Before and After Making:
Investigating Creative Practices with Digital Fabrication

In 1997, Neil Gershenfeld spoke of, "the coming revolution on your desktop" and claimed that "personal fabricators" will soon be as commonplace as the desktop printer. What is commonly referred to as the "maker" movement quickly followed as access to high-end manufacturing machines like computer-numeric controlled (CNC) mills, 3D printers and laser cutters became attainable to a wider public through send-out services like shapeways.com, hack labs, membership organizations like Tech Shop. Policy makers and educators look to the new accessibility of fabricators as a way to reinvigorate student interest in science, technology, education and mathematics (STEM) and researchers in HCI have met the trend with innovative technologies, novel interactions with digital fabricators, and accessible computer-aided design tools.

As interest in fabrication grows, it is critically important to consider who we imagine makers to be and what they value in making. "Make" magazine, the leading publication of the movement and sponsor of the popular "Maker Fair" has been criticized for the overwhelmingly white male centric imagery featured on its covers including: fire breathing robots, projectiles, Dads and sons, and zero people of color. This vision of a "maker" is especially harmful if we position "making" in a central role in in STEM education, a field already plagued by lack of diversity, especially in sub-fields such as computer science. The goal of my dissertation research is to look to develop new modes of "making" with digital fabrications machines. While this is unlikely to single handedly overturn cultural stereotypes, I hope to present compelling design examples to demonstrate value in new approaches and encourage further research on digital forms of making as an entry point into STEM for new audiences.

Relationship to Existing Research

Existing work that aims to expand diversity in digital fabrication as associated computational design method does so by looking choosing historically feminized application domains (hand-crafts) or looking to make software and algorithms more accessible to novices. Underlying these studies is a narrative that participation is linked to the kind of project that is made. This idea is supported in educational literature as well. Eccles describes a concept of "expectancy-value perspective" that individuals undertake when making decisions about their lives. This value is linked to two ideas: how well one feels they can do in the domain and how much they value it. Accessibility may be one way to generate an expectation of success in a field and value may be achieved by showing students how to do something they already like, with computers.

While these approaches have shown some success, I find two aspects of this research problematic and limiting in terms of expected success and value. First, the evaluations of studies generally follow the same structure. Students participate in a workshop using their computational craft tool and pre and post-tests measures their feelings about STEM subjects. Positive results indicating that students are more interested in STEM after the workshop make it difficult to distinguish whether the making activity changed their perspective, or the workshop culture and environment in which the activity was situated that led to positive feelings about these fields. What happens when there isn't a workshop or when student's transition into a culture that is very similar to the workshop? Margolis' and Fishers studies of undergraduate women in computer science reveal that a large factor influencing women to leave CS was a sense that their values did not align with the majority of students. Since the systemic changes necessary to create a more equitable environment in STEM progress more slowly than technology, it is difficult to avoid a clash between what one does in a small group with what they might encounter in school or the workforce. Developing a strong value for STEM methods in making could be key in encouraging participation. This is a strategy that has worked as women in CS in particular have developed the ability to define themselves as something outside of CS but through which CS can be useful (I am a designer, an artist, a musician, a poet and coding is a different way to explore those disciplines). Similarly X & Y use SAT scores to suggest that women are more likely to score highly on both verbal and mathematical portions of the SAT where men tend to have more disparity between their math and verbal scores. They suggest that this gives women more choices when it comes to career paths and they tend to chose paths where their broad skill sets are seen as an advantage rather than an outlier. Given the overwhelming interests of women in both fine arts, humanities, and computer science, connecting computation and fine art is a promising way to reach women. Yet, there is very little discussion of the way in which fine arts practice relates to digital fabrication. The heavy focus on handcraft and computation may go part of the way, but I believe that handcraft lacks an intellectual and representational dimension that is found in fine arts. [Really need to find better literature differentiating craft and fine art]. Additionally, each art or craft method (painting, composing, writing styles) developed as a response to the materials and culture and it is problematic to simply insert a new technology into the mix without questioning how this technology fundamentally shifts the process of making and reading of what is made. Additionally, it binds technology to existing practices rather than looking into vastly new creative spaces that open up with each new technological innovation [include that quote from Beyond Being There about designing new media not replicating old in digital spaces].

