Board 37: Student Experiences in a University Makerspace: Design as Decision Making

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1. Introduction

Design thinking is an important skill for university students both within and outside of engineering majors. It is difficult to teach and learn for a number of reasons.¹ Senior capstone courses are a traditional means of teaching design but have limitations as they are resource-intensive and often a one-time intervention.

The growth of academic makerspaces has provided an opportunity to infuse more hands-on design learning experiences throughout students' education. These spaces also offer resources to students outside of engineering majors and make room for more interest driven learning than more formal design courses. While academic makerspaces are seen as a place for students to engage in design practice, how much explicit support do these spaces provide for design learning? Many students use makerspaces as a means to engage in fabrication work for courses, such as senior capstone design courses, that formally teach and scaffold design for students. How do students engaging in interest driven fabrication projects outside of a design course structure navigate design decisions in makerspaces? What support and resources do these students seek and where do they find it?

This study begins to explore these questions by looking at how one university makerspace supports design. How do students navigate a fabrication project in the makerspace? How and to what degree do they engage in design? How do students perceive their design processes and decisions? Broadly this research looks at undergraduate student experiences of navigating interest-driven fabrication projects in a university makerspace. This work focuses on student engagement with design and step-by-step tutorials.

To look at how students navigate makerspace resources to complete project work outside of the structure of a course that explicitly teaches design, we engaged 7 undergraduate students in a 10-week research group that provided instruction around tracing and making sense of experiences in the makerspace but not instruction around how to design, what project to make, and how to make it. In this group, students initiated and engaged in personal sewing projects in a university makerspace and documented their experiences weekly as they planned and executed their projects. We look at traces of student activity through this self-authored documentation, focusing on how students saw design, how design practice or thinking manifested in their projects, and what resources supported their engagement with design.

We present our findings in two parts. We first look at how students talk about design (4.1) and how they feel design relates to their project and the makerspace (4.2). We see students speak of design as conceptual, design as digital, and design as planning. We also see that students choose fabrication projects because design is out of reach, characterize the makerspace as more a place for fabrication than design, and feel that they can only make minor design decisions.

In the second part we look at how students use tutorials and step-by-step instructions as a means of engaging in project work, but still engage in "design decisions". Finally, we specifically look at one student's experience and draw attention to her project choice, tutorial choice, and five moments where she makes design decisions.

3. Methods

To understand the experiences of students engaging in independent project work in a university makerspace, we formed a small research group of undergraduates who pursued open-ended personal projects in the campus makerspace while self-documenting and discussing their experiences along the way. The work described here is the result of a post analysis of the students' work conducted by two researchers who participated in the group—a graduate student who facilitated the research group and one undergraduate student participant.

3.1 The Research Group (Data Collection)

Setting: Our study takes place at a *large public university* where we focus on undergraduate student experiences in one of the campus's several *makerspaces*. This particular makerspace is open free of charge to all students on campus and run by the university's innovation center. To obtain access to the space, students must take a 30-minute safety training, pass a safety quiz, and sign a user agreement.

Structure: Seven undergraduate engineering students in an engineering design major—three students in the major and four students applying for the major—participated in a 10-week, 2 credit research group during Fall 2017 academic quarter where they 1) engaged in a **personal sewing project** using the university makerspace, 2) **documented** and 3) **collectively analyzed** that project work. Students were asked to spend 3 hours a week working on and independently documenting project work in addition to 3 hours a week in a group meeting making sense of their projects together.

Personal Sewing Project: Students were asked to individually choose a project in the domain of sewing and work on it throughout the quarter. This allowed the team to capture project work as it happened rather than analyze a retrospective account of a project after completion.

The prompt was open-ended with very few constraints to simulate the creative freedom of individuals pursuing interest-driven work outside of a design course structure. The design prompt required that the students utilize some of the sewing resources in a particular makerspace on campus and that the project be completed by the end of the quarter. Students were also free to pursue and utilize whatever resources they saw fit to learn the skills needed to carry out their projects.

Over the course of the research group, students obtained access to the makerspace, selected and pursued sewing project(s), and learned the fabrication skills needed to complete their work. Tom and Lindsey pursued e-textiles projects—LED bike gloves and glowing beanbags; Maddie, Maria, and Brittany constructed garments, Vanessa worked on reusable cloth menstrual pads, and Tiffany constructed hair scrunchies.

