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DIGIFAB KITS: MINI MOBILE MAKERSPACE DESIGN IN THE ARTS CURRICULUM

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Artist educators work in a great diversity of locations from informal community spaces to formal learning spaces in schools and museums. Art educators are exploring modes of transdisciplinary curriculum connecting art to science, technology, engineering, and math (STEAM) to meet the diverse challenges of making and learning. One of the roadblocks to maker forms of education is access to digital fabrication technologies such as 3D printers. To bring digital fabrication to a wider range of arts learning contexts, I designed a mini mobile makerspace that focused on 3D printing that I am calling a DigiFab Kit. As an extension of the concept of the FabLab Classroom model, I share my design decisions and experience of 3D printing in a mobile framework. My development of DigiFab Kits is an exploration of curated object collections that deploy as mobile makerspaces with adaptable curricular concepts appropriate to technology that can be used anywhere there is electricity.

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OVERVIEW

I have designed a mini mobile makerspace focused on 3D printing called a DigiFab Kit to bring digital fabrication technologies to more arts learning contexts. Artist educators work in a great diversity of locations from informal community spaces to formal learning spaces in schools and museums. Arts learning contexts vary widely from setting up a relief printing studio in a community center commons room to conducting a painting class in a museum gallery, but art educators are expanding their creative methods with the rise of maker culture incorporating electronics and digital fabrication creating an even greater diversity of making. With such diversity, it is always a challenge to explore creative practice and materials in art making, and this is particularly challenging with specialized equipment such as a 3D printer. Whether it be thinking through modes of the transdisciplinary curriculum as in connecting art to science, technology, engineering, and math (STEAM) or engaging in critical digital making (Knochel & Patton, 2015), art educators are deploying mobile makerspaces to meet the diverse challenges of making and learning. My design of the DigiFab Kit focused on assembling three core collections within the kit to enable 3D printing, engage design concepts, and incorporate 3D printed parts into projects. To enable 3D printing, I have a Printrbot Play, hand tools relevant to the process, filament, tape to cover the build plate, and the necessary USB and power cords. To engage making and design concepts I have a handheld scanner, laptop/tablet hybrid computer, and various curricular content in electronic slideshow format. To round out the kit, I have an assortment of electronic components such as an Arduino microcontroller, DC motors, breadboards, and LEDs to introduce project work that can incorporate 3D printing in the making process. These collections are in a deliverable package that enables increased opportunities for making in a wider array of arts learning circumstances (see Figure 1).

CONTEXT FOR THE DESIGN

Over the past three years, I have been developing art curriculum and professional development opportunities for K-12 teachers and students focused on STEAM. My philosophy in these events is that STEAM curriculum should focus on the fundamental importance of making to learning, often involving work with digital technologies and an attitude of do-it-yourself (DIY) tinkering (Martinez & Stager, 2013). The importance of "thinking through materials" (Guyotte, Sochacka, Constantino, Walther, & Kellam, 2014, p. 17) becomes a central foundation for impactful STEAM curriculum. In workshop and coursework, I approach a range of making opportunities utilizing digital fabrication technologies, but I have been particularly interested in 3D printing for the ways

that it combines efforts in design thinking both through the arts and engineering. Design thinking is an iterative methodology that emphasizes process and involves different stages of divergence and convergence in exploring solutions to an inquiry (IDEO, 2012). Design thinking utilizes iterative methods and conceptual stage development and has been explored extensively in art education (Bequette & Bequette, 2012; Strickfaden & Heylighen, 2010; Vande Zande, 2007). Design thinking is increasingly a part of curriculum development in both arts and sciences (Honey & Kanter, 2013; Vande Zande, 2010). From graphic design to engineering, design thinking can provide a core methodology by which artists, scientists, and engineers pursue inquiry and this has motivated my curriculum kit design to further incorporate 3D printing into arts curricula.

FIGURE 1. Stackable roller case allows for three-tiered packing: The top tier holds tools and electronics, the middle tier holds handheld scanner and power cords, and the bottom tier holds the Printrbot Play 3D printer.

One of the roadblocks to my work with K-12 students, teachers, and undergraduate pre-service art teachers is access to the 3D printers and makerspace studio environments. I have worked in university computer labs, high school classrooms, and museum spaces with 3D printing, and the need for equipment, electricity, and time is always a challenge. DigiFab Kits extend the concept of the FabLab Classroom model (Blikstein, 2013) by creating a more mobile makerspace with a special focus on a more comprehensive spectrum of concepts related to fuse deposition modeling or what is commonly referred to as 3D printing.

My decisions concerning the design of the DigiFab Kit are motivated by material and conceptual components of a transdisciplinary arts curriculum utilizing digital fabrication. Transdisciplinarity "concerns that which is at once between the disciplines, across the different disciplines, and beyond all discipline" (Nicolescu, 1999, p. 3). The transdisciplinary mode of learning has two characteristics: (a) it is *a priori* positioning of knowledge as interconnected, complex, and transcending total categorization; and (b) it arises from the need to address complex problems. Ultimately, transdisciplinarity may suggest disciplines that have yet to be defined, and it is this emergent quality that makes this approach vital for a focus on using digital fabrication technologies such as 3D printing. DigiFab Kits are designed to extend the material and fabrication opportunities in arts learning contexts that go beyond more traditional materials. My decision to focus on 3D printing instead of materials such as clay or cardboard was to incorporate a digital process that will have increasing importance to future design practice and is currently underrepresented in arts curricula.