While most research of technologies for digital fabrication maintains a tight focus

Figure 1: In Slumber, Antoni sleeps in a gallery attached to an EEG machine. When she wakes, she weaves her wave patterns into a tapestry, which she then sleeps under. The piece comments on the body, cycles, craft, and technology.

around the actual mechanics of making (attach A to B, semantics of code environment), I hope to widen the frame to situate making with digital fabricators within existing fine arts practices in order to think about new ways we can interact with and explore these technologies. Additionally, through qualitative studies and observations, I hope to evaluate these approaches outside of the workshop setting with individuals as they go about their everyday life in order to see how making works into everyday exploration and responses real life inspirations and responses.

Looking to existing arts practices, one sees the actual practicalities of making an artifact bookended by other closely related activities that I am calling the "before" and "after" of making. Before making, one must have ideas and, contrary to popular conceptions of artists, this is not something that just arrives in a stroke of genius, but is developed though continued practice and experimentation in and out of the art studio. After making, the work must be subject to an audience in a specific place and time.

While it might be tempting to imagine art-making as a perfectly ordered cycle (idea-make-display-repeat) it's easy to find examples that challenge this idea. For instance, in Janine Antoni's project "Slumber" (Figure 1) the "making" phase is indistinguishable from the performance and artwork itself. In computational design, where artists program generative functions to produce new imagery or sounds, generating ideas is often closely tied to the process of executing lines of code and seeing what happens. As blurry as the boundaries may be, the components always exist is some regard. Additionally, lines between fine arts disciplines are difficult to tease out and one "kind" of fine art tends to bleed together with others. At a recent Kraftwerk concert (Figure 2), I found myself witnessing something that was simultaneously an example visually artistic (real-time 3D renderings on album themes), poetic (stylized, minimal lyrics), musical

Figure 2: Kraftwerk's performances blur the distinction between art, music, and performance as they comment on the nature of technology and human experience.

(they perform music), and performance (their movements, or lack there of, are highly planned and coordinated). One of the members performing on stage was solely responsible for the graphical portion of performance, showing how musical performance and performers serve multiple roles across artistic domains. Additionally, many of the people working in these spaces identify themselves as "artists" rather than the particular domain their work tends to be situated in (i.e. musician).

The aspect uniting all of these works is that they are ruminations on a theme or idea presented in sensory form. In each case, making is not undergone not only for the sake of pleasure but rather, as a communicative endeavor that plays with the unique characteristics of each representational medium. It is this type of making that I see as missing from "maker" culture. I don't mean to be elitist and imply that all making should take place this way, but there should be a pathway into making that supports this kind of pondering or critical questioning about how certain feelings, sentiments or ideas can be communicated in different forms and how the form of the expression impacts the expression itself. Instead of questioning what we *can* make with technology, I hope to support users in questioning technological processes as kinds of media and how particular characteristics of that media lends to an overall message [this begs for a McLuhan something or other].

The dissertation that I am proposing will form a narrative through research projects that investigate how technology figures in the before, during and after phases of making and what new kinds of experiences with making this might make possible. AnyType, a completed research project lent valuable insights into the "before" and the ways in which technology can promote visual literacy and idea generation. I propose completing a two-phase projects for the dissertation, (1) a study the way musicians customize or build their own instruments and the role that physical performance plays in the design of these instruments and (2) a design project for students to explore new modes of fabrication that is informed by (1) and AnyType.

Before Making: Informing the Senses

"One's destination is never a place, but a new way of seeing things."
- Henry Miller

In art, learning to have ideas is often equated with learning to "see." Seeing is a term that is as multilayered as sight itself. When we say "seeing" sometimes we mean it in a biological sense, other times in a way of understanding as in, "I see your point" as well as a way of making meaning from imagery as explained in "Ways of Seeing." As we walk around our environments there is not one single objective view of what is happening. As Berger says, "we only see what we look at, to look is an act of choice." If one looks at an old building they may see various aspects of it like the ornate brickwork, the historical architectural styling used, or the trash on the steps. When pondered in context of ones life and culture, each sight provokes new understandings interpretations, and representations.

