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Aaron D. Knochel

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DIY Prosthetics:

Digital Fabrication and Participatory Culture

Aaron D. Knochel

Cody stood in the front of the class, arm outstretched with a smart phone attached to his wrist, instructing all of us over his shoulder to huddle in for the group selfie. As he reached out to touch the screen, the phone came loose and fell with a crash to the floor.

“I knew that was going to happen,” Cody uttered in frustration.

I suggested he keep searching 3-D model sharing websites like Thingiverse for a suitable 3-D model of a smart phone holder that could be adaptable to many phones. Remember, I advised him, the objective is to think through how your do-it-yourself (DIY) prosthetic can assist in artmaking, in this case photography. He responded, “That’s why I’m prototyping it to take selfies!”

Cody’s experience developing a 3-D printed assistive device for artmaking was a result of curriculum I had developed to explore socially engaged design, assistive technologies, and digital fabrication in particular to this project 3-D printing. I introduced my preservice art education students to a growing field of design practice that focused on developing open source, affordable prosthetics to kids that could otherwise not afford them. Many of these projects involve three important concepts significant to art education: (1) rapid prototyping via digital fabrication; (2) a participatory design process that is enabled by connectivity and sharing; and (3) a commitment to a socially engaged practice of making that collaboratively builds ideation and social good. In the following, I outline my own experience with my university preservice art education students learning about 3-D printing, developing design practices that have deeply embedded participatory frameworks, and exploring the potential for art education as a socially engaged practice that combines creating and making while having positive social impact.

DIY Prosthetics and Socially Engaged Making

In May 2011, South African carpenter Richard Van As suffered an accident in his Johannesburg woodshop resulting in the loss of his index and middle finger and parts of his other two fingers on his right hand. After release from the hospital, he was

researching hand prosthetics and, being frustrated by the few costly options, began prototyping his own models. Van As’s search involved scouring countless online resources and contacting other fabricators and designers through social media, eventually leading him to special effects artist and puppeteer Ivan Owen from Bellingham, Washington. In particular, Van As was inspired by a YouTube video demoing a large mechanical hand where the oversized finger movements are actuated by tendon-like cables (Owen, 2011). The two men began collaborating using various forms of electronic communication, and eventually prototyped a mechanical prosthetic for Van As.

However, that is only the beginning of the story. While Owen was visiting South Africa, they were asked to help 5-year-old Liam Dippenaar, who was born with a rare congenital condition called amniotic band syndrome that had left him with no fingers on his right hand (Henn & Carpien, 2013). The two men agreed and began developing aluminum prototypes for Liam (Owen, 2012). In September 2012, the Robohand project was born. Moving from aluminum to 3-D printing for fabrication methods, the project took on greater momentum with increased capacity to rapid prototype via fuse deposition modeling made possible through the donation of two Makerbot Replicator 2 Desktop 3-D printers (Makerbot, 2013). By January 2013, the Robohand project had published an open access collection of 3-D models and instructions¹ and has been developing new iterations of prosthetics, including the Robofinger and Roboarm, ever since.

Their project has captured the public imagination. Several other initiatives that focus on what I call DIY prosthetics are making an impact on the accessibility and affordability of these assistive digits (Figure 1).

Project	Description	Website
Unlimited Tomorrow	Developed by 17-year-old founder Easton LaChappelle, Unlimited Tomorrow has an open source design for a roboarm and is currently developing an exoskeleton to help paraplegics walk again.	http://theroboarm.com
e-NABLE	The e-NABLE community is a distributed network of individuals from all over the world who are using their 3-D printers to create free 3-D printed hands and arms for those in need of an upper limb assistive device. The community collaborates on ways to help improve the open source 3-D printable designs for hands and arms for those who were born missing fingers or who have lost them due to war, disease, or natural disaster.	http://enablingthefuture.org
Thinking Robot Studios	Natasha Hope-Simpson and TRS CEO Kendall Joudrie use the latest in 3-D modeling and 3-D print technologies to provide customized solutions for orthopedic implant and prosthetic systems that also do not overlook aesthetic value. TRS provides optimal solution, taking into account the patient's anatomy, pathology, and targeted restoration of functionality and mobility at prices comparable to off-the-shelf (generic) components.	http://thinkingrobotstudios.ca
Not Impossible: Project Daniel	Project Daniel is a December 2013 project created by Not Impossible, LLC to use 3-D printers to make prosthetic arms for children of war in South Sudan.	http://notimpossible.com
Open Bionics/ Open Hand Project	UK-based crowd sourced design initiative with a focus on development of cost effective open source bionic hands, Open Bionics has also just released a range of prosthetic hands for kids that are designed with popular culture references.	www.openbionics.com www.openhandproject.org
Limbitless Solutions	Limbitless Solutions is a non-profit organization devoted to building a generation of innovators who use their skills and passion to improve the world around them. They use additive manufacturing to advance personalized bionics and solutions for disabilities at affordable prices.	http://limbitless-solutions.org

Figure 1. A chart showing a range of organizations focused on digital fabrication and open source prosthetics design.

