Coming to Grips:
3D Printing for Accessibility

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ABSTRACT
In this demonstration, we discuss a case study involving a student with limited hand motor ability and the process of exploring consumer grade, Do-It-Yourself (DIY) technology in order to create a viable assistive solution. This paper extends our previous research into DIY tools in special education settings [1] and presents the development of a unique tool, GripFab, for creating 3D-printed custom handgrips. We offer a description of the design process for a handgrip, explain the motivation behind the creation of GripFab, and explain current and planned features of this tool.

Categories and Subject Descriptors
K.4.2 [**Computers and Society**]: Social Issues – *Assistive technologies for persons with disabilities*

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Design; Human Factors.

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3D Printing; Assistive Technology; Children; Digital Fabrication; Developmental Disability; Motor Impairment; Rapid Prototyping; Special Education

1. INTRODUCTION
Historically, assistive devices and custom accessibility solutions have been costly and offered little in the way of selection. With the "maker" movement, a resurgence of the Do-It-Yourself (DIY) culture, there is an opportunity to create individualized and low-cost assistive technology (AT) solutions and to empower end-users to create those solutions themselves. Our current research has explored the role of making in special education by introducing 3D printing to students with cognitive and developmental disabilities [1]. In working with students, faculty, and support staff at a special education facility, we have identified several uses for 3D printing in this setting, including Science Technology Engineering and Math (STEM) encouragement and employability skills for students, tactile objects to promote accessible education, and a means to create assistive aides and AT-friendly modifications to existing technologies. In this paper, we discuss an example of a 3D-printed assistive aide created in collaboration with occupational therapists at this site.

As part of a 6-month long study evaluating 3D printing at the investigation site, we spoke with two occupational therapists (OTs) about the accessibility needs of the students on campus. We worked with these OTs to develop a specialized stylus grip for a student with motor impairments who was not able to hold writing implements unassisted. This paper presents the design process we embarked on with the therapists, reflects on obstacles, and introduces GripFab, a simple software interface for generating specialized 3D-printable handgrips to assist in holding various objects. We believe tools like GripFab can empower persons with disabilities and other users to create functional assistive devices with entry-level DIY technologies.

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Figure 1. A custom 3D-printed grip designed to hold a stylus.

2. DESIGN PROCESS
During our 6-month evaluation of a special education facility, we spent 2 months working with OTs on a project for a student with limited grasping capability that was negatively impacting the student's ability to write and use the iPad. We developed a set of requirements and conducted a series of iterative prototyping sessions to arrive at a 3D printed solution to this challenge.

2.1 Gathering Requirements
We interviewed two OTs who regularly administer therapy sessions with this student about their prior unsuccessful explorations helping this student access an iPad using off-the-shelf products. They found the cushioned pen grips and ergonomic styluses were designed to provide support and comfort to a person without a motor impairment rather than to supplement a person with reduced hand strength and a different gripping position. They also described the different methods they used to create workarounds with common crafting supplies such as tape, cardboard, and air-dry clay. These DIY solutions were not uncommon in their work, but the OTs stated that they were not durable and frequently failed after repeated handling.

2.2 Prototyping and Iteration

Based on the therapists' previous explorations with off-the-shelf solutions and crafting, we suggested utilizing 3D scanning technology to transform their ephemeral modifications into a more permanent 3D-printed object. The OTs created three air-dry clay models of the student's hand and unique grip. Two of the designs featured a cuff-like ring fitted to the student's thumb for support and the third was a small wedge intended to augment the stylus similar to a traditional soft pencil grip. We scanned all three designs with the Makerbot Digitizer. The Digitizer creates a 3D model, stored as a stereolithography (.stl) file, for use with CAD software. We then took the models and performed minimal edits to smooth out the bumps and cracks from the clay and to create geometric openings where a pen or stylus could be inserted into the grip. After these modifications, we 3D-printed plastic prototypes of the grips using a Makerbot Replicator 2x.

The therapists conducted test sessions with their student to see which grip shape worked best. The thumb-cuff designs caused discomfort for the student and the wedge design proved to be too tiring to hold, and so the therapists opted to create a new model from clay. This second model was again digitized by us, edited for form and function, and then 3D-printed for testing.