3.2 Individual Documentation

Students were asked to individually document their experiences pursuing sewing projects through a *digital journal* document stored in a shared Google Drive. Students engaged in two distinct documentation practices that resulted in - 1) **Field Notes Entries** and 2) **Reflection Entries each week**.

Field Notes Entries: Field notes were intended to help the students trace project activity as it happened. These were modeled off of ethnographic field notes, but given the time constraints

and limitations of self-documentation, did not contain the “rich detail” of rigorous ethnographic notes. Students were given a template to organize their notes and encouraged to document any work related to their project, including conceptual work like planning and project decisions, sourcing materials, physical fabrication, and information seeking and sharing. Students completed a header for each instance of project work that contained the project name, date, time started and finished, a title, and a summary followed by time-stamped activities described in as much detail as they were able.

Reflection Entries: Reflective entries were intended to complement the field note documentation by prompting students to reflect on their experiences creating more synthesis and more personal accounts. Students were given structured prompts to guide their reflections. Throughout the quarter, these prompts became more open ended, based on group discussions. Prompts related to A) student experiences B) resources C) design and fabrication, D) topics from the previous meeting, E) project choice, and F) different modes of learning. In this analysis we draw from reflection entries where students speak about design or instruction sets and tutorials. In six of the ten weeks, prompts explicitly related to design were posed. These prompts can be seen in the appendix and relate to similarities and differences between design and fabrication; degree of design and fabrication in student’s projects, support of design and fabrication in the campus makerspace, and feelings toward design and fabrication.

3.3 Group Sensemaking

Each week students met in a three-hour meeting facilitated by the first author. In these meetings, students shared their experiences and analyzed their field note entries and reflection entries as traces of project activity. This included 1) round robin updates where students shared highlights 2) discussions-based experiences and topics of interest 3) construction of timelines of project work, and 4) coding and thematic analysis of field notes.

3.4 Data Analysis

Following the research group, student’s journals were anonymized via pseudonyms and were qualitatively analyzed by two researchers over the course of 6-months.

Thematic Analysis: First two researchers engaged in grounded qualitative analysis of all 7 students’ journals (both field note entries and reflective entries) through multiple rounds of iterative open coding which resulted in a number of themes. These two researchers chose the theme of design and use of tutorials for further analysis.

Further Analysis Reflection Entries: More focused open coding and thematic analysis was performed on 7 students’ reflection entries around the topic of tutorials and design. The results of this analysis are described in section 4.1 and 4.2.

Further Analysis of Decision Making: These results prompted us to focus on the use of tutorials and decision making as a lens on design. We summarize students use of tutorials in 4.3. Finally we further analyzed the experiences of one student, Lindsey, through the lens of decision making. We use the Questions, Options, and Criteria (QOC) framework to look at the design space of each project.² We analyze what was present in the tutorial and where and how Lindsey sought additional information as well as the final decision and rationale for that decision.

4. Findings

4.1 Design As

We begin by looking at how students talk about design in contrast to fabrication. Each week, students responded to reflection prompts in their digital journals. A recurring prompt for a number of weeks (week 1-5, 8) asked students about their views on design and fabrication and how these concepts related to their projects, resources, and makerspace support. Through these responses, we see students talk about design in a number of ways. Three ways of seeing design are highlighted here - 1) design as conceptual, 2) design as digital 3) design as planning.

4.1.1 Design As Conceptual

Students talk about design as more conceptual and open-ended than fabrication - as broad, hard to understand, being done in the head, and requiring more thought.

***Broad:** "Design is extremely broad. There's graphic design, interaction design, user experience design, etc. " - Tiffany R1-C*

***Hard:** "It's a lot harder to understand what design is than fabrication/construction. " - Tiffany R1-C*

***In the Head:** "I have mostly been designing in my head but need to sketch out some of my ideas. I have a particular dress pattern in mind at the moment though. " - Brittany R5-C*

***Conc** though Maddie*

4.1.2 Design As Digital

Students talk about design as digital in contrast to strong physical associations with fabrication. They mention computers and software as important design resources including software such as Adobe Illustrator (a vector drawing program), Sketch and Axure (prototyping software), and Rhino (CAD). Lindsey mentions Thingiverse, a digital file sharing platform used for sharing, using, and remixing design files primarily for 3D printing. It's interesting to note that students were engaging in sewing projects, but much of the software mentioned is in reference to 3D printing and laser-cutting processes. Paper as a physical design resource for sketching provides a counterpoint view to design as digital.