New Media Potentials and Participatory Culture

In the fall of 2013, I became involved in an initiative at State University of New York (SUNY) New Paltz focused on digital design and fabrication technologies with a particular emphasis on additive manufacturing or what is more commonly referred to as 3-D printing. Through a unique set of state laws that encouraged private-public partnerships with the SUNY system, SUNY New Paltz established a partnership with MakerBot leading to one of the first Innovation Centers in the country showcasing up to 30 MakerBot Replicator Desktop 3-D Printers functioning like a print service bureau for 3-D objects (SUNY New Paltz, 2014). I took interest in the initiative as a part of my own research exploring innovative digital technologies for their potential impact to making and art education curriculum. In the past, I had learned digital video editing, interactive media, and website design as a part of my broader research agenda to engage emerging technologies in the arts learning space. I felt that 3-D printing presented an interesting array of new capacities that would expand new media potentials for art practice and art education curriculum.

Understanding new media potentials in education can take into account many expressions of technology, but the importance of participatory frameworks that govern contemporary digital technologies is significant for its impact on civic engagement (Blandy, 2011; Delacruz, 2009; Jenkins, Purushotma, Weigel, Clinton, & Robison, 2009; Rheingold, 2008). Jenkins et al. believe all educators should devote curricular time to fostering “*new media literacies*: a set of cultural competencies and social skills that young people need in the new media landscape” (p. xiii). Jenkins et al. contribute to an expanding discourse on literacy that takes into account the multimodal practices of today’s learners (Barton, 2007; Beavis & O’Mara, 2010; Gee, 2003; Lankshear & Knobel, 2011; Thomas, 2007), but in particular how these practices are changing through collaboration and networking with increasingly multimodal and social technologies. Problematically for me and other visual learners and creators, what Jenkins et al. and other digital media and learning scholars seem to imply is the centrality of connection, both social and technological, in these new media literacies that relegate the role of art and design as tertiary to full

participation; there is little more than an acknowledgment by the authors of artmaking as inherently good as a “creative process” used to “express” oneself (Jenkins et al., 2009, p. 6).

In many instances, art education that draws from theories in visual culture studies has led to many investigations of art and technology that go beyond notions of creative expression. Certain performance art has been shown to investigate identity formation and technology’s inscription upon the body (Garoian & Gaudelius, 2001, 2004; Sweeny, 2008). The conception of the postmodern subject within visual culture studies places the performing student beyond a relationship of passive reception to media forms. As Eisenhauer (2006) states, “diverse and alternative understandings of visual subjectivity emerge not simply as effects, but rather as active forces in the formation of diverse pedagogies” (p. 166) that can empower students beyond a discourse of media bombardment. Digitally hybrid art practices of art collectives and critical designers, with a clear emphasis on engaging audiences in nontraditional art spaces, make work that speaks to their cultural, social, and political concerns through dynamic forms of collective intelligence (Darts, 2004). These works redefine art as “an *event* that has a **performative and transformative side for society** through *doing* (**poiesis/enabling/fabulation**—not poetics) as productive desire” (Jagodziniski, 2009, p. 339, emphasis in the original). Additionally, these *art as event* interventions rely on collaboration and networking to take advantage of a range of electronic connectivity that enables the sharing of information and ideas.

This gap between the enthusiastic potentials of new media and the understanding of how art and design figure into these potentials reflect on broader misconceptions of what is art education. It also points to important inquiry, as students and faculty become a part of multimodal participatory cultures: How can art education provide insight in theorizing and designing curriculum to maximize the potential of participatory art and design practices? As Howard Rheingold (2008) states, “the unique power of the new media regime is precisely its participatory potential, the number of people who participate in using it during its formative years, and the skill with which they attempt to take advantage of this potential, is particularly salient” (p. 100). For Rheingold, the power of new media productions is how we perform on them, and the range of new media literacies that Jenkins et al. are calling for in a media education agenda of the 21st century draw heavily on educators’ ability to facilitate deeply participatory frameworks that maximize collective intelligence and iterative problem solving fueled by the crowd. Art educator Elizabeth M. Delacruz (2009) states, “kids and families, students

