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# School-based and Museum-based Makerspaces

Rebecca Helen Johnson
*University of Wisconsin-Milwaukee*

# SCHOOL-BASED AND MUSEUM-BASED MAKERSPACES

by

Rebecca Helen Johnson

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ABSTRACT

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Rebecca Helen Johnson

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Making and makerspaces, as a means and setting for creation, have grown in popularity in recent years. As makerspaces appear in schools and community educational settings, the Maker Movement's prominence and influence on education grows. As different people have served as the developers and facilitators for these makerspaces, no makerspace is the same, because the intentions and values of these developers and facilitators differ. Studying the effects of these different intentions and values on the decisions made by the facilitators has allowed me to research the theories surrounding the Maker Movement in actual practice. My research contributes to the conversation around makerspaces by providing a real-world example of the application of elements of the Maker Movement being applied in both a school-based and museum-based setting. The question I aim to answer is: how do makerspace facilitators design an environment, transfer a philosophy of making, and construct a curriculum and pedagogy that engages children in making and for what purposes? My research and observations led to a discussion and recommendations for practice that revolve around equipping makers with the ability to make choices as well as projects by promoting a maker mindset, designing an environment, and enacting a pedagogy that centers making as learning.

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# Chapter 1. The Problem

## 1.1 Introduction

The purpose of this chapter is to introduce the reader to the problem surrounding makerspaces in school- and museum-based settings. In the following sections, I provide background information on making and makerspaces, state the problem I am researching, determine the purpose of this study, state the research question, explore the significance of this study, and provide an overview of the chapters to follow. First, I provide a basic introduction to making as it relates to education, followed by a brief history of how making has been incorporated in education. I then state the research problem, outlining the responsibilities facing educators who apply making principles in their classroom or as a part of their organization. The subsection addressing the purpose of the study outlines the existing research surrounding makerspaces and how this study fits into that context. The subsections that describes the significance of the study recognizes the contributions of this study to the overall conversation around makerspaces in education. I provide an overview of the conceptual framework in an effort to ground my study in the context of the existing conversations around making in education and identify my philosophical approach to the study, which is interpretive and constructivist. I also reveal the methodology I used in the study, providing an introduction to the observations and mappings I completed to better understand the choices made by facilitators in makerspaces. This first chapter aims to provide an overview and a starting point in the process of my research.

## 1.2 Background to the Problem

### 1.2.1 Making and Makerspaces Defined

Making and makerspaces, as a means and setting for creation, have been defined by various people in various ways, especially as the Maker Movement has grown in popularity in recent years. Educational researcher Kimberly M. Sheridan and colleagues offer perhaps the simplest definition of making: “developing an idea and constructing it into some physical or digital form” (Sheridan, Halverson, Litts, Brahms, Jacobs-Priebe, and Owes, 2014, p. 507).

Making does not need to revolve around a step-by-step process of building something. Instead, facilitators can focus on "structuring learning around primary concepts" and encourage makers to solve a problem relevant to their interests (Brooks & Brooks, 1999). Simply put by Mark Hatch, makerspaces serve as locations where people can make, share, give, and learn (Hatch, 2014). Making is simply the created manifestation of an idea in a physical or digital form. Sheridan and colleagues describe makerspaces as "informal sites for creative production in art, science, and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products" (Sheridan et. al, 2014, p. 505). Makerspaces have the potential to infuse creativity and problem-solving, using art-making and design-thinking through a variety of curricula proposals, pedagogical methods, and physical environments that privilege self-directed learning for audiences beyond a specific classroom.

Art educator Robert Sweeny describes the journey of the Maker Movement and its implications for makerspaces, referencing the outgrowth from *Make Magazine*, published by Maker Media, into Maker Faires. Since 2006, Maker Faires have "allowed both amateur and professional tech hobbyists to gather and share techniques and to sell their products to the public" (Sweeny, 2017, p. 353). According to Sweeny, makerspaces naturally evolved out of groups who formed with interests in "DIY technology initiatives" and took different forms, such as "hackerspaces, computing clubs, and hobbyist gatherings" (Sweeny, 2017, p. 353). Expanding on these groups, Maker Media, with the help of funding from the Defense Advanced Research Projects Agency (DARPA), "has been instrumental in bringing makerspaces into U.S. public high schools," while facing scrutiny due to the connection between public education and military research (Sweeny, 2017, p. 353).

### 1.2.2 Making in Education

Throughout the history of education, the prominence of making has changed, as well as its implications for students. Making, under the category of technical education, used to exist as an option within a school environment for students, who may or may not have been college-

bound, to learn a trade skill. Vocational classes, like autos and wood-shop, have largely disappeared within schools, during this 21st century digital technology-focused era and service economy, which mirrors our current attitude regarding products and consumption (Wallenborn & Heyneman, 2009). With the availability of information on the Internet, purchasing items and researching them online has become the default action over building or repairing items or taking them apart to see how they work. A growing number of people interested in infusing technology skills with the physical creation of objects, however, has resulted in an insurgence of makerspaces: places that are dedicated to the creation of objects, sharing of ideas, exploration of materials, and learning of new skills.

Like technical education, visual art education's prominence has varied greatly both throughout history and also currently from school to school. Visual art instruction promotes creativity, problem-solving, critique and evaluation, and interpretation. These higher order thinking skills enable learners to complete projects of their own design. Robert Sweeny references the intentions of the Maker Movement as they relate to art education, writing that the primary focus is to "place emphasis on the creative problem solving that can take place when learners interact with a wide variety of materials" (Sweeny, 2017, 353). Visual arts education emphasizes the application of knowledge as the assessment for students. The ultimate goal is for students to make something or, as listed in Bloom's Taxonomy, create (Anderson & Krathwohl, 2001). Students who create have applied the knowledge that they have gained to a digital or physical object of their own design and production.

### 1.3 Statement of the Research Problem

As makerspaces appear in schools and community educational settings, the Maker Movement's prominence and influence on education grows. Teachers, community educators, and parents recognize the value and potential of making in education. As different people have served as the developers and facilitators for these makerspaces, no makerspace is the same, because the intentions and values of these developers and facilitators differ. Studying the effects of these different intentions and values on the decisions made by the facilitators has

allowed me to research the theoretical context — constructivism, constructionism, and others — surrounding the Maker Movement in actual practice.

Designing an environment that is conducive to product and creative development is important in a makerspace. Researching the decisions behind the physical environment setup of makerspaces, along with the results of those decisions, enables people to see how design of the learning environment can impact makers' efforts towards collaboration and leaning towards exploration. In some cases, collaboration and exploration may not be goals of a specific makerspace, which would influence the design of that environment as well. My research focuses on how facilitators create an intended flow through the physical environment of a makerspace and how their movements relate to the needs of makers.

Curriculum design is also an important responsibility for teachers and makerspace facilitators. Influenced by the pedagogy the facilitator follows, the curriculum implemented in a makerspace may differ from any curriculum designed for the traditional classroom, whether that makerspace is part of a school or not. The curricula of different makerspaces will likely have different focuses, different means of motivation, and different desired outcomes. Some makerspace curriculum encourages exploration, while others encourage problem-solving, while still others encourage something different. The pedagogy of the facilitators and the implementation of the curriculum, however, may not align, depending on a variety of factors, including the context in which the makerspace exists. The pedagogies and curricula are also influenced by the intended purposes for making. As I aimed to study both the pedagogy and curriculum of makerspaces, I investigated how pedagogy can inform curriculum and what outside factors influence the outcomes. By determining this, I can indicate what factors makerspace facilitators need to take into account when developing their pedagogy and developing their curriculum.