Artistic disciplines like design, art, and architecture generally weave between lessons of seeing and making. It's assumed that no matter how good ones technique is, it's worthless if it is not accompanied by a good idea. In contemporary art post-Duchamp, one might even make the argument that technical skill is no longer necessarily to produce a compelling artwork and the the primary work of an artist is to present 'works' using the medium and methods that best communicate the message. Whether or not one believes that artistic talent can be learned, the educational focus on learning to see implies that sight is much like any other physical skill, it can be developed to some degree by practice. As an analogy, anyone can learn to play tennis. Some people are more gifted at others or respond to learning better but with practice, anyone can improve. I believe the same can be said about art. Not everyone can be Damien Hirst (nor would want to), but with practice, we can all develop a better sense of our artistic intelligences.

Through my design and study of AnyType, I realized that interfaces are a powerful way to provoke specific kinds of "seeing" into the world. In AnyType, requiring users to capture images and videos within non-traditional frames like long rectangles and arches. The shapes where then used to construct the letters in a typeface. This defamiliarizing constraint was productive in shifting attention to new aspects of the environment, including familiar environments. Users began to question how a particular visual texture or color would "communicate" in the context of a typeface. Some users asked themselves what patterns and shapes communicate "anxiety" or "serenity" when placed into letterforms. Individuals used AnyType over and over again, often more than
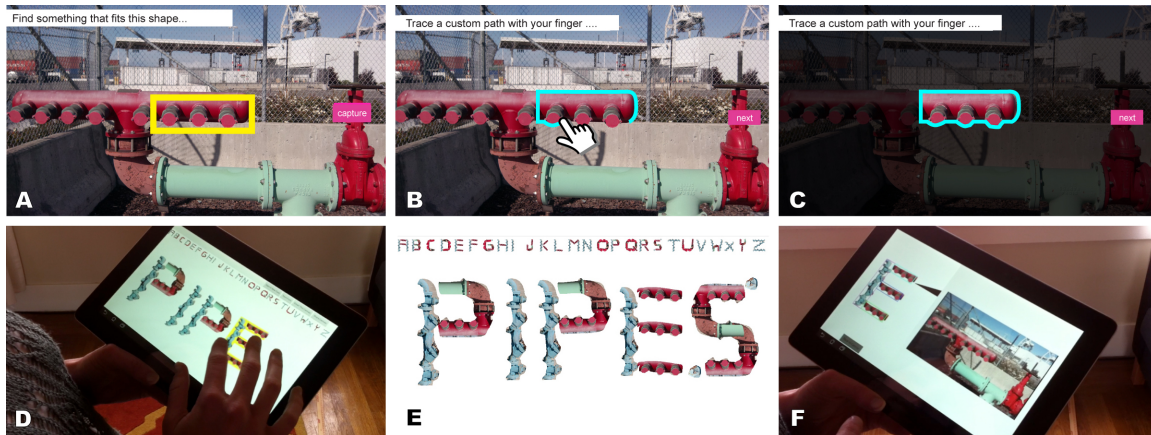
Figure 3: The AnyType UI. A. the user finds a shape to fit into the frame on screen. B+C. The user can create a custom tracing of the object. D+E. Using their customized alphabet, they create a composition to share with others or save for themselves. F. A history view reveals the original photos that comprise the letters.

we asked them to, in order to explore new constructions and ideas. They saw the application as a way to ponder their own feelings, make artworks for friends and loved ones to view, communicate nuanced expressions, and generate design inspirations to use in other domains. It is important to note that the individual did not always like the fonts produced by AnyType and the task of finding items in shapes was said to be "hard" by many participants. While we often associate these aspects with bad design, continued engagement and the sophistication of meaning generated by some participants with AnyType suggested that challenge and disappointment might have been productive features of in informing the next creative idea.

