, from which they can develop more creative and imaginative contraptions that will lead to a future based on imagination and creativity.

8. REFERENCES

[1] Berzowska, J. and Coelho, M. 2006. SMOKS. *CHI '06 extended abstracts on Human factors in computing systems - CHI EA '06* (New York, New York, USA, Apr. 2006), 538.

[2] Bottoni, P. et al. 2008. CoPuppet : Collaborative Interaction in VirtualPuppetry. *Transdisciplinary Digital Art. Sound, Vision and the New Screen*. 326–341.

[3] Brosterman, N. and Togashi, K. 1997. *Inventing kindergarten*.

[4] Buechley, L. et al. 2007. Towards a curriculum for electronic textiles in the high school classroom. *ACM SIGCSE Bulletin*. 39, 3 (Jun. 2007), 28.

[5] Buechley, L. and Eisenberg, M. 2009. Fabric PCBs, electronic sequins, and socket buttons: techniques for e-textile craft. *Personal and Ubiquitous Computing*. 13, 2 (Aug. 2009), 133–150.

[6] Buechley, L. and Perner-Wilson, H. 2012. Crafting technology. *ACM Transactions on Computer-Human Interaction*. 19, 3 (Oct. 2012), 1–21.

[7] Coelho, M. 2009. Pulp-Based Computing : A Framework for Building Computers Out of Paper. (2009), 3527–3528.

[8] Cruz-Martín, A. et al. 2012. A LEGO Mindstorms NXT approach for teaching at Data Acquisition, Control Systems Engineering and Real-Time Systems undergraduate courses. *Computers & Education*. 59, 3 (Nov. 2012), 974–988.

[9] Hertz, G. 2009. Methodologies of Reuse in the Media Arts: Exploring Black Boxes, Tactics and Archaeologies. *Digital Arts and Culture 2009*. (Dec. 2009).

[10] Kaihou, T. and Wakita, A. 2013. Electronic origami with the color-changing function. *Proceedings of the second international workshop on Smart material interfaces: another step to a material future - SMI '13* (New York, New York, USA, Dec. 2013), 7–12.

[11] Kuznetsov, S. et al. 2011. Breaking boundaries. *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11* (New York, New York, USA, May 2011), 2957.

[12] Mapes, D.P. et al. 2011. Geppetto: An Environment for the Efficient Control and Transmission of Digital Puppetry. *International Conference on Virtual and Mixed Reality: Systems and Applications*. 270–278.

[13] Marshall, P. et al. 2004. PUPPET: Playing and learning in a virtual world. *International Journal of Continuing Engineering Education and Life-Long Learning*.

[14] Martin, P. and Johnson, E. 2011. Constructing and implementing motion programs for robotic marionettes. *Automatic Control, IEEE …*. 56, 4 (2011), 902–907.

[15] Mazalek, A. et al. 2011. I'm in the game: Embodied puppet interface improves avatar control. *Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction (TEI '11)*. (2011), 129–136.

[16] Mellis, D.A. et al. 2013. Microcontrollers as Material : Crafting Circuits with Paper , Conductive Ink , Electronic Components , and an " Untoolkit ." (2013), 83–90.

[17] Peppler, K. 2013. STEAM-Powered Computing Education: Using E-Textiles to Integrate the Arts and STEM. *Computer*. 46, 9 (Sep. 2013), 38–43.

[18] Perner-Wilson, H. 2011. *A Kit of No Parts*. Massachusetts Institute of Technology.

[19] Resnick, M. and Rosenbaum, E. 1993. Designing for Tinkerability. *M. Honey & D.E. Hunter (Eds.) Design, make, play* (Routledge, London, 1993), 163–181.

[20] Resnick, M. and Silverman, B. 2005. Some reflections on designing construction kits for kids. *Proceeding of the 2005 conference on Interaction design and children - IDC '05*. (2005), 117–122.

[21] Saul, G. et al. 2010. Interactive paper devices. *Proceedings of the fourth international conference on Tangible, embedded, and embodied interaction - TEI '10* (New York, New York, USA, Jan. 2010), 205.

[22] Tillis, S. 1999. The Art of Puppetry in the Age of Media Production. *TDR/The Drama Review*. 43, 3 (Sep. 1999), 182–195.

[23] Walser, R. 1990. Elements of a Cyberspace Playhouse. *Proceedings of the National Computer Graphics Association* (Anaheim, CA, 1990).