### 1.3.1 Purpose of the Study

Researching the theories of the Maker Movement in actual practice, especially in a space dedicated to making, allows for the ability to determine the effectiveness of the Maker Movement in education, across different educational settings. To answer the question “Why make?” I reference Constructivism and Constructionism as educational philosophies, as well as project-based learning and STEAM education, as pedagogy, and creativity as it relates to making. The common tie between all of these involves hands-on learning or project-based learning, because the learning relates to a real-world application. In schools or in the community, tying learning to the real world encourages meaningful learning that enables students to solve real problems, which can aid in eventually solving the problems of society.

Another main aspect of the Maker Movement is the element of sharing and giving, in regards to knowledge. Makers are encouraged to collaborate when brainstorming an idea and when bringing that idea to physical completion. The Maker Movement works in tandem with the idea of open source, which is a concept that drives free software that is available for anyone to use. Providing free and open access to knowledge in order to better society is a major component of the Maker Movement. The philosophy of sharing answers can be thought of as cheating in traditional educational settings, but the makerspace, fueled by constructivist pedagogy and aspects of project-based learning, can be a collaborative space where makers share their ideas and knowledge with each other and the larger community. The environment of the makerspace can influence the purpose of making by encouraging creativity, exploration, and collaboration, through the curriculum, pedagogy, and design of the space.

Current research surrounding makerspaces focuses on the space as a setting and the makers within the space. My research focuses on the choices of the makerspace facilitators in the philosophy, pedagogy, and environmental design of the makerspace. Studying the choices that makerspace facilitators make, in regards to the environment they design, philosophies they

impart, pedagogies they draw from, and curriculum they implement, allows me to determine the purposes and possibilities for the makerspace and the Maker Movement in education. In some cases, the makerspace facilitator may not implement any aspects of the Maker Movement, which is a choice worth studying as well, because knowing other theories that are influencing makerspace practitioners can lead to a broader knowledge base from which to draw ideas when implementing pedagogy or curriculum related to making or facilitating the development of a new makerspace and understanding the purpose of that makerspace.

### 1.3.2 Research Question

The question I aim to answer is: how do makerspace facilitators design an environment, transfer a philosophy of making, and construct a curriculum and pedagogy that engages children in making and for what purposes?

### 1.3.3 Significance of the Study

My research contributes to the conversation around makerspaces by documenting and analyzing real-world examples of the application of elements of the Maker Movement in both a school-based and museum-based setting. As making becomes infused in education, the maker philosophy is guiding curriculum and pedagogy. Throughout educational history, the idea of making has changed and evolved, with dedicated makerspaces replacing or accompanying technical education settings. As this evolution continues, research into makerspaces and their effects on students must continue as well, in order to provide an avenue for enhanced education. As makerspaces become more commonplace, educational administrators seek out professional development for their staff, in order to effectively facilitate making as a part of the education they aim to provide for their students. Contributing to the existing literature surrounding makerspaces means that I provide insight into makerspaces that may be shared with educators to further professional development supporting the use of makerspaces in educational settings.

By researching and physically mapping makers' movements through makerspaces, I provide an accompaniment to current literature, such as *The Third Teacher* (2010), regarding classroom and educational design. A makerspace is often not a traditional classroom, so its design must set it apart. My maps and findings allow readers to see how specific design elements influence the atmosphere and movement throughout the case of two specific makerspaces.

Focusing on the decisions made by makerspace facilitators allows my research findings to present not only the effects of those decisions on the makers and makerspace, but also the context in which makerspace facilitators must make decisions. Researching decisions helps put into perspective the considerations that should be made in future decisions regarding makerspace facilitation, such as how decisions impact the design, curriculum, and pedagogy of makerspaces, and how the design, curriculum, and pedagogy impact makers.

While this research is limited to the scope of two makerspaces, it can serve as a window into working makerspaces, revealing relevant themes, points of action, and other instances that necessitate decision-making. Those interested in starting or operating a makerspace can see the results of decisions and the impact of those decisions on the makers and on the makerspace itself within specific contexts attached to place and purpose. They can learn which decisions need to be made, and how those decisions can impact the makers and the sites they serve.

### 1.4 Overview of Conceptual Framework

The concept of making has grown in prominence and influenced education in school-based and museum-based settings. I work within a constructivist paradigm, as I am generally concerned with how meanings are constructed through interactions (Leavy, 2017). In order to develop a conceptual framework in which to analyze the impact of making on education, I researched the concept of making, educational researchers' perspectives on education, and

the surrounding influences on making in education. Before observing makerspaces in action, I designed a conceptual framework that displays the growing prominence of making through for-profit makerspace developer Mark Hatch's views on making and the cultural roots of making.

Making is commonly considered a part of STEM (science, technology, engineering, and math) education, but my work is informed by perspectives on making in education that relate art education to making as well, in order to later reference STEAM (science, technology, engineering, arts/design, and math) education. Referencing research from both volumes of *Makeology* by Kylie Peppler, Erica Halverson, and Yasmin B. Kafai, I focus on making as it relates to learning activities that are designed and implemented by facilitators, makerspaces as physical environments and communities for making, and students who develop their identify as makers.

The influences on making in education range from educational theories to aspects of the educational system in which making takes place. Educational concepts like project-based learning, Constructivism, Constructionism, and STEAM education influence the implementation of making in educational curriculums. The idea of creativity as it relates to education can also influence the implementation of making in education. Access and approachability to new technology and techniques can influence makers and facilitators within the educational system, which also can influence the implementation of making in education with its standards for students. Whether designed by facilitators or others, the environment can influence the implementation of making as well. Analyzing these theories and related concepts enabled me to apply elements of their educational best practices to my discussion and recommendations for practice for makerspace facilitators.

### 1.5 Overview of Methodology

Methodologies suggest the ways of acquiring and the criteria for judging knowledge (Blair, 2016). Working from a constructivist viewpoint and taking a qualitative case study approach, I focused on understanding the decisions made by makerspace facilitators and the impact of those choices (Stake, 2016). In order to understand the social and contextual

influences that drive facilitator's decisions, including the internal and external pressures faced by the facilitators that may limit the extent of their decisions' implementation within the makerspaces. Within the constructivist paradigm that guided my research, I had to remember that my observations do not reflect an objective truth, but instead represent the impact of contexts and individual choices on makerspace development.

I aimed to complete a comparative ethnographic case study focusing on the facilitators' decisions and the impact of those decisions on the makerspace programming. I tried to design my strategies for data collection to be as similar as possible for both makerspaces. Facing challenges of time and differing levels of responsiveness from the school-based and museum-based makerspaces, I was unable to design a perfectly comparable study for both makerspaces. Recognizing that the school-based makerspace and the museum-based makerspace could not be completely compared informed my data analysis, and I then knew to look for what contexts surrounded the makerspaces that made them unable to be directly compared.

My research strategy involved observing facilitators in the school-based and museum-based makerspaces. My methods of data collection focused on determining how the facilitators' choices influenced the philosophy, pedagogy, and design of the environment within the makerspace as a learning environment. Observations of the makerspaces in action allowed me to compare facilitators' intentions with actual occurrences. During my observations, I mapped the movements of the facilitators through the space, recording their actions at each area within the space.