***Done digitally:** "Fabrication requires a lot of physical resources to actually make a project, while design is usually something done digitally or through sketches. " - Lindsey R3-C,*

***Shared Online:** "For 3D printing, I'm either using Thingiverse or designing something myself." - Lindsey R5-D*

***Associated with software:** "Additionally, I have access and experience to all of Adobe CC, so I can use Illustrator or Photoshop for designing. " - Maddie R1-B*

The computers are the main design resource, and they contain numerous pieces of software meant for design work: Rhino, Illustrator, etc. The computers are definitely meant to encourage design, especially using software that students may not have access to. " - Lindsey R2-C,

***Not Physical:** "Most of the machines in the makerspace are more for fabrication than design. For example, the 3D printer and laser cutters are meant to create the correct piece and are for fabrication purposes. " - Lindsey R2-C*

***Associated with paper and sketching:** "It might be more satisfying to finish building a physical product than to finish designing something on a piece of paper/on a device, since the physical object is right in front of you to interact with. " - Tiffany R1-C*

4.1.3 Design As Planning

Students talk about design as a planning process that happens first in able to facilitate fabrication.

Preceding

Fabrication "Design, then, is something that occurs before fabrication in order to have a clear idea of how to actually construct the project. " - Lindsey R1-C,

Enabling

Fabrication: "I feel that I am more empowered to fabricate when I walk into the space because of all the fun looking machines, but without designing first this can be difficult." - Brittany R2-C

Planning : "When I think of design, I think of planning and testing. I think of sketches and visualizing what something could look like. " - Tom R1-C,

Planning Stage: "It's possible that there is some overlap in terms of tools, but for the most part I see the divide between design and fabrication as the difference between the planning and actual development stages. " - Lindsey R1-C,

4.2 Design as Out of Reach

Next we look at how students see design in relation to the sewing projects they are pursuing in the university makerspace. Here we see that design in many ways feels inaccessible - 1) student's choose projects that are "pre-designed" and primarily fabrication, 2) students feel that the makerspace supports fabrication more than design, and 3) while their projects are mostly fabrication, students still make "minor design decisions".

4.2.1 I chose a fabrication project because

Students speak about their projects as primarily fabrication and mention various rationale for choosing projects with limited design requirements. Most students chose to do a project more on the side of fabrication than design because they are new to sewing and don't feel like they have the knowledge and skills to "design from scratch". Lindsey is motivated to learn sewing skills not necessarily to design. To her, design requires more awareness of her "limitations and overall capabilities" with sewing. Tiffany leans toward a simple project that is more on the side of just fabrication because of time constraints. Tom has "no clue where to begin" with e-textiles so he feels it's not "a bad thing" to learn from others' solutions.

I chose fabrication because

was interested in

gaining skills: "I was interested in gaining sewing skills through a cool project, and not necessarily designing something when I was unsure of my own limitations or overall capabilities. " - Lindsey R3-C, "

wanted a simple

project: I intentionally chose a project that leaned more towards the fabrication spectrum since it doesn't require a lot of time to think about design decisions and I wanted to start off with a simple project to work on. " - Tiffany R3-

have no clue where to

begin: "Did I chose a fabrication project intentionally? In this case I would say yes because I wanted to do something with etextiles but I have no clue as to where to begin. Yes, I suppose I could "follow" Edison to find yet another way it wouldn't work but since others have solutions, I don't think it's a bad thing to learn from them and use them. " - Tom R3-C,

since I am a

beginner: "Since I am a beginner when it comes to sewing, I unintentionally chose projects that were more on the side of fabrication rather than design, just because I hope to have more guidance for my first sewing project. " - Maddie R4-C,

My project is primarily

fabrication:

Since making hair scrunchies is a quite simple sewing project compared to others, I would definitely categorize it as more of a fabrication decision. " - Tiffany R3-C,

"I think my project has more elements tied to fabrication and less so design. If I go back to Karen's baking analogy, someone else did "make" this recipe of the gloves and I am sort of executing that design. " - Tom R3-C,

