

The Talking Makerspace: An Inclusive Audio-Tactile Display for Learning About Making

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ABSTRACT

Makerspaces are becoming increasingly prevalent within both informal and formal spaces. Part of the appeal of makerspaces is their ability to democratize design and invention. Despite this appeal, many makerspaces still present considerable barriers to participation for people with disabilities. This is particularly disheartening because prior research highlights the ways that tools like 3D printers and laser cutters can, for example, be revolutionary in their ability to quickly create tactile media for people with visual impairments. In this paper, we present a tool that aims to provide a more inclusive introduction to Making, targeted specifically toward people with visual impairments. Our tool introduces users to digital fabrication methods such as 3D printing and laser cutting through a combined auditory and tactile experience. As users interact with a smart speaker and physical objects, they learn the fabrication process behind different artifacts produced within the makerspace, without the need for vision. We see this as an important shift in defining who is implicitly and explicitly included within the Making community. As we continue this work, we hope to move beyond this first step and encourage more makerspaces to actively take steps to be more inclusive.

Tools, Skills and Materials

• Tools→Smart speakers • Tools→Digital fabrication • Skills→Making

Keywords

Makerspaces; digital fabrication; accessibility; visual impairment

1. INTRODUCTION

While the Maker Movement has touched the lives of many people all around the world, a problematic reality is that many people have yet to gain access to tools of digital fabrication and invention. For some, the barriers are economic, as joining a Makerspace can be prohibitively expensive. For others, it is a matter of having access to such a space within one's home community. Still for others, the problem is deeply rooted in the inaccessibility of the machines themselves. This has been a considerable obstacle for people with disabilities. Furthermore, one of the largest issues with makerspace accessibility has been a lack of clarity surrounding who and what makerspaces are for. Without this knowledge, many Makerspaces do not get frequent use among people with disabilities [6]. The disability advocacy community constitutes a wide spectrum of abilities and concerns. In this paper, we will focus on people with visual impairments. Specifically, there have been concerns about the inaccessibility of the Maker Movement to blind and visually impaired (BVI) people [7], which is problematic because of the many benefits that Making can provide them. For example, 3D printing makes the creation of tactile educational aids for BVI students much more accessible to teachers and other stakeholders [5].

The inaccessibility of makerspaces demonstrates a larger issue: makerspaces rarely reflect their educational uses in their physical design. Most provide the necessary tools for prototyping, fabrication, and other Making activities, and many also provide knowledgeable staff that serve the role as educators. But the space itself is rarely designed with education in mind: they usually lack educational aids, written or visual explanatory information, or other physical artifacts designed to teach. And out of the few that do provide such aids, almost none provide the necessary support for BVI people to properly understand how Making is done.

2.1 Accessibility in The Garage Makerspace

In order to contextualize this work, we focused on improving accessibility for BVI users in a local makerspace: The Garage Makerspace at Northwestern University. While this makerspace was designed for entrepreneurial students who need to prototype with hardware, it has

since become more of an educational space due to the high number of visitors The Garage receives every day. In conversations with employees at The Garage, we learned that several tour groups of prospective students visit daily, as well as other groups of visitors who schedule their own visits. A staff member of The Garage usually gives these groups a guided tour, bringing them to the Makerspace and offering a high-level overview of its uses. The Garage staff have found that visitors are rarely familiar with the digital fabrication tools in the space and how they work. Therefore, objects made with the equipment are used as visual aids to help visitors better understand what the different machines can produce. While there is an inherently tactile element to these objects, their tactility is currently underutilized, preventing people with visual impairments from understanding how the digital fabrication tools at the Makerspace are used to produce the objects. Further, The Garage staff often use the tools themselves as a strictly visual aid to explain how they work, once again excluding those with visual impairments. This is especially true since the tools are dangerous to touch when in operation and therefore cannot provide an equivalent tactile experience.

Particularly within The Garage Makerspace, which welcomes visitors new to Making every day, we think there is a gap in educational tools that can enable people with visual impairments to understand how maker equipment works. Therefore, we redesigned the front desk of The Garage Makerspace, utilizing its existing visual aids within a multimodal interactive experience that combines a tactile display with a conversational user interface.

We consider tactility to be a crucial component of our project, not only because it is a clear affordance of objects produced in makerspaces, but also because it has long played a role in design for BVI users. This includes tactile maps [9] that can help BVI users navigate physical spaces and tactile pictures [8] that allow BVI children to enjoy picture books. And since maker equipment enables the easier creation of aids such as tactile maps [4], we wanted to include examples of these aids within our solution.