DESIGN IDEATION & PROCESS

3D printing provides immense opportunities in developing experiential learning in STEAM education. Curricular models of experiential learning train students in digital fabrication skills that introduce powerful 21st-century capacities in creative problem solving, rapid prototyping, and inquiry. Significant to the advance of digital fabrication in curricula is the development of makerspaces. Makerspaces are often

FIGURE 2. Early collection phase of the components in the Digifab Kit. Note the roller carriers for the filament spool that enable the printer to be more compact.

comprised of various forms of manufacturing (e.g., numerical milling machines, laser cutting, welding, electronics manufacturing) including 3D printing. The capacity of 3D printing to quickly and accurately manufacture parts positions it well as a key element in learning through making. Indeed, research has shown that makerspaces are the dominant location where the majority of entry-level 3D printing occurs (Bosque, 2015). Public schools and libraries are exploring forms of maker inquiry and problem solving that is associated with its environs. Makerspaces may be difficult to establish in many settings because they can be expensive, require a lot of space, and present safety concerns for student and teacher users. The DigiFab Kits are intended to address these concerns by providing carefully selected resources designed to function well in diverse learning spaces (see Figure 2).

The DigiFab Kits take inspiration from a range of my experiences: (a) working with elementary art teachers who have no classroom and assemble "Art on a Cart" curricula so that they can take the art classroom to students; (b) facilitating STEAM professional development opportunities for New York State Master Teachers focused on 3D printing; and (c) consulting with Spark Media Project in Poughkeepsie, NY in developing a makerspace curriculum for their afterschool program.

Additionally, I am intrigued by the use of the kit as a conceptual investigation. I take inspiration from artists in developing kits that have conceptual content as seen from artists such as Marcel Duchamp's *Box in a Valise (From or by Marcel Duchamp or Rrose Sélavy)* (1935-41) (see https://www.moma.org/collection/works/80890?locale=en) and George Maciunas' *Fluxkit* (1965) (see https://www.moma.org/interactives/exhibitions/2011/fluxus_editions/category_works/fluxkit/index.html). I am also inspired by kits that assemble particular material strategies such as electronic gadgets provided in Make: Kits (see http://www.maker-shed.com/collections/make-kits). Beyond conceptual inspirations, libraries, universities, and K-12 schools are experimenting with the use of mobile makerspaces to meet the challenges of making in a diverse set of contexts and needs (Craddock, 2015; de Boer, 2015; Gierdowski & Reis, 2015; Moorefield-Lang, 2015). Examples that have influenced my thinking include library programs like the Arrowhead Library System mobile makerspace, developed in 2014, that shares equipment relevant for making among seven small to mid-size libraries in southern Wisconsin (see http://als.lib.wi.us/Makerspace/). Mobile making has played a role in developing making opportunities in a range of urban spaces such as the Gadgiteration project (see http://www.gadgiteration.org/), and most closely aligned with my own interests in community-based youth media, All of these education programs are engaging with issues of maker education in ways that are mobile, open, and accessible—which are all characteristics that have motivated my design.

The DigiFab Kit was designed for the conceptual and practical demands of a digital fabrication curriculum for the arts. The DigiFab Kits explore the relationship between material collections and the curricular concepts that they produce. For example, to accomplish 3D printing, there are the practical requirements of the printer and the filament delivery system for the 3D model file. While this serves practical needs of 3D printing, it does not put the objects into relation with a design process. Additional curricular