As I analyzed the data from the maps and noticed patterns, I was able to distinguish whether each movement was to lead a maker, to be led by a maker, or independent of a maker's influence. I also interviewed the lead facilitator in the museum-based makerspace in order to further understand his intentions for the makerspace.

## 1.6 Chapters to Follow

The following chapters in my thesis include a conceptual framework and literature review, an overview of my methodology, the findings of my study, and suggestions for practice. Chapter Two is a review of literature that relates to educational theories, creativity, and other concepts that relate to making in education, which informed my approach to this research. Chapter Three outlines the strategies I used to compile and analyze the data that I collected. Chapter Four reports the findings I developed through the compilation and analysis of the data I collected. Chapter Five includes recommendations for art educators or other makerspaces facilitators based on my findings.

# Chapter 2. Conceptual Framework and Literature Review

## 2.1 Introduction

My conceptual framework examines how the Maker Movement has grown in popularity and influenced education and the philosophies and pedagogies held by makerspace facilitators. In Figure 1, I outline the direction my conceptual framework took, highlighting how my research focused on the philosophy, pedagogy, and design of the makerspace environment. I investigate making's influence on education and art education's relation to making. While exploring how the evolution of the Maker Movement has influenced the philosophies and pedagogies of making held by makerspace facilitators, I identify how the physical space and design of the makerspace promotes the development of makerspaces as communities of practice, and I recognize how facilitators can develop maker identities through the transfer of their philosophy of making and development of their pedagogy in teaching makers and making.

The evolution of the Maker Movement is the largest influence on making in education, as the definition and prominence of making expands. The philosophies and pedagogies of making help to define and develop makerspaces as more than just settings in which making occurs, but as communities of practice in which the physical design of the space contributes to the making that occurs within it. As the youth who enter a school- or museum-based makerspace may have many different motivations for doing so, examining the ways to encourage the development of a maker identity — acknowledging their making style, for one — enables a facilitator to transform students into makers. Making's incorporation into education is marked by implementation practices that can vary greatly. Art education, as a complementary practice, can also guide the process of integrating a makerspace into a learning environment.

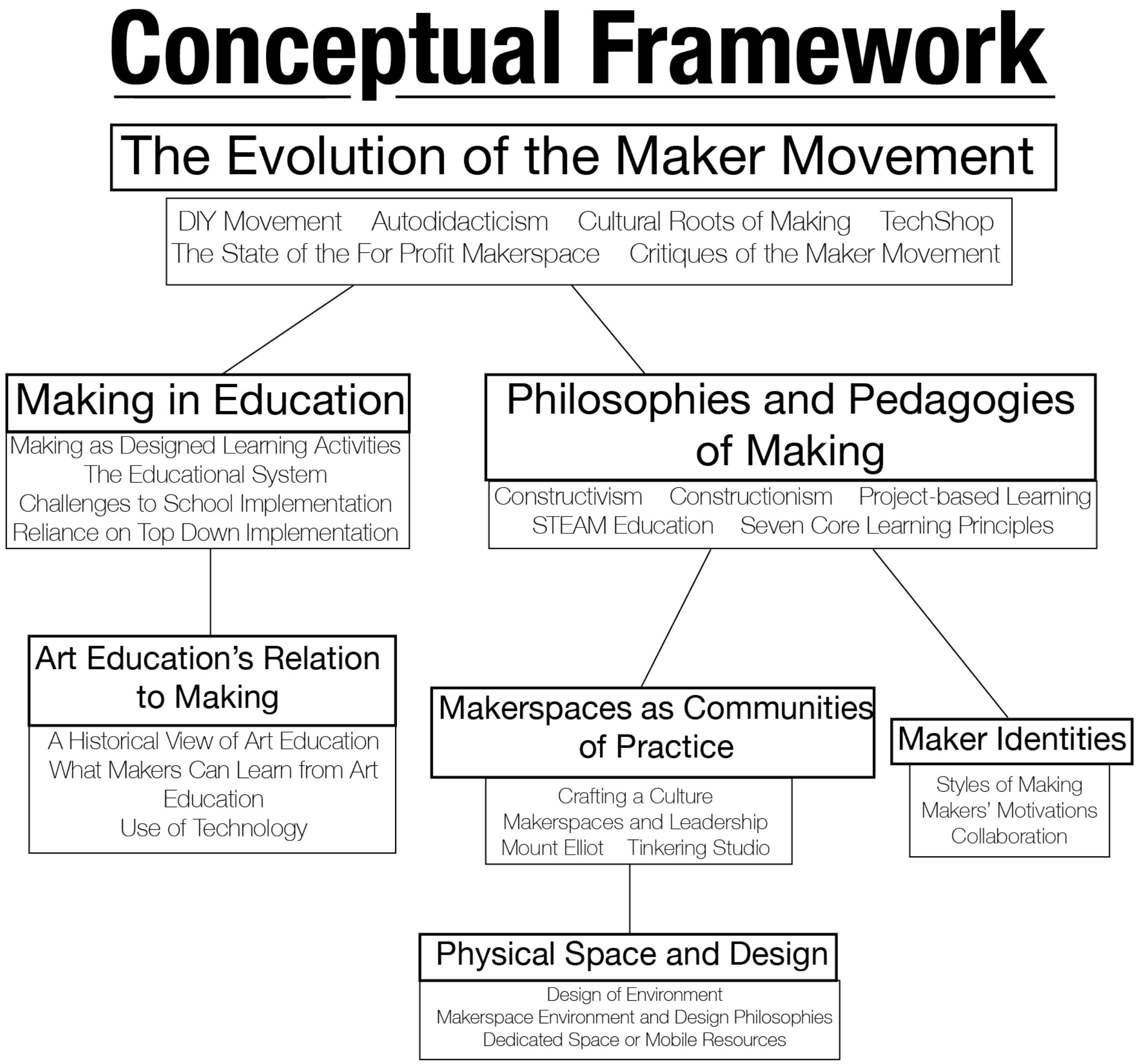


**Figure 1: Conceptual Framework Flowchart**

## 2.2 The Evolution of the Maker Movement

### 2.2.1 DIY Movement

Making grew out of the Do-It-Yourself (DIY) craft movement, which gained popularity in the early 1950s. This movement predated the Maker Movement and holds values of "dignity in creation, making as activism, and personal production rather than mass production" (Bender, 2016, p. 125). Similarly, tinkering, "an age-old practice of mending and repairing household objects," promoted the idea of repairing an object rather than buying a new one (Wilkinson,

Anzivino, Petrich, 2016, p. 161). A tinker, as someone who repairs objects with whatever is on hand, develops "an expanding repertoire of knowledge that developed over time and through experience" (Wilkinson, Anzivino, Petrich, 2016, p. 161). Along with tinkering, the DIY movement contributed to and influenced the Maker Movement, including the development of collaborative makerspaces.

### 2.2.2 Auto-didacticism

Auto-didacticism is learning without the guidance of masters. As a part of the Maker Movement, auto-didacticism is a common way of building skills among adult makers. Within hacker culture, which grew in popularity at MIT in the 1960s, extreme auto-didacticism is an assumed byproduct of engineering schools. Commonly attracting students "with extraordinarily high academic achievement," engineering schools serve as a community with "their own values and social practices," including "self-sufficiency, auto-didacticism, individualism, and competition" (Blikstein & Worsley, 2016, p. 66). The common image of a hacker is that of a disheveled individual white male young adult learning anything that interests him on his own. Relating hacker culture to education can run into problems after taking this image into account, because that culture "only works for a small elite group of high-end students" (Blikstein & Worsley, 2016, p. 66). Expecting students to learn individually conflicts with the notion of an educational makerspace, instead aligning more towards an individual, solitary workspace.