and communities are plugged in, cued to the latest electronic developments and diversions, ready to creatively adapt them to their own purposes” (p. 13). However, as adaptations go, the demands of participation rely heavily on an ability to utilize an increasing array of software that contributes to the force of new media in a visual culture. Even more importantly, participatory frameworks in education provide an ever-greater capacity for involving students in art and design practices that are engaged in issues important to them and the larger society (Rheingold, 2008). In my own journey learning and becoming a part of the 3-D printing community, I was also intrigued by the potential for object exchanges in the form of openly shared 3-D models that could radically expand new media content beyond 2-D and increase our capacity for civic engagement to the physical world.

Robohands for Making Art

As I learned techniques in 3-D modeling, developed an understanding for the 3-D printing workflow, and became familiar with the material and technical properties of 3-D printers, I wondered how I might engage these potentials of art as event, participatory design, and socially engaged making in my coursework with preservice art educators. After becoming familiar with the Robohand project, I started analyzing videos of kids using Robohands to grasp a range of objects. I was struck by how the structure of the Robohand design taught the user (and designers) what a hand is or does. In other words, its function was a sort of pedagogy of purpose: grasping objects most effectively with a spherical or cube-like volume. What if they wanted to pick up a paintbrush? Or use a camera? What if the Robohand was designed for a user that wanted to make art? How might the design enable the user to interact with art materials that are commonly found in an art education classroom? This line of inquiry became the provocation for a design research project for my upper level art education students, including Cody, in the spring of 2015 enrolled in my course. As a part of our inquiry, I had several outcomes for my students: participating in a community of designers by remixing and developing different solutions for DIY prosthetics intended to enable artmaking; building their skills in 3-D modeling and 3-D printing (none of my students had any experience with either); developing a design process that would include ideation and iterative prototyping (we used design thinking as a framework to structure this process); and engaging in issues of accessibility and disability important to preparing future teachers. Our process included learning a simple 3-D modeling cloud-based software called Tinkercad,² utilizing the open source collections of 3-D models available on Thingiverse, and having prints made at the Makerbot Innovation Center printing facilities. I also created a

Digitally hybrid art practices of art collectives and critical designers... make work that speaks to their cultural, social, and political concerns through dynamic forms of collective intelligence.

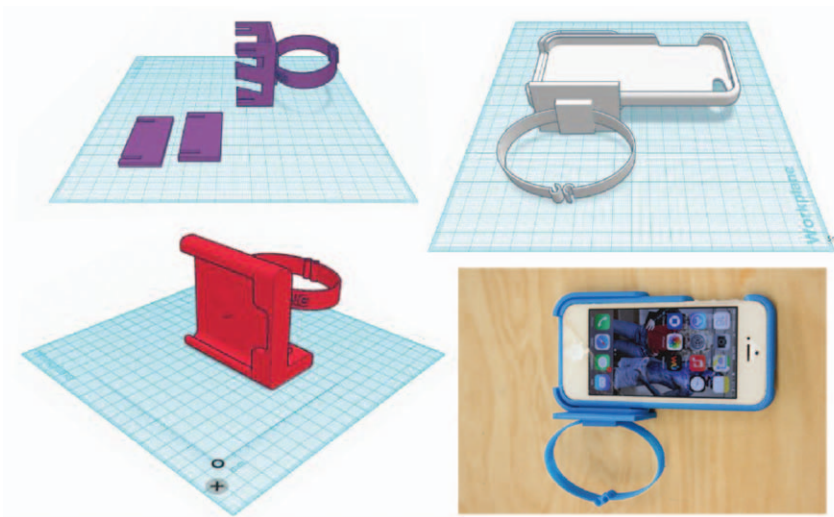


Figure 2. Cody's first prototype (top left) proved unstable and after several iterations he arrived at a working prototype (bottom right).