The way in which AnyType provoked specific kinds of "seeing" in users allowed it to function as a kind of "semiotic instrument" for creating thoughtful images and messages to friends and loved ones. [Insert Turkle tool / instrument distinction as a closeness and emotional connection to the object and relate this to AnyType]. It was semiotic in the sense that it operated on a layer of sight that situated what was seen with who was seeing it and how it could be used in a communicative expression. An object was no long seen as what it was (like grass), but rather what it might signal to a viewer of the font (sustainability, fertility, a location, outdoors, health). Various symbols were unified into a typeface allowing them to intercommunicate. For instance, grass and sky might further illustrate an outdoor environment; grass and green ground photographed from a videogame might communicate something about virtual representations. On top of those meanings was the word within which someone constructed with the letters. The word juxtaposed the images yet again.

After Making: Performance

Art-making in highly context dependent and, aside from having a good idea, the ability to realize and communicate that idea to an audience draws of several factors beyond the control of the individual artist. As Becker explains, "all artistic work, like all human activity, involves the joint activity of a number, often a large number, of people." (Becker, Art World, p.2). David Byrne connects development of musical styles and genres to environmental factors rather than individual genius. He presents an argument to suggest that, "the origin of jazz solos and improvisations was a pragmatic way of solving a problem that had emerged: the 'written' melody would run out while the musicians were playing, and in order to keep a popular section continuing longer for the dances who wanted to keep moving, the players would jam over those chord changes while maintaining the same groove" (How Music Works, p.21). The process of constructing and artwork then becomes a process of negotiating the materials and situations at hand and crafting a response in such a way as to produce an intended, but not prescribed, reading in a viewing public. The nature of the work depends highly on who this public is, where they are seeing the work, and what their particular expectations they might have. A great piece of art weaves all of these aspects into a powerful, immersive and transformative experience.

I am interested in gaining a deeper understanding of a different practice, one in which artists design, create, and perform with their own customized instruments. I am interested in how they negotiate between their ideas, the circumstances of performance, and available materials in the design process and how that can inform the design process of other "instruments" for making. I intend to begin semi-structured interviews with designer/performers in order to understand the nature of their design decisions and how that figures into a larger artistic process. What materials are used and why? How does a physical performance impact the design? How much control does one introduce into the interface? What is one trying to communicate, how does this mode of making figure in that message? What skills are learned in the process? Furthermore, how can these insights extend the idea of design of "semiotic instruments" for digital fabrication?

[Insert paragraph about why studying musicians can lead to insights making in the fine arts in general: I will make an argument that art forms aren't isolated. Musicians are more and more accompanied by visuals, they make videos, they do performance work, they perform at art galleries, and they collaborate with groups. Plus, Becker talks about all of them so why can't I?]

Study Design: Phase 1 - Study

Population: musicians that design their own instruments for both acoustic and digital performance. Examples include Walter Kitundu and Holly Herndon. Looking specifically for people with a history of experience performing. Need both to contrast issues of digital in this space. Hoping to snowball sample based on early interviews. Begin recruiting from CNMAT at Berkeley, CCRMA at Stanford, Mills College, Thingamajig music festival in Oakland, possible links through Cycling '74, look at NIME publications for additional insights and publications from IRCAM and Ars Electronica.

Expected Challenges: staying out late to go to some of these performances, they go super late. Realize that lots of people have asked these questions before, but then refining interviews to hone in on specifics in relation to transferability to other domains. Fear of embarrassing myself, as I'm quite a novice in this domain and people can be particularly uppity about music. Unknown unknowns.

Study Design: Phase 2 - Creating a Design Object

I plan on synthesizing the findings of the complementary previous studies by designing a new "semiotic instrument" for digital fabrication? The audience for the design is not necessarily fine artists but everyday folks who may be as young as high school aged. The goal is to encourage and support the forms of making seen in both studies. My hunch is that this design will be deceptively simple, minimal, but powerful…one can dream! I hypothesize that my research and the object that I build will also offer a critical perspective of various practices within design.

- Co-constructed interactions
- Interface as provocateur
- Minimalism
- Fluidity of use in and out of studio.
- Juxtaposition instead of construction.
- User Performance

Through evaluations, I'm hoping to study everyday use with the application as well as pre and post thoughts about digital fabrication. How does this connect an individual to topics in STEM. How does this promote critical questionings of technology itself?