Makers try new things, experiment with new materials, and learn new technology, encouraged not by outside sources but by their own intrinsic motivations and interests. While completely independent auto-didacticism would not be functional for children in a formal or informal learning environment, building intrinsic motivation is a key priority for instilling a maker mindset.

### 2.2.3 Cultural Roots of Making

The roots of the Maker Movement can be tied to three main events in recent history. First, the FabLab's invention at MIT around 2001. Second, *MAKE* magazine's hosting of the first Maker Faire in 2005. Finally, the general growth surrounding "technology-rich informal

education programs" (Blikstein & Worley, 2016, p. 65). These three events grew from communities with a longstanding dedication to technological innovation often becoming immersed in a culture of hacking (MIT), Silicon Valley culture (*Make* magazine), societal acceptance and fears of American inadequacy in terms of math and science education compared to China leading to a need for a STEM-focused workforce (informal education programs) (Blikstein & Worley, 2016). These recent cultural developments have influenced the Maker Movement and its existence in education, as has the growth of tinkering in education.

#### 2.2.4 TechShop

Mark Hatch, the CEO of TechShop, "a membership-based, do-it-yourself (DIY), open access, fabrication workspace," published *The Maker Movement Manifesto* in 2014 (p. 3). While his makerspaces were only open to people aged 16 and up, his concept is all-encompassing of making for all ages. He directly references the education system frequently, often indicating how making can be valuable to students. His Maker Movement Manifesto describes the necessary elements of a functioning makerspace.

TechShop opened as a franchise of for-profit makerspaces designed with an intention to provide industry-standard equipment to those who had a goal of producing a final product to serve a purpose. Through workshops and training, makers who paid to join could use any equipment within the TechShop setting to produce work of their choosing. TechShop's model was touted as a standard for makerspace operation.

Although TechShop's United States locations were forced to close on November 15th, 2017 as a result of financial struggles, Hatch's manifesto, further explained in subsection 2.3.6, can provide a framework to building an engaging, equipped makerspace in which adults or youth can explore making. As a for-profit business model, TechShop was unsuccessful, but the "essence of the TechShop vision was to develop a network of makerspaces, members, curriculum, standards, instructors, and learning that would fuel the brith of new technologies, products, jobs, and companies" (Woods, November 2017). Hatch's concepts of making "have inspired thousands of youth to view themselves as inventors, problem solvers, creators, and

makers" (Woods, November 2017). The integrated pieces of his concept can support making as a hobby or potential business for adults and making in education for children.

#### 2.2.5 The State of the For Profit Makerspace

Ian Cole, an Orlando-based maker and founder of The Maker Effect Foundation and Maker Faire Orlando, acknowledges Hatch's TechShop as having "made a huge contribution—but then had a disproportionate voice in defining the Maker Movement" (Cole, 2017). While Hatch's *Maker Movement Manifesto* (2014) emerged accompanying TechShop, the concepts can apply to for-profit makerspaces and non-profit makerspaces, school-based makerspaces and community-based makerspaces. Upon TechShop's abrupt closing, Cole discovered that there appear to be other makerspaces in every market where a TechShop was open, implying that those involved in the Maker Movement do not rely on TechShop's model to function.

Cole describes TechShop's model as the "build it and they will come" model, referencing its "large facilities and a huge catalog of tools" that helped them raise over $11 million in investment. When faced with financial trouble, TechShop shifted to a licensing model, allowing co-development with strategic partners, such as corporations, universities, municipalities, and real estate developers (Woods, May 2017). This shift in business plan was ultimately unsuccessful, with TechShop announcing its intent to declare bankruptcy and close all of its locations on November 15, 2017. (Woods, November 2017).

Throughout its tenure, TechShop's team worked hard to present TechShop as a leader of the movement, as nonprofit makerspaces "struggled to run [their] space and share [their] challenges" (Cole, 2017). While "TechShop was highlighted in the press as the standard," their business practice was jeopardizing their ability to remain open. Meanwhile, nonprofit makerspaces have continued in their processes and remain open. While TechShop as a business model has failed, the Maker Movement associated with TechShop continues in makerspaces throughout the United States and the world. For-profit makerspaces can serve as a model for youth-focused makerspaces, expanding the range of the Maker Movement, inspiring teachers, administrators, and parents to offer making activities to children.

### 2.2.6 Critiques of the Maker Movement

With Make Magazine and Maker Faires playing an integral role in making culture, these "demographically biased and male-centric" pillars of the Maker Movement are designed for a certain population: "college-educated, affluent, White men" (Blikstein & Worsley, 2016, p. 66-67). These depend on a final product to sell magazines and entice attendance at Maker Faires, resulting in a culture "in which product takes precedence over process" (Blikstein & Worsley, 2016, p. 67). It also becomes apparent what purpose technology serves, according to this culture's views. Projects designed to "solve (often frivolous) 'first-world' problems" undervalue many other forms of making, especially those forms that may be more accessible to lower income makers (Blikstein & Worsley, 2016, p. 67). This aspect of maker culture can attract interest to the idea of making, but it does not necessarily promote approachability.

The "job market" culture is a result of often exaggerated claims of a shortage of engineers and qualified computer scientists to fill job openings. It is often coupled with the perception of scientific educational inferiority to China, and the results often include a "STEM pipeline," guiding students through STEM courses towards eventual careers in STEM. While this culture was well-intentioned to guide more students into STEM careers, the results have "influenced the tools, goals, and pedagogies incentivized (or allowed) in schools" (Blikstein & Worsley, 2016, p. 68). This impact on education has led to computer programming, formerly considered "an expressive tool and a foundational literacy for every child," to become a gateway into computer science careers. With a main goal of creating more engineers, many makerspaces ended up "backgrounding the goal of exposing students to powerful ideas and tools for self-expression" (Blikstein & Worsley, 2016, p. 68). Instead of guiding students along a narrow path, making can expose them to a wide variety of materials, techniques, and skills, despite their future careers intentions.

The multitude of after school programs focusing on STEM activities serve as another cultural influence on the Maker Movement. With more accessibility to technology due to lower costs, informal learning environments have increased their offerings with the aim of preparing

participants for the job market with crucial STEM skills. The accessibility of these programs, however, is often limited to those who can afford the workshop fees or museum entrance fees. The necessity for the workshop facilitators to reach as many participants as possible can also lead to a "fast, scripted perpetually 'introductory'" model of workshop, which Blikstein and Worsley call "keychain syndrome," referencing the "trivial objects" made quickly in an introductory workshop (Blikstein & Worsley, 2016, p. 67). Limited to quickly finished make-and-take projects, participants may never be able to move on to more complex projects requiring "more complex facilitation, curriculum design, and equipment (Blikstein & Worsley, 2016, p. 68). The "keychain culture" may serve as an approachable entry point to making, but it does not engage makers past an introductory knowledge.

