Evaluating Accessibility in Fabrication Tools for Children

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ABSTRACT
In recent years, several new threads of research have found their way into the Interaction Design and Children community. Two of these threads-designing for children with special needs, and designing fabrication activities for children-have been especially fertile grounds for discussion and reflection. The intention of this workshop to bring interest to these two realms simultaneously by choosing to look at children's fabrication activities through the lens of accessibility. This paper presents the initial challenges of this enterprise, frameworks and best practices for inclusive fabrication activities with children, examples of current relevant research, as well as discussion and conclusions.

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1. INTRODUCTION
The Interaction Design and Children community has long shown interest in designing experiences and interfaces that engage children in fabrication activities. We recognize that building, sculpting, crafting, and physical model manipulation can be powerful learning tools for a wide variety of concepts, and that these practices can be effective across age, gender, and skill level. Recent IDC papers touching on these kinds of embodied and kinesthetic learning activities include a discussion of designing tangibles for learning[2], several examples of supporting programming and algorithmic thinking through tangible interfaces [14][13], and a workshop on digital fabrication for educational contexts at IDC 2012[8].

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There has also been a recent increase in the IDC community of examining interaction design for children as it applies to accessibility. In the past few years, IDC has accepted full papers on open-ended tangible environments for children with disabilities[5], supporting design contributions of children with Autism spectrum disorders [4], as well as several poster presentations and last year's workshop on interactive technologies for children with special needs[1].

Given these two strains of research, a workshop addressing the accessibility of fabrication tools for children is not only relevant and timely to IDC, but also to a larger set of designers, researchers, educators, and occupational therapists as well. We encouraged submissions that dealt with any combination or subset of three main topics: presentation of fabrication tools for children through the lens of accessibility, principles for accessible design that can be applied to these tools, and specific activities and strategies that can be used to introduce these tools to children with developmental and physical disabilities.

As the papers we received often covered several of these topics, this paper will highlight the contributions of the workshop participants in each of the topics as opposed to a paper-by-paper breakdown. This is followed by a discussion of some of the larger themes brought out in our workshop, and ends with conclusions and potential next steps to take in the realm of accessibility design in fabrication tools for children.

2. INITIAL CHALLENGES
As Hurst and Kane bring up in their paper, there are some significant hurdles to clear in both the creation and adoption of assistive technologies as well as in enabling not only children, but children with disabilities to 'do-it-themselves'. We identified two separate but equally important challenges: the high rate of abandonment among users of assistive technology, and the lack of appropriate fabrication tools for those with disabilities.

2.1 Assistive Technology Abandonment
One of the primary hurdles in assistive technology design is abandonment. The numbers are shocking: in a study of over 200 adults with disabilities, almost 1/3 of assistive technology devices were abandoned[10]. The reasons for this high attrition rate involve lack of agency in selecting the device, ease (or lack thereof) of obtaining a device (i.e., a user will pick an inferior device if it is easily obtainable), how well a device works, and a change in user ability that causes the device to no longer fit the needs of the user. While this study was run with adults, there is no reason to suppose that these motivations would be much different with children, and serves as a baseline set of motivations from which to work.

2.2 Inaccessible Tools
It is plausible to think that if children were making and modifying their own assistive technology, many (if not all) of the aforementioned abandonment motivators would disappear. There is no greater agency one can take over a physical object than making it oneself. Due in part to this sense of agency, a child may be more inclined to fix their device (or seek help in getting it fixed) as opposed to tossing it away. Similarly, through the act of making and then using a device a child may form some good ideas of how to improve it. Further, if their needs change they already have the know-how to adapt their device to a new set of constraints. Yet if we think of the typical tools one might want to use for making (e.g., a drill press, chop saw, hammer and nails, soldering iron, sewing machine) it is evident that not only are these tools not accessible to a large portion of the disabled population, they are potentially dangerous for children with disabilities.

3. FRAMEWORKS FOR INCLUSION
As Hurst suggests, if we can get people with disabilities making and modifying their own assistive technology, they may be less likely to abandon it; however, traditional shop tools are ill-suited to children with disabilities. Hurst suggests two practical resources for inclusion via online communities and digital fabrication, while Alper and Peppler provide a broader framework for inclusive design based on work by Resnick and Silverman.

3.1 Online Communities
A crucial element in the rise of 'maker' culture has been the availability of information and the willingness of online communities to share projects, write how-to demos, and answer questions from aspiring makers. Sites like Instructables[6] contain literally thousands and thousands of guides on making almost anything. Although discussions about web accessibility are outside the scope of this discussion, our experience has been that most children with disabilities have some method of accessing information on the web (e.g. screen readers, closed-captioning tools), making it a viable option for a wide audience.