"My project is more on the side of fabrication than design. I think the fact that I chose something that was pre-designed and had clear instructions so that I wouldn't have to come up with much points to the importance of fabrication in this project. " - Lindsey R3-C, "

"I did some sketching to think of ideas for projects I wanted to make, but I did not make the patterns myself. The pattern companies do most of the designing and leave the fabrication fairly easy for the user. " - Brittany R4-C,

design:

"The a-line skirt/dress will definitely be more design than fabrication. I think designing the pattern and adding elements like pockets and buttons will make the dress/skirt more design-based. Especially if I decide to make it a dress, designing the sleeves and neckline will definitely be interesting."" - Maddie R3-C,

"I think my project is more leaning towards to design since I didn't get any help from other resources. I created from my skill set and some design elements." - Vanessa R3-C,

4.2.2 The Makerspace as a place for ...

In a few reflection prompts, students were asked how if they felt the makerspace was a place that supported fabrication or design. Many students see the makerspace as primarily “meant for fabrication” because “most of the equipment and tools provided are used to build or fabricate physical objects”. Tiffany mentions that “you CAN do design” in the makerspace but it is not necessarily well supported. She thinks “the best way to approach a project is to come up with a design, research, and plan at home” then come into the makerspace to bring the project to life. Brittany mentions she felt “a little intimidated” when first entering the makerspace because she felt that “you must enter the Makerspace with a project in hand”.

Lindsey and Vanessa mentioned instances of design support. Lindsey states it “feels like a space that supports design” and recalls “deciding 3D prints and laser cuts in that space”. Vanessa feels that the space can “somewhat empower to design” because it supports a community of people who can exchange ideas.

The makerspace as a place .

for fabrication: "In many ways, the space has always felt like somewhere meant for fabrication, as opposed to solely design. Most of the machines in the makerspace are more for fabrication than design. " - Lindsey R2-C

"The Makerspace seems to be much more fabrication oriented than design oriented. There are computers where people will design their 3D printing projects or their laser cut projects, but there does not seem like there is a place in the Makerspace devoted to facilitating and inspiring design. " - Brittany R2-C

"At the makerspace, tools for makerspace are more towards fabrications since there is tool like sewing machine." - Vanessa R2-C

"The co-motion makerspace, in my opinion, is a strong direct representation of fabrication. Most of the equipment and tools provided are used to build or fabricate physical objects. "" - Tiffany R2-C

to go after you have a design: "I feel that the space is heavily fabrication-oriented without many design resources. When first entering the Makerspace last year, I felt a little intimidated because I was under the impression that you must enter the Makerspace with a project in hand and knowledge about all the machinery. " - Brittany R3-B

"I think the best way to approach a project is to come up with the design, research, and plan at home where you can talk to others about the design and brainstorm. Once you're solidified on a design, then the best way to make that come to life is to visit the makerspace. "" - Tiffany R2-C"

where design can happen:"I definitely feel like the space has the physical tools for both designing and fabricating, maybe a little more fabricating since most of the tools are for making designs which one has thought out already. " - Tom R2-C,

"The makerspace definitely feels like a space that supports design and where I can design things. In fact, I know I've decided 3D prints and laser cuts in that space."" - Lindsey R3-C,

"The MakerSpace somewhat empower to design because makerspace is a also a community that help people to exchange ideas."" - Vanessa R2-C

"You CAN do design or design-thinking in the makerspace, but it may limit you in terms of space, the environment (maybe you like designing in a quiet space), and the physical resources (since i remember hearing during the orientation that we can't use their desktop computers to do anything design-related). " - Tiffany R2-C

4.2.3 Some minor design decisions i made were

Students primarily choose fabrication projects relying on “pre-designed” instructions, sewing patterns, and tutorials. However they do see moments where they can or must make “minor design decisions”. There are elements of the projects students do not feel like they can change, but elements that one “can be flexible with” such as color of materials. Fabric choice is seen as within reach, but there are mixed thoughts as to whether that counts as design. Lindsey mentioned that she’s not sure how “how much weight” to put on “decision like ‘what fabric do I use’ as it does not dramatically change the “steps” followed or the general materials and amounts prescribed to complete the project.