## 2.3 Philosophies and Pedagogies of Making

### 2.3.1 Constructivism

With the intent to teach students to think, Constructivism promotes connecting the knowledge they learn with their own lives through meaningful problem-solving. In *Democracy and Education* (1916), John Dewey emphasizes the importance of teaching students to think, claiming that "all which the school can or need do for pupils, so far as their minds are concerned…is to develop their ability to think" (p. 159). Defining the concept of thinking, Dewey writes that "thinking is the method of intelligent learning, of learning that employs and rewards mind," clarifying the difference between learning knowledge and thinking (Dewey, 1916, p. 159). Dewey's method to building connections relies on creating a situation that is not routine for students, but not so new that they cannot make connections to the event from their own lives (Dewey, 1916, p. 161). Building on the knowledge that learners already have from previous experience, constructivist teaching guides learners through a process of inquiry and exploration. "In a constructivist classroom, the teacher searches for students' understandings of concepts, and then structures opportunities for students to refine or revise these understandings by posing contradictions, presenting new information, asking questions, encouraging research, and/or engaging students in inquiries designed to challenge current

concepts" (Brooks & Brooks, 1999). Allowing learners to experiment with the knowledge they already hold, constructivist teaching involves growing learners' knowledge base through practical methods of engaging with the knowledge teachers want learners to know.

Brooks and Brooks promote the use of experience-based learning championed by Dewey. Dewey challenges the concept that "thinking is often regarded both in philosophic theory and in educational practice as something cut off from experience, and capable of being cultivated in isolation" (Dewey, 1916, p. 160). Instead, Dewey suggests that students should "do something with material in carrying out his own impulsive activity, and then note the interaction of his energy and that of the material employed" (Dewey, 1916, p. 160). Dewey argues that the first approach to any subject in school should be as "unscholastic" as possible, related to the ordinary life that exists outside of school (Dewey, 1916, p. 160). These activities and events "give the pupils something to do, not something to learn," expanding their engagement in the process and building the connections that form when students learn naturally (Dewey, 1916, p. 161). According to Brooks and Brooks, the first of the five principles of a constructivist classroom is that "teachers seek and value their students' points of view" and the third is that "teachers pose problems of emerging relevance" (Brooks & Brooks, 1999). Respecting students' visions ties their intrinsic motivations and interests to their learning. Dewey also emphasizes the importance of constructing problems for students that are genuine, instead of simulated. Students should be presented with problems that have a context, that would require observation and experimentation outside of school. The problems should be the students' own problems, not a problem from a textbook that has no relevance to the real world. These requirements ensure that questions are designed for meaningful thinking that is relevant to the real world, and are not simply an external requirement to meet.

In Constructivist teaching, the meaningful use of newfound knowledge, versus the storage and subsequent regurgitation of knowledge, is paramount to ensure understanding of the material. Dewey challenges "the accumulation and acquisition of information for purposes of reproduction in recitation and examination" (Dewey, 1916, p. 164). Brooks and Brooks

concur, promoting that "teachers assess student learning in the context of daily teaching," requiring that students demonstrate their use of the knowledge they've learned rather than demonstrate their ability to recall the knowledge (Brooks & Brooks, 1999). According to Dewey, "pupils who have stored their minds with all kinds of material which they have never put to intellectual uses are sure to be hampered when they try to think," as they have not been required to actively use the knowledge they've collected in a meaningful way (Dewey, 1916, p. 164). By using the knowledge they've accumulated, students in a Constructivist classroom retain the knowledge that relates to their lives through genuine problem-solving. Makers in a makerspace can solve problems in a hands-on way through making, applying their knowledge in a relevant way, as I recommend in chapter 5.

### 2.3.2 Constructionism

Consistently referenced in the field of education, Seymour Papert's concept of constructionism is often thought of as simply learning-by-making. In a collection of essays in *Constructionism: Research Reports and Essays, 1985-1990* (1991), Papert compares constructionism to the similarly named constructivism. Defining constructivism as learning by building knowledge structures, Papert expands the theory of constructionism by referencing the context in which learners construct a public entity. In other words, through constructionism, students are producing real-world solutions that are shared outside of the learning environment. Everything that students learn is understood by being constructed.

Papert describes a situation in an art room that greatly influenced his views on education. While visiting a school in which he intended to observe the outcomes of a math class that was dedicated to a computer program called Logo instead of math, Papert discovered students were carving sculptures out of soap, and he found himself desiring the finished product that the students created (1991, pp. 4-5). He wished there was a way to make the product of the math class as desirable as the product produced by the art class, as well as mirror the level of enthusiasm the art students held for their project . Constructionism promotes this idea by emphasizing the importance of construction as a means of understanding

knowledge, especially with a meaningful end product. While makerspace facilitators' pedagogy may or may not recognize the finished product as important, the end product of making is often taken into account when designing the making activities.

Papert also recognized the importance of informal learning environments, as he references kits of building materials with micro controllers and other such digital additives that were relatively new technology in the early nineties. These "cybernetic construction kits" he hoped would change how learners develop skills in mathematics, enhancing their intrinsic motivation to learn mathematical concepts because they would need that knowledge to build the models, "even if teaching were poor or possibly nonexistent" (Papert, 1991, p. 7). This would, in turn, make teaching better, "since one of the reasons for poor teaching is that teachers do not enjoy teaching reluctant children," or teaching could even become "less necessary" (Papert, 1991, p. 7). The idea of providing materials and stepping back is common for makerspace facilitators, as is the promotion of intrinsic motivation through the development of making activities that directly relate to makers' background knowledge and interests.

Constructionism focuses heavily on technology, and is often referenced in technology education, or STEM education as it would likely be known now. Papert (1991) explains this emphasis by acknowledging that "computers figure so prominently only because they provide an especially wide range of excellent contexts for constructionist learning," which has now expanded with more easily attainable technology for students (p. 8). Technology is not a required component of constructionism, but it is a likely addition to making activities as it opens the doors to many more abilities and skills in the STEAM realm. As technology and hands-on construction is often incorporated into makerspaces, Constructionism serves as a valuable guide for aspiring makerspace facilitators, and I refer to it as part of my recommendations in chapter 5.

### 2.3.3 Project-based learning

Project-based learning (PBL) is a approach to education that allows students to engage with a challenge. The Buck Institute for Education (BIE), a nonprofit organization dedicated to

supporting teachers by creating, gathering, and sharing high-quality project-based learning instructional practices, describes project-based learning as "a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging and complex question, problem, or challenge" (BIE, 2016). Project-based learning researchers Joseph Krajcik and Phyllis Blumenfeld describe project-based learning as situated learned, "based on the constructivist finding that students gain a deeper understanding of material when they actively construct their understanding by working with and using ideas" (Krajcik & Blumenfeld, 2002, p. 318). The Buck Institute of Education argues that project-based learning is "an effective and enjoyable way to learn" that allows students to "develop deeper learning competencies required for success in college, career, and civic life" (BIE, 2016).

In the 1990's, studies of student experience revealed that students were overwhelmingly unengaged with learning in schools, suggesting that developing new ways of teaching that focus on student engagement would be a valuable pursuit for educators (Krajcik & Blumenfeld, 2002). Other studies also indicate that college students' knowledge obtained in high school "remained at a superficial level" and even the best students at the top colleges "often had not acquired a deeper conceptual understanding of material" (Krajcik & Blumenfeld, 2002, p. 317). Meanwhile, educator and philosopher John Dewey argued that students become more personally invested in the material when they participate in meaningful tasks and problems similar to real-world experts facing the situation. Building on Dewey's constructivist views, Krajcik and Blumenfeld identified four major ideas in learning sciences that contribute to Project-based learning: active construction, situated learning, social interactions, and cognitive tools.