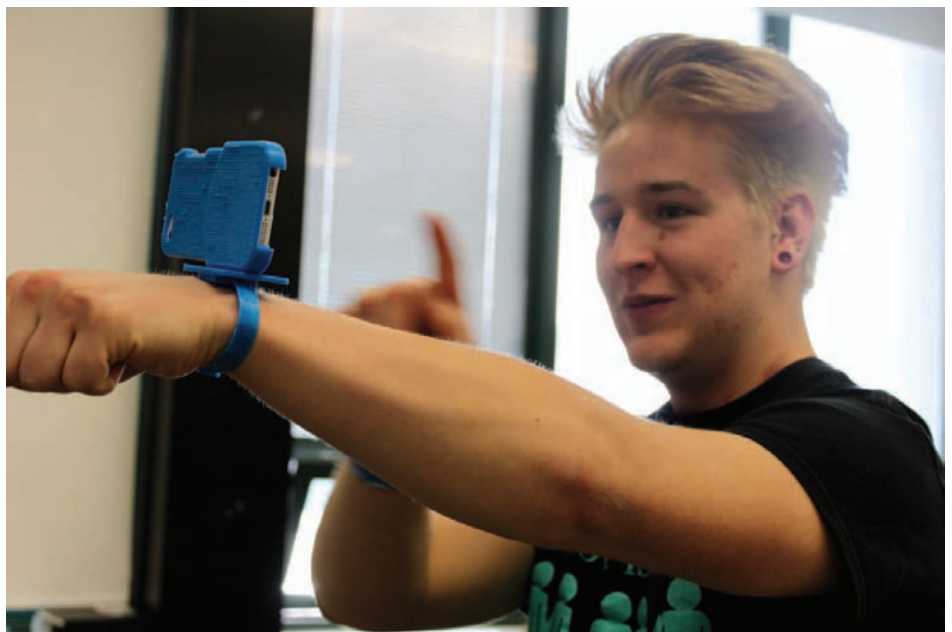


Figure 3. Cody testing out his prototype.

number of sessions in class where we could test ideas, provide feedback to one another about our design choices, and discuss issues of accessibility and art education on a broader scale that included students with other disabilities. I provide three examples of student work from that experience with a particular focus on their design solutions and how they developed a design practice deeply involved in participatory culture.

Cody: Mashup Designs

Cody was a dual major in both Art Education and Photography degree programs, and with the challenge of fabricating an artmaking prosthetic he decided to explore the ability to take photos with a smartphone. Cody's design approach was similar to a mashup. Mashups are media productions that bring together two or more media artifacts into something new. Cody's design practice utilized a range of open source 3-D models available through Thingiverse combining them into unique object configurations that

allow someone to attach their smartphone to their wrist. His design took on two major iterations. First he locked in on a wrist bracelet with a simple locking mechanism that could be put on fairly easily using an index finger and thumb. Then, with this bracelet fixture chosen, he started to test different enclosures for the smartphone that would allow the user to make screen selections, have a clear pathway for the lens to capture images, and be secure. As the opening story shows, Cody's interaction with early prototypes allowed him to experience the instability of the device once he used the smartphone touch screen. Cody demonstrated perseverance, an important aspect of the iterative design process, as his smartphone dropped a couple of times before deciding that this iteration needed to be improved. He moved on to a couple of different smartphone enclosures eventually settling on a version that was akin to a full-back case with an opening for the camera lens (Figures 2 and 3).

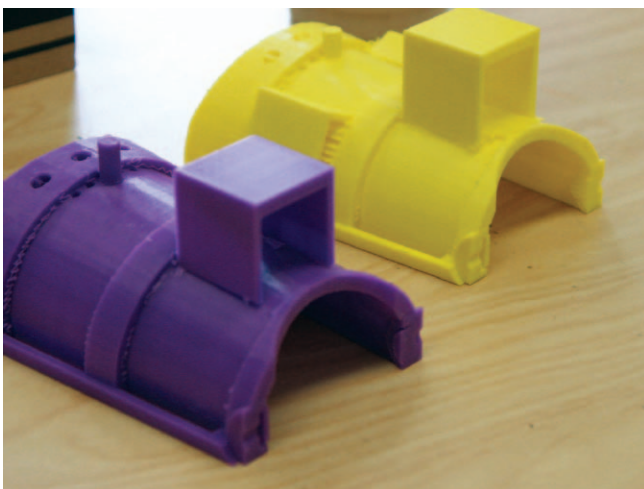


Figure 4. Student preparing a tempura paint palette during our ideation exercise of understanding what it might be like to use art materials without the full use of your hands.

Jessica: Embodied Inquiry and Remix

Jessica was inspired by our investigation of assistive technologies in artmaking. In one of our ideation exercises I had my students restrict the use of some of their digits on both hands by simply taping them up while trying to make art with ink washes, tempura paint, relief printmaking, and oil pastels (Figure 4).

Our exercise activated Jessica's interests not only in the role that assistive technologies can play, but also she became inspired by the



embodied understanding of making art within such restrictions. Several students, including Jessica, continued this exercise at home on their own exploring their relationship to materials, their bodies, and the creative extension that may emerge from enforcing certain restrictions on the act of making.