2. DEMO DESCRIPTION

Our project is inspired, in part, by commercial voice assistants. While their increasing popularity has also benefited BVI users, they still are not designed intentionally for people with disabilities, and there are many shortcomings in their level of accessibility for BVI users [2][3]. We therefore focused on designing a solution specifically with BVI users in mind.

We created an interactive display that combines a conversational user interface with tactile elements to help BVI users understand how maker equipment is used. Our display is placed at the front desk of the Makerspace, which is where visitors first enter the room (Figure 1). An Amazon Echo Dot configured with a custom Alexa skill provides the conversational user interface, while the display consists of five individually labeled examples of objects made with maker equipment. Each object was produced by a different digital fabrication tool: the Formlabs Form SLA 3D Printer, the Inventables Carvey CNC router, the Makerbot Z18 FDM 3D printer, the Ultimaker 3 FDM 3D printer, and the Glowforge Pro laser cutter. Each object is attached to a small platform that supports the labels, which are in Braille and standard text (Figure 2). These platforms ensure the labels are consistently located across the objects, allowing BVI users to more easily identify them.



Figure 1: Our tool is located on the front desk of The Garage Makerspace. Each object has an attached platform that supports the labels, ensuring consistent labeling.



Figure 2: A closeup of the Form object. This object was printed by The Formlabs Form 3D printer, and it is now used in the tactile display to inform visitors about how the Form works. Notice the attached platform, labeled in Braille and standard text.

The conversational user interface is launched by asking Alexa to “open the Makerspace guide” (or by using similarly-worded phrases). After giving a brief introduction to the Makerspace and the tactile display, Alexa will wait for a question from the user. The user can then ask about any of the objects, which will begin a conversation. Alexa will adapt its explanations of the objects and maker equipment based on the prior knowledge of the user, which it gauges by asking its own questions. In its explanations, Alexa will constantly refer to the tactility of the objects as it explains how each one was fabricated, ensuring that the descriptions can be understood without the use of vision. For example, if the user asks Alexa about the object made with the Form 3D printer, it will begin a dialogue:

User: *“Tell me about the Form.”*

Alexa: “The Form is a 3D printer. Do you know what a 3D printer is?”

User: *“Yes.”*

Alexa: “Great! Most 3D printers use heated plastic filament to create objects. This one is different because it uses stereolithography, which means it has a laser that cures a liquid resin into a solid. As you pick up the object, you may notice that

it is pretty heavy. That is because the resin is much denser and more durable than filament used in other types of 3D printers. As you run your hands over the print, you will also notice you cannot feel the individual layers. That is because they are only 25 microns thick, which is even thinner than a human hair. Such precise prints take a lot of time. This print took over 24 hours to make.”

If the user had responded that they didn’t know what 3D printers are, Alexa would have adjusted its response to something simpler:

3D printers slowly build a three-dimensional object layer by layer. The Form is a special 3D printer because it can make very precise and smooth prints. The layers in this object are even thinner than a human hair! But making such precise objects is slow. This print took over 24 hours!

The conversational nature of our prototype is designed to help the display work with a wider distribution of users, while also making it more approachable and intuitive than other types of auditory interfaces. We also wanted to focus on drawing comparisons between the different objects in our explanations, as this provides another useful way of understanding the many types of digital fabrication tools. Therefore, the explanation we give for one object often compares and contrasts with other object(s), encouraging the user to continue exploring our display and building their knowledge of Making.

Lastly, our solution was designed to fit seamlessly into The Garage Makerspace by utilizing the existing objects that were already located on the front desk of the Makerspace. However, since our goal was also to include examples of tactile aids for BVI users, we used a tactile map of Northwestern University that we 3D printed using the Ultimaker as one of the objects. For the tactile map, our explanation encompassed not only how the map was made, but also how it demonstrates the appeal of 3D printers for BVI users.

3. CONCLUSION

2.1 Lessons Learned

While we began our design process by trying to help BVI visitors to The Garage Makerspace locate particular digital fabrication tools, we realized the space had bigger issues with the accessibility of understanding how its equipment is used, not necessarily knowing where it is. This is especially true since most of its visitors are only passing through to learn about Making at The Garage Makerspace, not to use the space itself. Therefore, our prototypes are centered around providing visitors with information about Making, no matter what their prior knowledge may be.

Our design could be improved in the future by integrating other materials that may provide a richer tactile experience. For example, layers of cardboard could be used to create a magnified, low-resolution model of how a 3D print is constructed. We could also include parts of the digital fabrication tools, such as a 3D printer extruder, to better illustrate the technology involved in Making. We also look to further expand the conversational aspects of the interactive experience. We want the user to be able to ask more complex questions (e.g. “How can I use a 3D printer?”, “What’s the material made out of?”, etc.), and we want the interface to be able to ask the user more nuanced questions, which would allow the conversational experience to be further tailored to each user. Conducting formal user testing, specifically with BVI users, would also give us concrete feedback about whether our idea actually reaches individuals with visual impairment and introduces them to the space in a comprehensive, inclusive manner.