Maddie, who is planning to buy a commercial skirt pattern, talks about how the skirt will be design because she wants to modify it by adding pockets and buttons, sleeves, and neckline. Outside of material decisions and physical modifications, Tiffany mentions resource design. She looked for a number of tutorials online to make scrunchies. As they were all a little different she combined different elements to create a process that fit her needs.

Some minor design decisions i made were

***fabric choice:** "I'm not sure how much weight I put on decisions like "what fabric do I use?". For example, if I decided to make another tote bag and chose my own type of fabric, I'd probably still be buying the general materials and amount mentioned in the instructions and following that design. Having a completely different fabric type wouldn't really change that unless I had to change steps to account for the different fabric. " - Lindsey R8-C*

"I haven't done any design yet. But I did make a crop top from a dress. I don't consider that as a real design. But when I move on to pads project. I will be actually measuring and choosing fabric. " - Vanessa R5-C

***compiling resources:** "So i guess in a sense, i sort of "designed" my own resource of learning by combining all of the tutorials and instructions that made sense to just me." - Tiffany R8-C*

***fitting needs:** "I'll probably need to make some minor design decisions after I make my first hair scrunchie and decide what specific adjustments I can make based on the step-by-step tutorial to better fit my needs and the needs of the people I'm thinking about making my scrunchies for (since everyone has different sized wrists or prefer larger or more ruffled scrunchies). " - Tiffany R3-C*

***adding elements:** "The a-line skirt/dress will definitely be more design than fabrication. I think designing the pattern and adding elements like pockets and buttons will make the dress/skirt more design-based. Especially if I decide to make it a dress, designing the sleeves and neckline will definitely be interesting." - Maddie R3-C*

***color:** "Apart from the actual circuitry of the project, I think there's actually a lot I can be flexible with. LED color, wool color, etc. " - Tom R3-C*

4.3 Use of Tutorials

Students were asked to pursue an independent project. As discussed above, given their limited familiarity and skills with sewing or pattern drafting, students sought tutorials and step-by-step instructions to follow in order to create a physical product. Students used resources provided online for free on YouTube, project blogs, and electronic sites like Adafruit. Two students purchased commercial sewing patterns.

Despite the choice to use prescriptive step-by-step tutorials, students encountered areas where they saw they could make "minor design decisions" like color of EL wire or yarn. They also encountered areas where the tutorial lacked information and they had to seek information elsewhere. They also encountered areas where instructions contained multiple options but no rationale for how to choose.

Three students made garments. One was working on drafting her own skirt, but used video tutorials on YouTube to give her step by step instructions of how to pattern draft. The other two students used commercial sewing patterns which walk you step by step through what to buy, shapes to cut, and how to sew the pieces together.

Lindsey took the approach of looking at many tutorials and looking across them to start to understand what dimensions of variation were and why one might make difference choices. Because her project was small, hair scrunchies, she was able to make many iterations. She played with different kinds of fabric and different proportions of scrunchies, she was making them for her friends. So she used the tutorial as support but then experimented as she got more comfortable.

Vanessa took a more ad-hoc approach. She watched YouTube tutorials of hacking to get the general concept, but did not follow step-by-step instructions and instead reverse engineered processes like hemming by looking at physical examples of hems on finished garments.

yet i did have to figure out: "Most of my materials were mentioned on the tutorial I am using, which means I didn't have to make a lot of decisions besides "what color do I want my EL wire to be". Yet, I did have to figure out what fabric and how much I needed for this project. I did this by searching online for how to make cornhole bean bags and determining what the common material was" - Lindsey R6-D

doesn't give me all the information:" If I just had to follow instructions and it literally told me to use the zigzag stitch on these settings then I don't think I'd really be learning on my own. Yet, the tutorial doesn't give me this information and I have to practice and test things out." - Lindsey R6-D,

rabbit hole of YouTube tutorials: "In addition to finding sewing patterns online, I also watched some YouTube tutorials of skirt/dress making, which eventually led to a rabbit hole of endless tutorials showing women going thrift shopping and upcycling hideous pieces of clothing into beautiful, trendy pieces. "" - Maddie R3-B,

you are not able to diagnose problems: It is tough to learn something totally new for you on your own because you just copy each steps from the tutorials. You don't know how each step function so when you encounter some difficulties or barriers, you are not even able to diagnose the problems. For example, I started to learn how to thread the bobbin by following the paper instruction provided from the makerspace, but I was lost. " - Maria R6-D, "

4.4 LINDSEY DEEP DIVE

This analysis is currently in progress, but we intend to include in the final paper. The current analysis in progress (as described in the methods section) is use of the QOC framework to explore the decisions being made, what options are considered, what criteria are considered, and where there are gaps in the tutorial and how additional information is sought. We present below our preliminary findings - design decisions of interest - to be further analyzed with the QOC framework.