Offering a realistic problem for students to solve, Project-based learning features authenticity as a means of promoting engagement for students. Correctly-implemented, or what the Buck Institute of Education touts as "Gold Standard PBL," project-based learning focuses on individual student goals for learning, and the lessons include a appropriately

challenging problem or question for students to solve or answer. This problem or question should be authentic to students' lives, featuring "real-world context, tasks and tools, quality standards, or impact" and relating to "students' personal concerns, interests, and issues in their lives" (BIE, 2016). Krajcik and Blumenfeld expand this idea, adding that the meaningful problems should be similar to what professionals do.

A real-world context is required for situated learning, which is a teaching process that involves presenting students with a problem that is meaningful to them, allowing students to observe and experience phenomena as they design their own investigations into the relevant problem. One benefit of situated learning is that it promotes student engagement by allowing them to "more easily see the value and meaning of the tasks and activities they perform" (Krajcik & Blumenfeld, 2002, p. 319). Students are engaging with a problem that is relevant to their community and meaningful to them, so they will have background knowledge going into it and motivation to solve a problem that actually affects them. A second benefit of situated learning is its ability to adapt to a wider range of situations. When students learn information in a context that is meaningful and relevant to them, they can relate it to their prior knowledge and experiences, forming connections between new and previous knowledge. This allows the students to "develop better, larger, and more linked conceptual understanding" of the knowledge compared to the superficial understanding they may gain through lessons focused on memorization or step-by-step instructed experiments (Krajcik & Blumenfeld, 2002, p. 319).

Active construction encourages a deeper understanding of concepts by allowing a learner to actively construct "meaning based on his or her experiences and interaction in the world," as opposed to the superficial learning that "occurs when learners passively take in information transmitted from a teacher, a computer, or a book" (Krajcik & Blumenfeld, 2002, p. 318). Developing understanding is a continuous process in which learners build on their previous knowledge by interacting with new experiences and ideas (Krajcik & Blumenfeld, 2002). Learners deal with primary sources of information by actively engaging with new

concepts and directing their own learning, rather than waiting for teachers and materials to reveal knowledge. Students in a project-based learning-focused classroom participate in real-world activities in order to create artifacts that solve real-world problems, as they "explore the surrounding world, observe and interact with phenomena, take in new ideas, make connections between new and old ideas, and discuss and interact with others" (Krajcik & Blumenfeld, 2002, p. 319). These authentic learning processes promote learners' active construction of knowledge in a real-world context.

Social interactions are required to create that conceptual understanding. According to Krajcik and Blumenfeld's research, the deeper connected learning stems from a specific kind of social interaction: "when teachers, students, and community members work together in a situated activity to construct shared understandings" (Krajcik & Blumenfeld, 2002, p. 319). Allowing students to engage with community members and their teachers as co-learners more closely replicates how students would learn and solve a problem outside of their classroom. Sharing and reviewing many ideas with others creates a "community of learners" in which students develop deep understandings through debate and conversation (Krajcik & Blumenfeld, 2002, p. 319).

In order to share and review ideas about a larger variety of relevant questions, Krajcik and Blumenfeld recommend the expanded use of cognitive tools, in order to "expand the range of questions that students can investigate and the multitude and type of phenomena students can experience" by making more information available to students and exposing them to new ways of analyzing that information (Krajcik & Blumenfeld, 2002, p. 319-320). Krajcik and Blumenfeld present the example of computer software, which supports and assists students to carry out tasks that would not be possible without the software. Cognitive tools, such as computer software, support learning in five ways: accessing and collecting data, providing visualization and data analysis tools, supporting worldwide collaboration possibilities, producing and testing models, and developing multimedia presentation abilities to illustrate the solutions discovered by students (Krajcik & Blumenfeld, 2002, p. 320). Project-based learning

promotes the use of technology as tools for research, creation, collaboration, and presentation, as well as the skill growth in technological tools with which students are already familiar. Using technology to collaborate allows students to connect with their own community and the real world, as they learn to "interact with adults and organizations, are exposed to workplaces and adult jobs, and can develop career interests" (BIE, 2016). The use of cognitive tools can support learners throughout all the processes of project-based learning inquiry. Incorporating all of these four learning sciences ideas, Krajcik and Blumenfeld developed a view of project-based learning, designing lessons to promote engagement among students.

Project-based learning does not lend itself to speedy completion. Instead, project-based learning requires an extended period of time time to fully understand the concepts surrounding the assigned problem. According to the Buck Institute of Education, students should be given ample time to solve their problem, including the processes of theorizing, researching, and experimenting. Krajcik and Blumenfeld expand on these processes to emphasize the more collaborative side of project-based learning, requiring time for students to "investigate questions, propose hypotheses and explanations, discuss their ideas, challenge the ideas of others, and try out new ideas" (Krajcik & Blumenfeld, 2002, p. 318). Students are the leaders of this process, making the decisions as to how they will work and what they will make, which promotes the skills of "critical thinking/problem solving, communication, collaboration, and self-management" (BIE, 2016). With an active learning style, project-based learning "makes school more engaging for students" by providing a "real-world relevance for learning" (BIE, 2016). Promoting a deeper understanding of content and maturation of skills, project-based learning prepares students to apply their content knowledge and their newfound skills to new situations throughout their lives. These skills require adequate time to build and practice in a project-based classroom environment.

Project-based learning requires more time because the process requires more interaction with the problem, collaboration, creation, and presentation of the results. Five key features of a project-based learning environment start with a "driving question, a problem to be

solved” (Krajcik & Blumenfeld, 2002, p. 318). To explore the driving question, students must participate in “authentic, situated inquiry,” using the problem solving processes that expert performers in that discipline would use (Krajcik & Blumenfeld, 2002, p. 318). Mirroring expert performers in a real-world situation, students, teachers, and community members work together to find solutions to the driving question. While working collaboratively to solve the problem, “students are scaffolded with learning technologies that help them participate in activities normally beyond their ability,” allowing them to use real-world materials and tools to explore a solution to an authentic problem (Krajcik & Blumenfeld, 2002, p. 318). Students then make “a set of tangible products,” producing “shared artifacts, publicly accessible external representations of the class’s learning” (Krajcik & Blumenfeld, 2002, p. 318). Solving the problem is not the entirety of the lesson, however, as students are then expected to reflect on their learning process, critique and revise their answers or solutions, and publicly present their findings. The complete process of project-based learning incorporates a full inquiry into a real-world problem, collaborative authentic processes using tools designed for the work, and presentation of the final designed and created solutions, which I analyze in chapter 4.

#### 2.3.4 STEAM Education

The implementation of science, technology, engineering, and math (STEM)-based skills in K-12 education in the United States grew out of the perceived global competition in math and science aptitude. Outpaced by other countries in math and science testing, the United States placed more emphasis on STEM education, aligned with President Obama's Race to the Top-District program (RTT-D), "which provided Department of Education funds for approaches to learning that were considered individualized and rigorous" (Sweeny, 2017, p. 353). Promoted by the U.S. Department of Education, STEM education "represents a bureaucratic, top-down approach to learning," as is common in developing educational policy, taking place through partnerships between "corporations, educational advocacy groups, and the U.S. government" advancing STEM initiatives in "public schools, after-school programs, and community spaces" (Sweeny, 2017, p. 353). Further reinforcing the push for STEM

education, the Elementary and Secondary Education Act was reauthorized in 2015, guaranteeing over $150,000,000 in funding for STEM education (Sweeny, 2017, p. 353).