3.2 Digital Fabrication
Traditional shop tools often require quite significant dexterity, standing, and strength and are unapproachable from certain heights or angles, making them inaccessible for most children with disabilities. However, there is now another class of tools referred to as 'digital fabrication' technologies that are far more accessible. These machines, like laser cutters and 3D printers, take input in the form of a digital file and perform the actual fabrication autonomously; meaning that if a child can produce the appropriate digital file at a computer, she can use the tool.

3.3 Low Floors, High Ceilings, Wide Walls
Alper and Peppler both point to Resnick and Silverman's reflections on designing construction kits for kids[11] as a useful framework to think about more generally inclusive design principles. In their paper, Resnick and Silverman describe three design constraints using architectural metaphor: low floors, wide walls, and high ceilings. Low floors indicate a low barrier to entry, providing simple concepts and examples to encourage a child to get started without feeling frustrated or getting lost. High ceilings allow for continued growth and increasingly complex projects, and wide walls imply multiple paths for self-expression and plenty of space to explore.

3.4 Ramps, Ladders, Frames, and Corners
While Resnick and Silverman provide a wonderful foundation, their framework is not specifically designed for children with special needs. Alper responds to this with some thoughtful additions: low floors with ramps, high ceilings and tall ladders, wide walls and frames of interest, and reinforced corners. Alper argues that in a mixed-ability maker culture, extra steps need to be taken to ensure a broad spectrum of participation. Adding ramps to low floors ensures that however easy a kit might be for normal kids, sometimes further modifications are necessary to put a technology within reach for children with disabilities. Similarly, along with high ceilings, tall ladders may be necessary to help a child with special needs reach their full potential. By scaffolding technologies with a high ceiling such as 3D printers, we can ensure that tools are used to their fullest potential. Alper also points out that while many children prefer wide walls and a diverse range of options for personal expression, some children, such as those with an Autism Spectrum Condition (ASC), may prefer focusing on more repetitive tasks using a specific set of tools, actions, or characters she refers to as 'frames of interest'. Finally, Alper suggests that in the corners where the widest walls, highest ceilings, or lowest floors meet, children with special needs require extra support in the form of reinforced corners. Many kids with disabilities are exceptionally talented and capable of incredibly sophisticated work, but may require specific adaptations or support in order to reach their full potential.

4. EXAMPLES
In addition to the kinds of support needed to enable children with disabilities to participate in fabrication, several authors provided examples and discussion centered around specific technologies or research that are particularly well-suited for enabling kids with diverse abilities to create and produce. Between the authors, six technologies were mentioned: Squishy Circuits, Scratch, E-Textiles, VizTouch, the Easy Make Oven, and MaKey MaKey.

4.1 Squishy Circuits
Squishy Circuits[7], developed by AnnMarie Thomas, consist of two kinds of play-doh; one is conductive, the other not. By layering conductive and non-conductive play-doh in different configurations, simple, tangible, 'squishy' circuits can be made and hooked into simple electronics.

4.2 Scratch
Scratch[9], developed at the MIT Media Lab's Lifelong Kindergarten group, is a drag-and-drop graphical programming environment for kids. By abstracting away confusing syntax and replacing it with different shapes of blocks, Scratch allows children to explore and experiment with programming in a more intuitive way. For fabrication, Scratch hooks in to some electronics boards, like the MaKey MaKey (mentioned later) and the Pico board, which has sensors, sliders, and other easily accessible inputs for kids to experiment with.

4.3 E-Textiles
The e-textiles movement has seen a rapid expansion in the past few years, and has become one of the few female-dominated maker subcultures. Technologies like the LilyPad Arduino developed by Leah Buechley[3], allow children to sew electronics into fabric with conductive thread, instead of having to use wire and a breadboard or a soldering iron. Other kinds of e-textiles like conductive paints, tapes, and Velcros are even easier to manipulate.

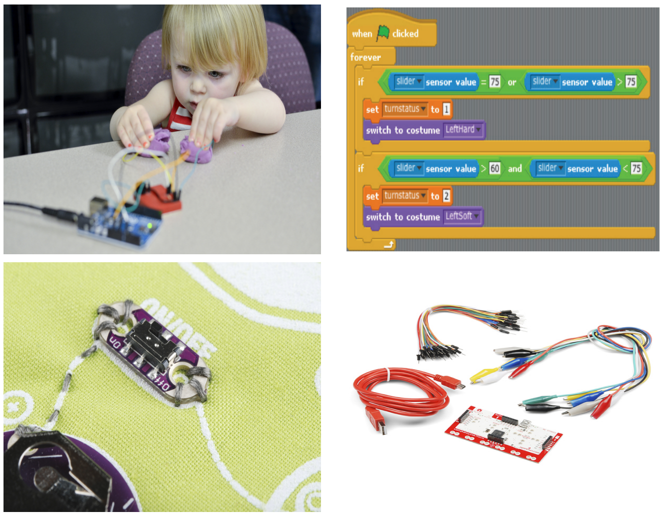

Figure 1: Clockwise, from upper left: A two-year old playing with squishy circuits, a snapshot of the scratch programming environment, some e-textiles work with the LilyPad Arduino, the MaKey MaKey kit.