Lindsey chose to construct glowing bean bags for playing the game cornhole at night. They include both sewing and electronics skills as bean bags are constructed out of fabric and EL-wire is attached around the outside to make them glow. Lindsey chooses to use a tutorial from the electronics supplier Adafruit.

We take a closer look Lindsey's experience through her project documentation. Lindsey has chosen to use a tutorial with "*clear steps to help guide me through my first solo sewing project*" - Lindsey R3. She looks at the project as "*pre-designed*" and expects that she "*wouldn't have to come up with much*" - Lindsey R3-C. Despite this expectation that the project is already designed and all she has to do is execute, she encounters a number of gaps in the tutorial where she must seek information elsewhere and make decisions based on known options and her personal criteria for the project. In reflecting on how much her project involves design or just fabrication, Lindsey characterizes some of the decisions she had to make as design moves. "*The closest I really have to get to design in this project is making fabric decisions and finding other instructions online for pieces that my Adafruit tutorial doesn't mention, like size of the squares to make the bean bags.*" Lindsey - R3-C

Below we highlight 5 decisions made through the lens of gaps encountered in the tutorial, options considered, criteria considered and their relationship to different options, sources of information and information seeking behavior to fill in these gaps. Two high-level decisions are first discussed - 1) what project to choose and 2) tutorial selection. Followed by 5 project decisions - 1) what fabric to use, 2) how to cut the fabric, 3) what el wire to choose, 4) how to close the bean bag, and 5) how to attach the el-wire to the bean bag?

4.4.1 PROJECT CHOICE

One of the first decisions Lindsey must make, it what project to pursue for the quarter. She has been given the constraints that it should be completed within the quarter (10 weeks) and should utilize the sewing equipment in the university makerspace. Lindsey considers a few different projects that she might be interested in pursuing. She chooses to make glowing El Wire Bean Bags that can be used to play the game cornhole at night.

Lindsey has a number of considerations (criteria) when considering what project to pursue. One of Lindsey's considerations is a desire to learn and acknowledgement of here current knowledge and understanding of both sewing and electronics. She is interested in an e-textiles project because it will push her to engage with soldering and sewing skills. She is also interested in utility, something *“that I could actually use”* and *“ honestly the prospect of it glowing in the dark seemed exciting.”* She is also interested in combining sewing and electronics - it is just interesting to her.

4.4.2 TUTORIAL CHOICE

Lindsey starts with one tutorial and expects that it will be easy to follow, but she eventually seeks other resources and makes decisions as she encounters knowledge gaps in the tutorial.

Lindsey uses a tutorial from Adafruit as depicted in Figure 1.³ This tutorial includes video content, gifs, multiple sections, links to other resources like how to solder. It is fairly rich with information compared to many tutorials.

Adafruit is a website dedicated to selling materials for hobby electronics. *“Adafruit was founded in 2005 by MIT hacker & engineer, Limor "Ladyada" Fried. Her goal was to create the best place online for learning electronics and making the best designed products for makers of all ages and skill levels.”* - Adafruit website. So unlike a tutorial from an unknown audience (maker) we can assume that this tutorial was designed for beginners and for the purpose of learning.

Figure 1. Glowing Bean Bag tutorial from Adafruit.

4.4.3 Vignette 1 Fabric Needs

One of the first gaps in the tutorial that requires Lindsey to make a choice is Fabric needs. The adafruit tutorial does not provide information as to what fabric, how much fabric, and where to get fabric. Lindsey must navigate other resources to make this decision. Analysis of QOC to come.

4.4.4 Vignette 2 Size Cut Fabric

One of the next gaps Lindsey encounters is about what size to cut the bean bag fabric. The adafruit tutorial does not provide enough information for Lindsey to cut the beanbag and she must seek resources elsewhere. Analysis of QOC to come.

