14. Digital Fabrication

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Definition and Background

A unique emphasis of design thinking is the ***prototyping*** phase. A prototype is a preliminary theoretical artifact that can be tested before polished and finalized. In maker culture and design thinking writ large, to materialize a theoretical artifact is to fabricate its existence. Digital fabrication is a popular method to materialize an idea and make a prototype digitally. Digital fabrication is an umbrella term that describes design and making processes that require digital modeling and manufacturing tools to create material outputs. With the proliferation of hobbyist digital fabrication technologies across workplaces and learning institutions, non-expert designers are afforded the opportunity to design and create prototypes of creative products at a low cost. Hobbyist fabrication is often celebrated as a motivator for professional undertaking. Personal interests in certain issues in the world can lead to innovative projects supported by institutions. The "20% time" method (also known as side-project time), made famous by Google, is one of such examples. Google employees were encouraged to spend 20 percent of their paid working time on something they thought would benefit the company and the world (Clark, 2021). Digital fabrication is a staple exercise in these experimental projects. The three main types of digital fabrication are 3D additive (3D printing), 2D subtractive (laser cutting), and 3D subtractive (CNC milling).

3D Additive –

The term *3D printing* is typically used to describe rapid 3D plastic prototyping, often generating a smaller scale model using cheaper materials until the design is settled and a mold can be created for mass production in more expensive materials. Typical hobbyist 3D printers function similarly to hot glue guns, except they use plastic filament instead of glue and the nozzle moves with motors on precise XYZ coordinates to build up a composite of slices or layers to create a cohesive model. The most common plastics used in 3D printing are PLA (polylactic acid), which is more biodegradable and creates less toxic fumes, and ABS (acrylonitrile butadiene styrene) like in toy bricks, which is much sturdier. In addition to plastics, makers have tinkered with 3D printing in typical materials like resin, clay, and metals, as well as more unconventional materials like chocolate, cheese, and pancake batter. 3D prints are made from 3D models in file types like STL (stereolithographic) or OBJ (object) from computer-aided design (CAD) software,

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which range from those for amateur hobbyists to those for professional artists and engineers. Some websites offer free or paid models to download and print. 3D printers come in a wide range, from hobby to professional, and many can now be found in university libraries and makerspaces.

2D Subtractive –

Laser cutting is often used to cut out pieces or add etched designs to usually flat materials like wood or plexiglass/acrylic, although the technology has become advanced to where one can laser cut pretty much anything, even toast and cookies. Laser cutters require digital design files that specify cut (vector) or etch (raster), and the laser cutting machine can vary the speed and power of the laser to affect the depth of the cut. Designers typically want to output an SVG (scalable vector graphics) file from design software, which provides precise coordinates of paths to cut out the final design. Laser cutters produce toxic fumes and are a fire hazard so are usually not found in libraries, but they can be found in fabrication laboratories (fab labs). Crafters can also cut thinner materials like paper, cardstock, and vinyl using computer-aided design vinyl cutters that likewise accept vector files and can be found in libraries and makerspaces.

3D Subtractive –

CNC (computer numerical control) mills or routers are advanced tools used to cut out a design from a pre-existing material, rather than build up from scratch. CNC milling can cut through plywood, plastic, foam board, and even metal to create a 3D design from a specific computer code. These are expensive machines and are only occasionally found in makerspaces.

Design Application

Digital fabrication is often used in ***rapid prototyping***, usually at a smaller or less expensive scale than the intended final result. Designers may preliminarily sketch ideas, but may also require material, dimensional prototypes to determine the feasibility and ***usability*** of the idea. Design thinking requires ***creativity*** as to the ***affordances*** and ***constraints*** of available technologies, but also consideration of material impact. For example, when hospitals faced a shortage of personal protective equipment during the COVID-19 pandemic, many makers joined the efforts with digital fabrication. 3D-printed plastic N95 masks did not work well as they could not create a tight, but breathable seal like the typical fabric, but Columbia University researchers were able to 3D print face shields and headbands (Gil & Trinidad-Christensen, 2020). Makers at Georgia Institute of Technology also used laser cutting to cut acrylic face shields (Toon, 2020). While digital fabrication is a technology, a tool, and a medium, it can also be an object of critique, especially in ***critical making***. 3D printing melting plastics or burning acrylics with lasers in themselves invoke design problems in terms of workplace toxicity and ethics of global warming, as do problems of ***equity*** and access to digital fabrication resources. The generation of waste plastic has led to creative recycling ventures, where the filament is melted down and re-extruded (Gonzalez & Bennett, 2016). Digital fabrication is most often tied to technical communication in terms of multimodal composition.

Pedagogical Integration

Scholars are using digital fabrication in pedagogy and in research to materialize concepts. For example, Aaron Santesso (2017) from Georgia Institute of Technology assigned his students to laser cut Renaissance style medallions inspired by the literature they were reading. As a Ph.D. student, Jonathan Fitzgerald (2015) from Northeastern University laser cut a complicated interwoven Early Modern pattern poem by an anonymous poet that he discovered on the EEBO (Early English Books Online) database. While at the University of Florida, I assigned my students to create 3D-printed tactile picture books for non-sighted children and share their instructions with the online maker community, Instructables (2018). A team at the Speculative Sensation Lab (2015) at Duke University created a project that captured the content of scattered cookie crumbs and translated the data into coordinates for a MakerBot 3D printer, creating abstract data creatures. Tiffany Chan (2018) from the University of Victoria reverse-engineered a 3D-printed printmaking plate from a 19th century illustration. While the learning curve might be daunting, many students are eager to learn new emerging technologies to help set themselves apart in a competitive career market and often comment how rewarding it is to have a tangible artifact at the end to show their peers.

Though certainly not ubiquitous, the diminished cost of 3D printing has made it a popular trend in DIY and maker culture as well as education. Just as kids learn spatial awareness through playing with dough, 3D modeling and printing connects one's understanding of virtual 3D space on a computer screen with a material 3D result. Replicating 3D objects used to be only for those who had mastered a craft or created a mold, but 3D printing allows for tinkering and generating small-scale models quickly to demonstrate 3D concepts. Some pedagogical implications of digital fabrication are teaching the design process through trial and error, revealing the importance of tactility in a visually dominant culture, and understanding familiar concepts through new perspectives.

For technical and professional communication, digital fabrication offers the opportunity for students to try materializing abstract ideas into tangible, testable models. In this process, students may learn to consider the ***affordances*** and ***constraints*** of material resources. Students can also practice ***testing*** the ***usability*** of their solution with the fabricated prototypes. As John Sherrill (2014) argued, these learning instances teach students about post-industrial configurations of product design, information exchange, and demonstrating ideas in technical communication. Data physicalization (constructing data with physical objects) also offers opportunities to communicate complex data like sequential trends over time using three dimensions to enhance accessibility, as seen in Rebecca Sutton Koeser et al. (2020) 3D-printed lollipop chart. In essence, digital fabrication offers opportunities to prototype, represent, and communicate in 3D space.

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