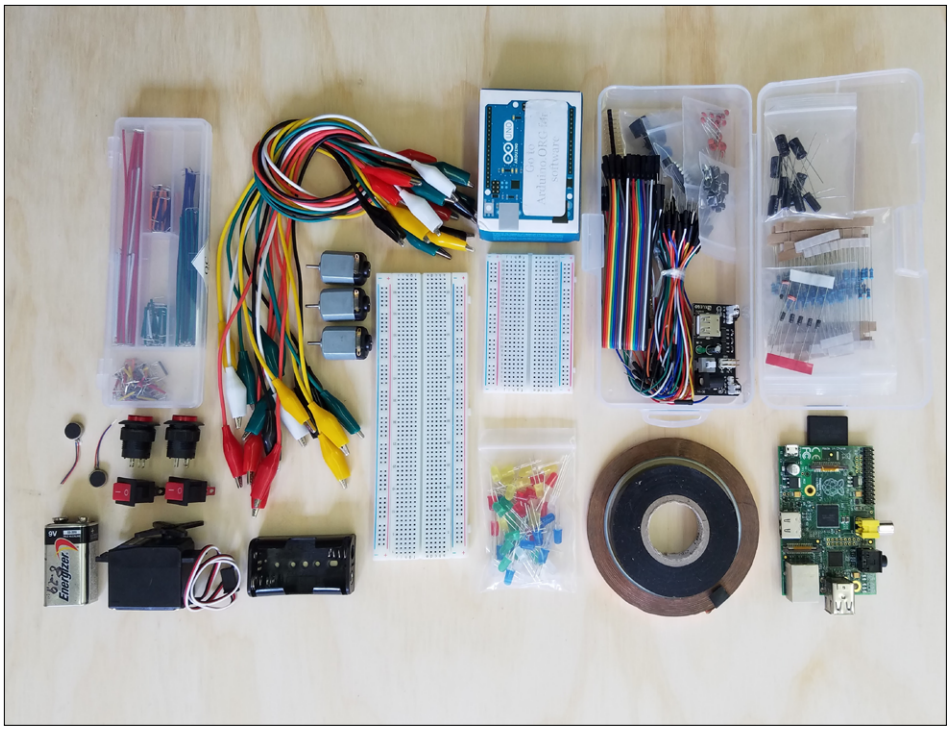

FIGURE 3. Electronics components such as an Arduino Uno, DC motors, switches, jumper wires and breadboards were added to augment 3D printing opportunities.

FIGURE 4. The range of tools relevant to 3D printing including from left to right roller carriers for filament spool, replacement printer parts, hand carving tools, allen wrenches, spatulas, pliers and an XYZ Handheld Scanner.

resources in the form of slideshow presentations showcase examples of 3D printed objects being used in design projects. Electronic components are included in the kit to suggest concepts that activate the 3D printed objects (see Figure 3). I also include already printed objects in the kit to demonstrate important printing concepts such as understanding the needs for material supports or analyzing build orientation.

My development of the DigiFab Kit is an exploration of curated object collections (both equipment and consumables) that deploy as a mobile makerspace with adaptable curricular concepts appropriate to the technology that can be used anywhere there is electricity. For the 3D printer, I chose the Printrbot Play that is both small enough to fit in the rolling case and utilizes a sheet metal construction making it very strong, structurally. For filament, I am using polylactic acid (PLA) filaments because they have relatively low emissions when melted and are a bio-degradable polymer. I have also included in the kit hand tools to service the printer, spatulas for freeing prints from the build plate, and a small amount of replacement parts (see Figure 4). In addition to these items, I have an XYZ Handheld scanner and a pair of rollers that enable the filament spool to be placed off the machine when dispensing material to increase my flexibility in delivering material to the printer based upon my set-up environment. To assist with presentation needs, I have a computer that can be used as a laptop, tablet, and monitor depending on how it is configured. These items are intended to allow for 3D printing design challenges but offer other maker capacities such as 3D modeling, electronics prototyping, and multimedia presentations.

FAILURE ANALYSIS

While the DigiFab Kit is indeed mobile, there are some limitations to its design that have become clear. First, the wheels on the stackable cart are small and do not pivot, making handling difficult in varied terrain. I run into issues when loading the travel cases, as tipping them over results in a disaster in the inner compartments. More internal containers are needed to keep small components safe and secure. Second, while the DigiFab Kit focuses on 3D printing, there is much more that can be done in terms of reinforcing design thinking processes and developing inquiry. I had intended to use the laptop and digital slideshows for this role, but it has proven ineffective presenting to groups larger than about six. My next step is to develop postcards about different design challenges so that I can use these as prompts to get participants working more independently. I am also learning that integrating more immediate, less technical modeling materials may, in fact, increase 3D printer use due to the role of material play in early ideation phases of the design process. Introducing 3D printing to the design process may, in fact, benefit by starting from more readily accessible, basic modeling supplies such as air dry clay or cardboard. Lastly—and this is a conundrum—3D printing is slow. No matter what you do, the Printrbot is really just a demonstration machine without much real potential for production because print time is too time-consuming. In addition to print time, there is also set up time such as ensuring that the build plate is level before connecting the computer to initiate the printing process. The hefty construction of the Printrbot Play—along with its size and rectangular shape—make it ideal for the case, but without an onboard display, it cannot be operated without the computer attached with a USB cord. I experimented with another small 3D printer, the Monoprice Mini, because of its use of MicroSD cards and interactive display to initiate printing, but the open design and less rigid construction make it vulnerable in the current travel case. Time requirements place real constraints on the affordances of makerspaces in a mobile framework. Instead of anytime anywhere, it is more accurate to think anywhere with enough time.

CONCLUSION

Artist educators increasingly work in a great diversity of locations and teaching modes of the transdisciplinary STEAM curriculum, and this has increased the challenges of making and learning. Overcoming the roadblocks to participate in maker forms of education requires a more flexible and mobile approach. I have shared my design case of a mini mobile makerspace to acknowledge the ongoing prototyping that is taking place within this phase of the maker movement to highlight what we might have to gain in deploying making anytime and anywhere. While the current DigiFab Kit prototype shows signs of needed improvement, there is rich potential for meeting learners' needs in an increasingly mobile capacity.

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