4.4.5 Vignette 3 EL Wire Color

A common decision that students seem like they have the knowledge to grapple with is aesthetic choices like color. Lindsey documents considerations when choosing EL wire color and Fabric color. Analysis of QOC to come.

4.4.6 Vignette 4 How do I Close the bean bag

While much of the tutorial is prescriptive without rationale. There is a branch point where two options are suggested. “You can hand stitch the bag shut or use velcro tape to make it easier to change the battery.” Lindsey seeks information and makes a decision as to how to do this. Analysis of QOC to come

4.4.3 Vignette 5 How do i attach the el wire

One of the challenges Lindsey encounters is how to attach the EL wire to the bean bag. Lindsey seeks resources, prototypes and makes a decision. Analysis of QOC to come

Concluding Remarks

In this work, we see talk from students about design suggesting they see design as digital, design as conceptual, and design as the planning that happens before fabrication. We are interested in their ways of talking about design because we believe their ways of understanding matter. Instead of suggesting that there is one “right” way to think about design that we expect students to know and learn, we are wondering what students are developing and how this might relate to makerspace and informal learning. Thinking like Goel and Pirolli who looked at design as a radial category (a perspective from prototype categorization theory), we note that we are starting to see the “prototype” concepts students have for design.⁴ We note that they have many ideas about design and some of their ideas are more aligned with the core “prototype” of design associated with engineering education. This leads us to ask what are students’ ideas of design and how do they relate to the more prototypical ideas?

In this work, we also see students connected design with the digital world. This leads us to ask, what might students’ exposure to digital manufacture mean for students’ thoughts about design and how we teach design? In the context of informal learning in makerspaces, students are primarily exposed to digital fabrication tools such as CNC routers, laser-cutters, and 3D printers. While spaces often have other equipment, these are what are primarily used. From the viewpoint of constructivism, if students are drawing their definitions and impressions of design from their experiences and their experiences are in makerspaces rather than formal design courses, what does this mean for their impressions of design?

These observations relate to what Tian et al refer to as Digital Fabrication Metaphors, fabrication metaphors supported by digital fabrication in contrast to craft and hand tool kinds of fabrication.⁵ They characterize digital fabrication as siloed, geometry agnostic, serial, and limited build volume. We are particularly interested in their notion of siloed which they further develop in the following way, “Siloed — The making process is broken into three distinct phases: users (1) design digital models using software, (2) convert that model to a machine parsable form (e.g. ‘slicing’, CAM programming, etc.), and (3) wait for the machine to produce the final object.” Stemming from this, we wonder how exposure to digital fabrication equipment might instill or support this metaphor of siloed process. We see this in the dividing of design as the planning that happens before the fabrication. Other types of making might support different metaphors. For example, woodworking or something where you adjust or plan along the way might support other metaphors. If students’ primary exposure is to digital fabrication in makerspaces instead of more traditional fabrication with ecologies of tools and modification along the way, then we might expect these a siloed conceptions and we might want (as educators and researchers) to attend to this siloed metaphor.

In this work, we also noted students talking about design as the conceptual digital work that happens before fabrication. They are not necessarily seeing design as an ongoing process or a process where manipulating materials is part of the conceptual work. This is in contrast to how Schon speaks about knowledge in action alongside conversations with and backtalk from materials.⁶ For Schon manipulation of physical things is very much part of design work (Schon, paper about digital material backtalk).⁷

In this work, we also see students constructing the makerspace as something that does more to support fabrication than design. For the students, you “can” design there but there is not a strong reason too. We wonder what this means for thinking about makerspace support. How might we design makerspaces that support design?

Finally, in this work, we paid attention to the role of tutorials in design. When students were asked to complete a project in a domain of fabrication where they have little experience in a makerspace they might not be familiar with yet, the students turned to step by step instructions as a means of cognitively offloading the design decisions. In particular, Lindsey refers to her tutorial as “pre-designed.” She is interested in learning and suggests that design decisions rely on a skillset she does not have or will get in the way of her learning basic sewing skills. She talks about scope and not being able to tell scope, saying “*I chose something that was pre-designed and had clear instructions so that I wouldn’t have to come up with much.*” Despite using tutorials, all of the students run into areas where they can or must make decisions and often did not have the knowledge of what choices they had or how to choose one choice over another. The students sought information to try to fill in these gaps but felt unsupported. This leads us to ask, how might we think about constructing resources that scaffold design decision making for students who are new to a domain of making? We also wonder, how might we think about tutorials as a means to structure and support design decision making for novice designers working in informal learning situations?