The top-down approach to STEM education has permeated public schools, but STEM education is still growing and developing. The Maker Movement and the expansion of makerspaces have enabled teachers to be the driving force of the implementation of maker education, which has helped to expand the concept of STEM education to STEAM education, incorporating the arts and design as an additional component. This growth is based on several factors, including teachers' interests and students' interests. When studying an online contest, Peppler and Hall discovered that what youth make on their own terms indicates their interests, and teachers can incorporate STEAM educational concepts as a way to bridge the gaps between what students don't know, what they're interested in, and what they will learn. When reviewing submissions to the make-to-learn youth contest, Peppler and Hall (2016) found that the categories describing what the youth made overwhelmingly skewed toward "Arts and Crafts" at 36.4% with "Mechanics/Engineering" next at only 18.8% of the projects. Other projects fell under the categories of "Electronics and Programming" at 15.8%, Shop Projects at 9.9%, Fashion at 5.1%, Digital Media at 4.8%, Cooking at 2.9% and Other at 6.4% (p. 145). Describing the "predominance of the arts and crafts entries" as unexpected, Peppler and Hall recognized the importance of not narrowly defining making for youth, ensuring that the "conflation of making and STEM learning that sidelines the traditional arts and crafts aspects" of the Maker Movement does not limit the STEAM-based skills that can be taught and learned in United States public schools.

By combining the top-down support for STEM education with the "grassroots, community-based collaborative" style of Maker Faires, STEAM education in public schools has the potential to form a philosophy and pedagogy that fuses the best of both worlds and relates to students. The challenge remains in ensuring that the makerspace in educational practices does not "sap the spontaneous, rhizomatic qualities that many find a compelling component of the Maker Movement" (Sweeny, 2017, p. 354). Maintaining the balance between all aspects of

STEAM education and ensuring that they relate to student interests will allow educators to build a curriculum dedicated to the implementation of science, technology, engineering, arts/ design, and math skills. Integrative approaches ensure that makers can apply a variety of knowledge to their work in a makerspace, which I analyze in chapter 4.

#### 2.3.5 Seven Core Learning Principles

Developing open opportunities for making can revolve around principles from the Maker Movement. In makerspaces within formal or informal learning environments, facilitators can take part in designing learning activities for making that incorporate learning principles that translate to specific standards that may exist in formal learning environments. Brahms and Crowley identified seven core learning practices through their work within the maker community. These seven core learning practices include: explore and question; tinker, test, and iterate; seek out resources; hack and repurpose; combine and complexify; customize; and share (Brahms & Crowley, 2016, 16). These learning practices provide a comprehensive framework for facilitators to use making as designed learning activities.

#### 2.3.6 The Maker Movement Manifesto

The valuable components of Hatch's Maker Movement Manifesto include: make, share, give, learn, tool up, play, participate, support, change (Hatch, 2014, p. 1-2). The physical act of making is just a fractional part of being a maker. For Hatch, making is the act of creating physical things, writing that "these things are like little pieces of us and seem to embody portions of our souls" (Hatch, 2014, p. 1). Hatch's approach to making a physical object assumes a great deal of care and personal investment in the object, not just producing an object to meet an external goal set by an instructor. Hatch describes a makerspace as "a center or a workspace where like-minded people get together to make things" (Hatch, 2014, p. 13). The like-mindedness of these people is simply their desire to make things themselves, but Hatch's concept of making extends beyond just the physical act of making something themselves.

Sharing is an integral part of Hatch's Maker Movement Manifesto, both to present a valuable attempt at creation to the public and to encourage the maker. (Hatch, 2014, p. 14-15). Sharing is especially important in situations in which every maker will likely have created something different, such as multiple solutions to a presented problem. Encouraging makers to continue their making process requires that the results, failed or successful, be shared first. Like an in-progress critique in visual art education, sharing the multiple attempts at making can enhance the making process through feedback from other makers. According to Hatch, "sharing makes a makerspace a community" (Hatch, 2014, p. 18).

An integral part of a making, especially in an educational setting, is to learn. Hatch references Project-based learning when he explains that making without learning is impossible, as "making brings about a natural interest in learning" (Hatch, 2014, p. 20). Learning through making stems from the questions the makers must ask themselves as they go through the making process, navigating the choices they must make throughout their design and execution. Facilitators in makerspaces can present learning opportunities for makers in a variety of ways, from open exploration to hands-on workshops. "Often knowledge developed through our experience is what encourages us to go back to the book to figure out what is happening," so the instruction portion of a workshop can feasibly occur before or after a hands-on approach to learning (Hatch, 2014, p. 71). Hatch emphasizes the hands-on experiential learning that occurs within a makerspace:

"True knowledge is born through experience. You have to physically bore into the details of something to fully understand it. Hands-on discovery and exploration are required to innovate. Mastery is required, time is required—a class on materials is not enough; you have to spend time experimenting in the lab or in the field. True, deep knowledge is hard won and comes with experience" (Hatch, 2014, p. 72).

Maintaining a space in which experiential learning can happen is paramount to a facilitator's mission within a makerspace aligned with Hatch's manifesto, as making cannot happen without learning.

Complementing his thoughts on sharing, Hatch's expansion of his thoughts on learning in regards to makerspaces aligns with his view of teaching and sharing. Exploring ideas, practicing skills, makers will be able to share what they have learned with someone who is newer to it (Hatch, 2014, p. 21). Learning, and then teaching others, is a natural process in Hatch's concept of makerspaces.

When Hatch describes his requirement of a maker to "tool up," he references a lengthy list of tools and materials that he believes are required in any makerspace wishing to revolutionize makers (Hatch, 2014, p. 23-26). While TechShop makerspaces were designed for adult use only, the importance of the variety of tools can be applied to youth-focused makerspaces as well. Hatch indicates that in his experience opening makerspaces, "a community of makers does not fully emerge until a complete makerspace is provided," and that "the advantage of a well-equipped makerspace is that it attracts people with a widely diverse selection of projects, creating a beehive of activity, passion, knowledge, and sharing" (Hatch, 2014, p. 23). Basically, the more equipment a makerspace offers, the more makers with ideas it is going to attract; and the more industry-standard the equipment, the more makers are inclined to work with it. Hatch describes the differences between the users who interact with the machinery and materials, comparing the engineers who "typically come to a machine with a set of things they are trying to accomplish" to the artists who "come to a machine to experiment and see what it can do" (Hatch, 2014, p. 27). The combination of these two styles of users can be an example of the different learning styles that experiential learning can reach through the process of "tooling up" in a makerspace.

Hatch encourages makers to be playful with their making. When describing a team of makers, he writes, "we are playful with the ideas, stretch them to extremes, and morph them ridiculously" (Hatch, 2014, p. 26). When makers are engaged with a process or idea that interests them, they can have fun with it. Hatch writes, simply, "building is a form of play" (Hatch, 2014, p. 28).

To be active in the Maker Movement, Hatch emphasizes the need to actively participate. Participation can range from collaboration to just working next to another person. Hatch describes makers in TechShop makerspaces as social creatures, as “even when they don’t collaborate directly, they will seek out the comfort of a peer group to hang out with” (Hatch, 2014, p. 28). The view of the inventor working in solitude is not an accurate portrayal of a maker in a makerspace.

Hatch’s Maker Movement Manifesto can serve as an example of actions that should be taken within a makerspace for adults. These examples can be tailored for use in youth-focused makerspaces, and stretch further than making as creation to incorporate guiding principles of sharing and playfulness into the pedagogies that govern makers’ use of the makerspace.