In the second evaluation, the new grip shape was deemed more comfortable (see Figure 1). Instead of using a cuff, this grip took advantage of the student's resting grasp enabling her to keep the grip in her hand without discomfort yet still allowed the student to press down firmly for writing or making selections on an iPad. This new shape was successful in the short-term, but after extended use the therapists made note of new challenges.

After building our first successful prototype, the therapists wanted to replace the generic stylus that the student had been using with a more responsive, slightly thicker one. The therapists also stated that even though the grip was comfortable, the way the stylus was held in place within the grip forced the student to stretch forward to reach her writing surface. Based on these new criteria, we modified the grip to accommodate the larger stylus and we extended the front of the grip so the stylus would protrude further forward. Instead of reverting to a new clay model, we utilized basic CAD tools to adjust the diameter and length of the stylus insertion point on the existing .stl file.

The revised grip design was 3D-printed and delivered to the therapists for testing. The final version of the grip was tested by the therapists with the student and is functioning correctly. The student now has a highly individualized grip made from a sturdy material that can be reprinted or modified with relative ease.

3. TOOL DEVELOPMENT

In evaluating the stylus grip design process, we noted that there were very few if any steps that required expert understanding of engineering or CAD tools. The biggest barrier to the OTs completing this project on their own was the time and lack of training. The therapists felt that they could master novice design software, but they simply did not have room in their schedules to learn the processes and spend extra time on the 3D model revisions that we provided for them. OTs and other faculty at the investigation site also commented that they would be keen to use a design repository similar to Thingiverse.com, but with content and privacy settings specific to their professional needs. A catalog of existing AT designs would be beneficial, but this would still leave much of the customization up to the OTs.

Based on the success and generalizability of this project, we are developing a tool to automatically generate grips similar to this one, but with an automated design process. We believe this is possible without creating a custom clay model for each person's hand because the grip prototype has been well received by a wide variety of users with diverse hand shapes and gripping abilities.

One of our design goals for this software is to obscure the complexity of the design process from therapists and even end users, so end users could potentially print their own custom grip. We have begun developing GripFab (see Figure 2), a software tool that enables the user to select a basic grip model, scale or mirror it to fit in the desired hand, and then choose from a variety of possible attachments. In our case study, for example, the therapists needed to be able to fit a different size of stylus. GripFab would provide the therapists with the ability to supply the stylus dimensions and then automatically adjust the base model of the grip to accommodate. Behind the scenes, GripFab accepts user-defined measurements and preset grip positions that it processes with OpenSCAD to generate a customized .stl file. The output file can be printed directly without editing. The program can rapidly alter a 3D model as the user presents new needs.

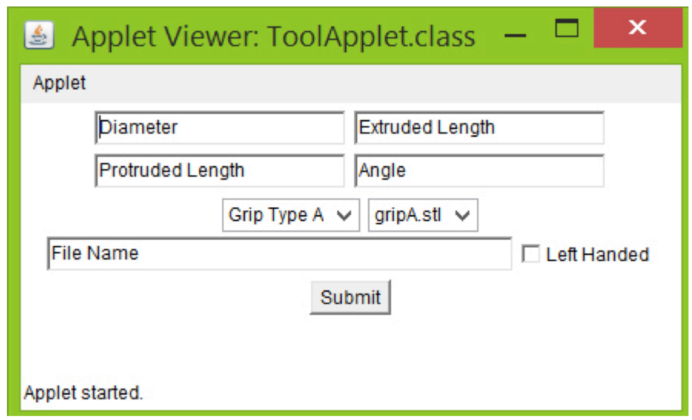

Figure 2. Screenshot of a prototype interface for GripFab.

4. CONCLUSIONS AND FUTURE WORK

We are continuing to develop GripFab and hope to test it with therapists at our original investigation site and other locations. At the time of this writing, the software offers one grip style based on our original grip project, but we intend to explore other generalizable grip postures common to hand/motor impairments. Additionally, we are expanding on the attachments that the program can generate. One example of an alternative attachment might be a grip with a slot for a fork for a modified eating apparatus. With continued testing, we would like to see end-users able to find, modify, and print an assistive grip for themselves without assistance.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Buehler, E., Kane, S.K., and Hurst, A. (2014). ABC and 3D: Opportunities and Obstacles to 3D Printing in Special Education Environments. (*ASSETS'14*).