This work takes on a pseudo *in the wild* energy that is not without limitations. By asking students to share their journals with the research team we do not get the full picture of their thoughts. By taking a traces approach to documentation, we are unable to capture everything. Given the

longitudinal nature of this work, details get lost over time and there are emotions and reactions that are difficult to capture in writing.

As a limitation and provocation for future exploration we acknowledge that students did not fully understand the word fabrication. Informed by the researcher's conceptions of how design is defined, students began to conceptualize their own understandings of the word fabrication which might or might not be correct. We see this in their field notes when some asked explicitly about its meaning while others associated it with the object, fabric. Future research might explore how we support students' conceptualization of fabrication without priming them to see different, disconnecting relationship to the concept.

Works Cited

1. Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of engineering education*, 94(1), 103-120.
2. MacLean, A., Young, R. M., Bellotti, V. M., & Moran, T. P. (1991). Questions, options, and criteria: Elements of design space analysis. *Human-computer interaction*, 6(3-4), 201-250.
3. Stern, B. (2015, November 23). Glowing Bean Bags with EL Wire. *Adafruit*. Retrieved from <https://learn.adafruit.com/glowing-bean-bags-with-el-wire/overview>
4. Goel, V., & Pirolli, P. (1992). The structure of design problem spaces. *Cognitive science*, 16(3), 395-429. <http://csjarchive.cogsci.rpi.edu/1992v16/i03/p0395p0429/MAIN.PDF> (design as a radial category)
5. Tian, R., Sterman, S., Chiou, E., Warner, J., & Paulos, E. (2018, April). MatchSticks: Woodworking through Improvisational Digital Fabrication. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (p. 149). ACM.
6. Schön, D. A. (2017). *The reflective practitioner: How professionals think in action*. Routledge.
7. Dearden, A. (2006). Designing as a conversation with digital materials. *Design studies*, 27(3), 399-421.

Appendix: Reflection Prompts

Design Prompt Week 1

C: Design: Reflect on the idea of design vs. fabrication/construction. How are these concepts different to you? How does this apply to resources. What resources relate to design? What about fabrication? Similarities/Difference? Why?

Design Prompt Week 2

C: Design: Reflect on the idea of fabrication vs. design in reference to your experience obtaining access to the space? What resources do you see for design vs. just fabrication? Does this feel like a space where you can design or that supports design? Do you feel empowered to design or fabricate at this point?

Design Prompt Week 3

C: Design: Reflect on the idea of fabrication vs. design in reference to your experience obtaining beginning your project? Characterize your project in terms of where it seems to fit for you on the spectrum of fabrication → design? Did you intentionally choose a project toward one end of this spectrum or the other? Why? Are there elements where you feel like you are going to need to

make design decisions? What resources do you see for design vs. just fabrication? Does this feel like a space where you can design or that supports design? Do you feel empowered to design or fabricate at this point?

Design Prompt Week 5

C: Design: Reflect on the idea of fabrication (think following a recipe) vs. design in reference to your experience obtaining beginning your project? Characterize your project in terms of where it seems to fit for you on the spectrum of fabrication → design? Did you intentionally choose a project toward one end of this spectrum or the other? Why? Are there elements where you feel like you are going to need to make design decisions? What resources do you see for design vs. just fabrication? Does this feel like a space where you can design or that supports design? Do you feel empowered to design or fabricate at this point?

Design Prompt Week 6

C: Design:

Design Prompt Week 8

C: Design: Now that we have started thinking about resources, relate resources back to this idea of design vs construction. You can think of it as a spectrum of how autonomous your project is, or whether you are making lots of design decisions or following someone else's instructions. Ownership might be a good way to think about it. If you are following a pattern is it your project or partially yours but partially whoever designed the instructions or pattern you are following? Decision making might be another lens. What fabric do I use? What tools do I need? Are you making these decisions based on what you want to make or do you have instructions that tell you what tools to get, what fabric to get. Think about how the space supports resources for making products vs. envisioning and creating your own projects - whatever that means to you.