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Work in Progress: Exploring the STEM Education and Learning Impacts of Socially-relevant Making through the Challenge Problem of Making Prosthetics for Kids

Mr. Jeffrey Craig Powell, UNC Charlotte

Jeff Powell is a graduate student at UNC-Charlotte studying Biological Sciences. He is a graduate of UNC-Chapel Hill's Biomedical Engineering program. As a student at UNC-CH, Jeff started The Helping Hand Project, a 501c3 non-profit and student volunteer group which supports children with upper limb differences. This includes using 3D-printers to create prosthetic devices for children. The non-profit includes chapters at four North Carolina universities, including UNC-Charlotte.

Johanna L Okerlund
Dr. Richard Jue-Hsien Chi, University of North Carolina at Charlotte
Dr. David Wilson

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Growing numbers of learners are engaging in STEM practices and learning through various forms of "Making" [1]. The Maker approach is fundamentally self-driven informal learning that centers on personally meaningful projects using physical and digital fabrication tools, such as 3D printers, to design, prototype, and make creative physical products. Our campus Makerspace is located within the College of Computing and Informatics. Since Fall 2016, it has been open for general use by the entire university community ($\sim$ 30K students), as well as the on-campus engineering early college high school ($\sim$ 400 students). The Makerspace is equipped with a wide variety of fabrication tools and is a specialized laboratory to support peer-driven informal STEM learning and foster a community of practice [2] around Making.

We are investigating the educational impacts of our on-campus Makerspace through an exploratory research project that focuses on a socially-relevant challenge problem: designing and fabricating prosthetic hands for children. The project is in partnership with a regional nonprofit organization that specializes in providing 3D printed prosthetic hands free of charge for children in need. The ongoing research is using this challenge problem to study questions about Makerspace-related learning and to develop the learning materials needed to enrich 3D printed prosthetic development activities for a new person or group. More generally, we are developing learning materials based on this Makerspace's experience that can be used in a variety of educational contexts. This paper provides an early-stage overview of our project, highlighting the challenge problem in the context of research on academic makerspaces.

Challenge Problem

Design and development of prosthetic devices is a common example for classroom learning [3, 4], but these devices are rarely intended for use by people outside of the classroom. The opportunity to create an assistive device for an individual with a limb-difference can be a strong motivator [5]. Basic prosthetic configurations may be based on previously successful designs [6], but each individual case is unique in limb configuration, which also changes as children grow, and designs must be customized. Taking the design and fabrication of prosthetic hands as a challenge problem provides a rich space of targeted STEM learning and design activities across the areas of Computing, Engineering, and Biological Sciences.

By studying learners engaging with this challenge problem, we aim to identify program components that are the most effective at bridging informal and formal STEM learning, and to create an ongoing makerspace community that serves social relevance. Research shows that integration of making approaches can positively impact learning outcomes (e.g., [7, 8]). This is not surprising and follows naturally from constructivist [9] and constructionist [10] learning perspectives. Rather than receiving knowledge through instruction, learners build their own knowledge by building external artifacts. Makerspaces embody constructionism by providing a space, the tools, and a supportive community to drive student-led building projects. Our vision is to create a sustainable living laboratory for self-guided innovation that transforms students and faculty across disciplines from persons with an interest in certain STEM-related projects to persons with a STEM-based affinity identity as Makers. Results will help catalyze and sustain Maker transitions by identifying design patterns for learning that emerge in the Makerspace, which can be applied more generally to foster synergetic interactions between formal and informal learning. This focus on design thinking will support learning from cross-disciplinary interaction, particularly in interdisciplinary peer learning of STEM concepts, exposing non-STEM learners to STEM concepts, and disrupting traditional teacher-student roles.

Initial Activities and Evaluation Design

At this early stage, we are piloting interventions, articulating research questions, and developing the instrumentation for evaluation. Our first two interventions have used variations of the challenge problem in formal university and high school courses: one was an undergraduate / graduate interaction design studio course that focused on exploring novel functionality of the devices with interactive technologies, the other was a group of on-campus high school students in their senior engineering design class who utilized open-source resources to create a prosthetic device for a local child. The high school students communicated directly with the child and his parents and set their own project deadlines, with the idea that this would create a greater sense of accountability than the average school assignment. Our second set of interventions have been in short session ($\sim$ 2 hour) outreach introductions to making and 3D printing, using the challenge problem so that students can engage with a real world application and feel empowered to pursue it further. The third intervention is to instrument entities who are already engaging with this challenge problem. Specifically, we aim to study our own Makerspace and their partnership with a campus student organization that provides 3D printed prosthetic hands for children. By studying these contexts, we can begin to answer maker-related research questions such as: In what ways is this challenge problem (when introduced formally or informally) an effective entry point into Makerspaces, engineering, applying skills for social good, or other related activities? How do sub-communities who are engaging with this challenge problem and the more general open-ended Makerspace community interact with each other? What resources do we need to develop to harness the interest that follows this challenge problem to continue to foster this community-driven innovation and service in a sustainable way? The prosthetics challenge is the primary focus for this research, but other challenge problems could certainly be used to help address these questions. The Makerspace partners with other campus groups that have rich potential for studying challenge problems such as an organization that designs and creates low-cost furniture for children and families in need and a multi-partner effort that has put on a technology fashion show for two years running.

The project evaluation strategy encompasses ongoing formative assessment and routine summative assessment of project outcomes across three project tiers: learning and engagement, dissemination, and lab culture/identity. Given the exploratory nature of informal learning environments and the evolutionary nature of Makerspaces, the evaluative process is also developmental in that both are iterative. Evaluation is being developed by the project contributors as it unfolds, to integrate a responsive evaluation practice, characteristic of organizational learning [11]. The design consists of a mixed-methods approach that includes both quantitative and qualitative measurements to measure the nature of lab use (tools used; time spent), products developed (quantity and quality measures), interactions in the lab space; engagement and knowledge gains surveys; interviews; lab usage (descriptions of participants, tools and products, traffic patterns). Development of analysis and outcome evaluation instruments is guided by impact categories for informal science projects [12]. We are considering assessment of: Awareness, knowledge or understanding; Engagement or interest; Attitude; Behavior; Skills; and Affinity Identity. At the learning tier, measurements focus on knowledge acquisition and transfer between users and communities. Engagement measures focus on activities and exchanges among lab users both inside and beyond the lab, as well as sense of engagement and community. The lab dissemination measures focus on the resources, collaborations and partnerships developed, traits and traffic flow of users, and products (prosthetics, design patterns) made. Qualitative measures include observations, product descriptions, and case study interviews. Quantitative measures are being developed to survey attitudes toward design, creativity, and sense of engagement and flow within the lab, as well as knowledge gains and transfer of knowledge application. Additionally, lab products and tools are being assessed for ease of use from the lab user perspectives, and for learning outcomes produced. We are continuing to run pilot activities through the Spring semester of 2018 and expect to report initial evaluation results in the Summer of 2018.

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