Jessica's design process focused on remixing a gauntlet design that she had found on Thingiverse to enable the user to hold a brush. A remix in this context involves a focused effort on modifying one design to improve on its features and meet contextual needs. Her first attempts allowed her to experience the gauntlet as a device that was uncomfortable and one that needed to be more refined in terms of limb measurements for the end user and versatile enough to hold several brush types (Figure 5). Her final prototype implemented more precise measurements to fit her arm, less material enclosing the arm for increased airflow and comfort, and a holding mechanism that could hold two different brushes (Figure 6).

Kaitlyn: Finding Unlikely Inspiration

Kaitlyn's design process, like her classmates, involved our ideation sessions, learning 3-D modeling and printing, and discussing the role of assistive technologies, but there are two notable differences that informed her design. The first is that she took the initiative to prototype her design in cardboard and the second is her inspiration came from a whole other realm of participatory culture in the fandom surrounding the video game Assassin's Creed (Figure 7).

First, her initiative in prototyping in cardboard emphasized the importance of prototyping in the design process to get the



Figure 6. Jessica giving a demonstration of her final prototype of the gauntlet brush design.

Figure 5. Jessica's early prototypes for gauntlet brush design.

Figure 7. Kaitlyn was inspired by the wrist-mounted weapon of the protagonists in the video game Assassin's Creed and started prototyping her design in cardboard (right).



They were able to... ask important questions about what it means to make art education accessible to all.

design into the world in whatever way possible. While our learning outcomes were focused on learning how to 3-D model and use the 3-D printer, the act of prototyping does not require high tech equipment. Second, her inspiration from a video game showcases how deeply embedded participatory culture is in our lives. Kaitlyn's creative act incorporates not only the range of issues that we were tackling, but also embeds this world of inquiry within the overlapping media cultures within which she takes part. In the end, her prototype replaces a poisonous dart with a pen, but more importantly her process and design are emblematic of the intervisuality (Mirzoeff, 2000/2006) of participatory culture (Figure 8).

Conclusion

Our journey learning about DIY prosthetics and 3-D printing is one filled with many objects from the open source collections that are shared online to the iterations of remixed prototypes that are a part of getting closer to a design that fits your needs. Examples from Cody, Jessica, and Kaitlyn illustrate a range of important concepts for learning and making in art and design in a participatory culture. They were able to engage in a much larger design community of DIY prosthetics in ways that allowed them to attend to their interests, whether they be in photography or video games, and ask important questions about what it means to make art education accessible to all. They demonstrated what it means to share and connect to ideas not only to larger online communities, but also within our classroom through the work sessions and mid-process critiques that we used to aid the prototyping process. While teaching art education students about prototyping using digital fabrication is important for the generations of students that they themselves will teach, the power and impact of participatory design processes enabled by connectivity and sharing has far greater potentials for art education. There is immense opportunity to explore socially engaged practices of making that builds collaboration, ideation, and social good. ■

Aaron D. Knochel is an Assistant Professor of Art Education at The Pennsylvania State University in University Park.
E-mail: aaronknochel@gmail.com

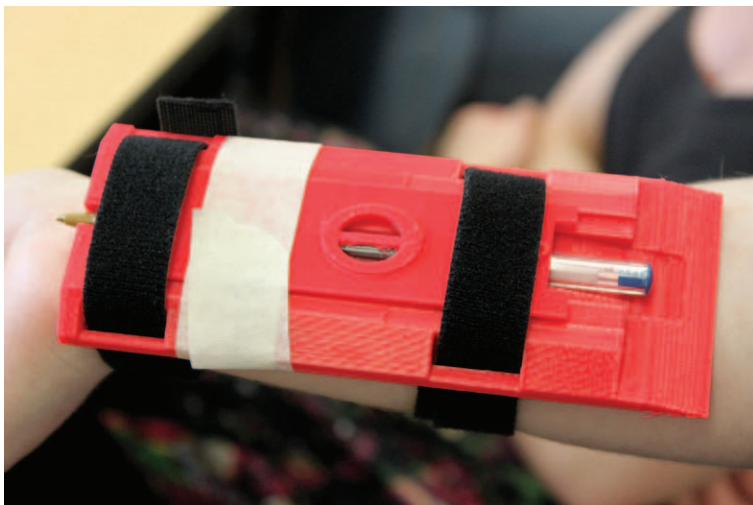


Figure 8. Kaitlyn's prototype of a wrist mounted pen device.

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Endnotes

¹ www.thingiverse.com/robohand/designs

² <http://tinkercad.com>

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