4.4 VizTouch

Many mathematics concepts are best understood through visual graphs. Unfortunately for users with little or no vision, these visual aids are unavailable for them and often make the underlying concept difficult to grasp. In response, Hurst's group at the UMBC created VizTouch, a software tool that generates a 3D printable tactile graph of any mathematical graphing function imported from Excel. By manipulating the graph and feeling out the axes and the curve of the line, blind children can access these math concepts in a sensory, tactile way that helps facilitate the understanding and learning of these otherwise inaccessible ideas.

4.5 Easy Make Oven

Hurst and her team have also created the Easy Make Oven, an interactive tabletop that scans real objects placed on it and creates a digital copy of them. This copy can be manipulated with a simple set of gestures that perform common 3D modeling tasks such as scaling as well as combine multiple scanned objects together into one model. These scanned models can then be exported as 3D-printable files, allowing the creation of physical objects by novice users without 3D modeling experience.

4.6 MaKey MaKey

The MaKey MaKey[12] is a kit designed by Rosenbaum and Silver to let anyone use the objects from their everyday surroundings as a construction kit. The MaKey Makey works by essentially tricking your computer into thinking that (just about) anything you hook up to the MaKey MaKey board is actually your computer's keyboard whereby different objects connected to the MaKey MaKey essentially 'turn into' key presses. The board uses alligator clips for connections and high-resistance switches to turn everyday objects into interactive toys (e.g., turn a bunch of bananas into a piano, or play Mario Bros. with a play-doh controller).

In fact, Rosenbaum has seen the kit used in many unexpected ways, many of them for children with disabilities: a custom game controller glove by for a child with Cerebral Palsy, a play-doh interface for a teenager with limited motor control to play a car racing game, and even 'haptic bracelets' to help visually impaired users control their mobile devices. Rosenbaum attributes the popularity and success of the MaKey MaKey to an emphasis on simplicity and flexibility in design. Moving forward we expect to see an even more diverse audience using the kit, including further work by those working on accessibility and fabrication with children.

5. DISCUSSION

There is some undoubtedly great work being done to enable children with disabilities to participate in DIY and fabrication activities, and we believe that this is a trend within the IDC community that will continue to see some growth in coming years. However, it is worth taking a critical look at some of the ideas and technology presented as well as examining what was *not* presented.

As Hurst and Alper point out, there is no 'one size fits all' solution in this domain. As diverse as able-bodied children are, children with special needs are often more so, sometimes needing highly individualized designs in order to succeed. The MaKey MaKey is an excellent example of embedding flexibility in design, as it can be used with many different physical objects and appears as a standard USB keyboard to the computer, requiring no special software or programming. Even so, those with poor motor control may have problems connecting the alligator clips, especially with sweaty fingers. The Easy Make Oven is an incredibly empowering way to introduce all kinds of kids to 3D fabrication tools. Yet without an alternate means of input, the gestural modeling commands will be out of reach for some. We point out these truths not as criticisms, but as testaments to the nature of inclusive design-simply because a device is not universal does not in any way make it inaccessible or unworthy of development.

While we did see some excellent examples of research that concerns accessible fabrication tools, we would of course like to see more, especially in the vein of enabling children to make, modify, and hack their own projects. While we believe that interfaces for digital fabrication technologies like 3D modeling and laser cutting are crucial, what about making simple tools more accessible? How do we make more accessible hammers, wire strippers, or soldering irons? What are the basic building blocks of building? Can we create a more-broadly accessible tool-chain from the ground up?

For the moment these questions remain completely open. It is our hope, in the recognition of great thinkers from Froebel to Papert who realized how valuable physical interaction and manipulation can be to childhood development, that we as a community do not relegate accessible fabrication solely to the creation of digital files, but that we search as well for truly embodied fabrication experiences for everyone.

6. CONCLUSIONS

We have brought together the two research themes of accessible design and children's fabrication activities in the hopes of bringing to light worthwhile approaches and current research that ties these areas together. We found truly enlightening theories for design and engagement, as well as inspiring examples of current research that is empowering children to take greater control of their disabilities. While there is no silver bullet of accessible design, we are very encouraged by current efforts and present a challenge to the community to continue to work on these challenging but rewarding problems.

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