A natural extension of our prototype would be a non-visual tool for helping BVI users participate within the Making process itself. While the majority of our design process was focused on building an educational aid, there are currently few ways for BVI users to participate in Making with digital fabrication tools. Further work could better develop ideas surrounding the use of auditory and tactile interfaces for makerspace equipment. For example, while existing work has explored the use of a tactile interface for CAD [1], our combined auditory and tactile approach could be more advantageous for BVI users of digital fabrication equipment.

2.2 Broader Value

Our tactile display has been used as a tool to introduce visitors to The Garage Makerspace. We observed a mother and daughter walk up to the front desk, interact with the objects displayed in our design, and then ask a staff member at The Garage about the different 3D printers used to create these objects. These particular visitors were not vision impaired, so they could see all of the relevant equipment, but they still proceeded to use touch and sound to interact with our design and learn about the larger makerspace. We observed the visitors use touch to identify the distinct textures of the objects and use conversation to learn about the purposes of the individual printers. This observation reinforces the aims of our idea to increase the reach of makerspaces through multimodal interactions for anyone who is unfamiliar with the equipment and purpose of a given makerspace.

The display portion of our prototype is now used on a daily basis for tour groups, but the interactive audio guide has not yet been used at The Garage Makerspace. However, we got the chance to test our tool at Northwestern’s Inclusive Making Expo. We had encouraging results from our informal testing. Users said that they liked that Alexa drew specific comparisons between the different objects on display. One user stated “I like how the descriptions have to do with specific, physical objects, and not just the equipment”. This user appreciated that the descriptions offered by Alexa were less abstract because the audio content was directly connected to the object they were feeling. Importantly, the users had fun using the device. Users specifically said that the conversational interactivity of Alexa was engaging and entertaining. This shows that an interactive conversational interface can be a fun learning tool to introduce users to Making and Maker equipment. As a success story, our tool provides evidence that technological devices can be implemented to improve the educational value

of a makerspace in an inclusive way. Thus, while we did not run a robust user study, we were pleased with the positive reactions to our tool from visitors and staff at The Garage and at the Inclusive Making Expo.

2.3 Discussion

Even though our design was primarily made for people with visual impairments, its benefits are far reaching. Within the current context of The Garage Makerspace, it offers a detailed explanation of the different example objects and their manufacturing process. Additionally, the tool's ability to explain how maker equipment works provides an important service to visitors with visual impairments, as the previous explanations used by guides primarily relied on vision. More generally, our tool could be employed in diverse types of makerspaces and educational spaces, offering an explanation of any kind of handheld object produced by digital fabrication tools. By supplying a tactile and auditory way to experience the products of a makerspace, the space becomes more accessible to visitors who may not otherwise have a clear understanding of what the tools can do.

While there are many limitations to our prototype, we see it as an important step forward in inclusive design for makerspaces. Providing an interface that BVI people can use without any guidance is a valuable way to increase their independence. The inclusion of our design within a makerspace is an important and intentional signal of the space's inclusivity that may not be provided consistently by a human guide. Our Alexa app also provides an inexpensive source of expert knowledge, ensuring that a makerspace can always have an accessible information repository without concerns for staffing. And since our tool doesn't rely on a human guide, it can scale to larger spaces where learning is often unassisted, such as museum exhibits.

Taking a step back, this demonstration aims to highlight a greater need within the Making community to develop tools that promote accessibility. Making and digital fabrication have the potential to advance significant personal agency and innovation, but before that can happen, we must do a better job of including more people in these spaces. This demonstration is a first step, in a localized context, but our goal in sharing this work with the larger FabLearn community is to grow awareness, concern and possible solutions for issues of accessibility and Making.

5. BIOS

Gabriel Caniglia is a recent graduate of Northwestern University, where he received degrees in Computer Science and Cognitive Science. His interests span human-computer interaction and immersive technologies. He now works in Boston as a software engineer.

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Thomas Young is a student at Northwestern University, where he studies Computer Science and Cognitive Science. He is interested in what lies at the intersection of mind and machine through the study of human-centered artificial intelligence.

Marcelo Worsley is an assistant professor of Learning Sciences and Computer Science at Northwestern University. A driving motivation for his research is to promote diversity, inclusion and equity in Makerspaces.

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