## 2.4 Maker Identities

Working to develop the identities of the children within the makerspace as makers is important to makerspace facilitation, because it sets the makers up for continued interests and efforts in making. In the case of adult-focused makerspaces, the makers likely choose to enter the space because they already self-identify as makers. For children, there are many motivations to enter the space, and they may not yet self-identify as makers. Helping children develop their identities as makers is key to promoting making in learning environments.

### 2.4.1 Styles of Making

Researchers Wohlwend, Keune, and Peppler (2016) identified four different styles of making that occurred in youth makers: play, design, collaboration, and technology. These styles were observed in children's approaches to making. Makers who lean towards the "play" side of making make by "inventing meanings and energizing discoveries," using play to entertain themselves with the materials in between or while experimenting with them (p. 92). Makers who lean towards "design" make aesthetic designs that involve "assembling innovation across artifacts" by crafting more and more aesthetically complex designs that require increased skill-building to achieve (Wohlwend, Keune, & Peppler, 2016, p. 93). Makers who lean towards "collaboration" share their knowledge and learn from others to gain an "extended

reach and growing expertise," whether they are learning from watching their peers, asking questions of peers or facilitators, or teaching others from their skill set (Wohlwend, Keune, & Peppler, 2016, p. 93). Finally, makers who lean towards "technology" are likely to participate in a trial and error process that eventually results in "efficient and effective problem-solving" (Wohlwend, Keune, & Peppler, 2016, p. 93). No maker remains exclusively in one quadrant as they participate in making activities, instead they may show a preference towards one style but move from style to style as their focus changes. Recognizing and embracing different styles of making requires makerspace facilitators to design learning activities that meet the needs of all makers, and I reference this need in chapter 5.

### 2.4.2 Makers' Motivations

Makers are motivated by a variety of sources, but their identities as makers mean that their motivation is often internal, based on their interests, persistence, and ability to take part in personal expression. To find ways to support motivation for making, Natalie Rusk researched practices that involved makers by expanding their abilities to make projects based on their own ideas and interests, "connect with others in a friendly community," "share creations and receive feedback," learn skills they can use in other projects and throughout life, and to have fun creating and sharing their projects (Rusk, 2016, p. 104-105). By basing the goal of motivating learners around their interests, facilitators can tailor the choices they make to the choices that will grow the makers' identities as active participants in making. Encouraging active participation in making involves cognitive and character development, resulting in a concept Oxman Ryan, Clapp, Ross, and Tishman (2016) call "maker empowerment" (p. 36). This concept focuses on the maker's sense of agency and motivation: students' discovery of their own passions, their capacity to pursue them, and the confidence and resourcefulness developed as they learn with and from others." (Oxman Ryan, Clapp, Ross, & Tishman, 2016, p. 36). A main component of applying intrinsic motivation to the making process is persistence. When experimenting with new materials, tools, skills, and concepts, there are often mistakes and failures. Tinkering or making relies on makers getting through the trails of mistakes and

failure, which can be encouraged by "using materials in ways they weren’t intended to be used, setting highly personalized goals, [and] encouraging quirky ideas" in order to help makers who are stuck in failure to free themselves (Wilkinson, Anzivino, & Petrich, 2016, p. 165). Another way to inform motivation is to instill a sense of personal expression into the projects. Allowing makers "to inject some of their personal choices, preferences, aesthetic predilections, and most importantly narratives into the physical representation of their thinking," promotes the building of their identity as a maker and enhances their understanding of the concepts being taught in the makerspace (Wilkinson, Anzivino, & Petrich, 2016, p. 167). These practices in promoting internal motivation in makers enhance the growth of their identities as makers through participation in making that interests them.

#### 2.4.3 Collaboration

Rarely does a maker work alone in a makerspace. Instead, makers collaborate, share resources and knowledge, and simply enjoy each others' company. The Maker Movement has grown from individuals making on their own to a robust community. Within makerspaces, groups of people of diverse genders, ages, and backgrounds make together, growing their knowledge base, skill set, awareness, and network. A maker within a makerspace community should be "motivated to learn with and from one another on how to use and combine materials, tools, processes, and disciplinary practices in novel ways" (Brahms & Crowley, 2016, p. 13). Working within a community should also expand to include sharing outside of the community to "widely disseminate projects, culture, and ideals" through online communities or Maker Faires or other avenues. Makerspace facilitators can encourage or discourage makers from collaborating through their established pedagogy and the design of the environment, and I make note of instances of attempts at collaboration in chapter 4.

### 2.5 Makerspaces as Communities of Practice

#### 2.5.1 Crafting a Culture

The facilitator’s philosophy of crafting a culture within a makerspace is of paramount importance in building a community of practice. First, facilitators can construct “ethos” within

the makerspace, “adopting and breeding a particular way of being,” giving makers a view of “what it means to connect with others around making” (Litts, Halverson, & Bakker, 2016, p. 200). Developing an ethos of resourcefulness is a common goal, as is developing in makers a “compulsion to share” their findings (Sheridan & Konopasky, 2016, p. 34). Creating a culture relies on expanding forms of ethos and building connections, promoting makers’ goals of building skills from interests. Referenced in section 2.2.3 Cultural Roots of Making, cultures that have contributed to the current Maker Movement include hacker culture, “jobs” culture, “keychain” culture, and product culture. These cultural philosophies contributed to the growth of the Maker Movement, but can be adapted for the incorporation of makerspaces into formal and informal learning environments. Blikstein and Worsley support the adaptation from a hacker culture to a learning culture, a “jobs” culture to a literacy culture, a “keychain” culture to a culture of deep projects, and a product culture to a process culture (Blikstein & Worsley, 2016, p. 73-75). A learning culture includes all makers in a meaningful way, pushes makers out of their comfort zone, and prompts collaboration. A literacy culture promotes the use of materials designed for children’s use, and thinking about children as individuals, not future workers. A culture of deep projects teaches from multiple disciplines and relates projects to makers’ “lives, interests, passions and their communities” (Blikstein & Worsley, 2016, p. 74). A process culture places the emphasis on the process instead of the end product. These cultural shifts allow makerspace facilitators to create a culture within the community of practice.

### 2.5.2 Makerspaces and Leadership

Developing a makerspace within a school requires school leadership support for an integrative development process. Factors such as “the leadership in the school, the space that was allocated for making, and the nature of integration the schools chose for incorporating making into teaching and learning” contribute to the development process and eventual use of the makerspace (Wardrip & Brahms, 2016, p. 100). The development of a makerspace within a school is often an example of education reform, the success of which is dependent on “the extent to which a leader understands the reform they intend to implement,” as well as the

structure surrounding the implementation (Wardrip & Brahms, 2016, p. 103). The importance of administration's understanding of making is paramount to incorporating proper professional development strategies that support the development and use of the makerspace and its integration into the existing educational landscape.

#### 2.5.3 Mount Elliot (Case)

Open opportunities for making involve makerspace facilitators designing a learning activity that is open-ended, with guidance rather than explicit directions, allowing makers to explore materials, processes, or a concept. Often, these open opportunities build makers' confidence in self-directed making and experimentation. Sheridan and Konopasky identify resourcefulness as a skill or trait positively impacted by open opportunities for making. In exploring a makerspace, Mount Elliot, they discovered ways in which the facilitators built resourcefulness into their open opportunities for making, allowing makers to "freely explore their interests without external expectations or pressure to provide a wellspring of ideas and passions to contribute to their own growth and the community" (Sheridan & Konopasky, 2016, p. 45). At Mount Elliot, makers develop their own ideas for workshops and other learning opportunities through various means, such as community meetings. Allowing makers to decide the direction of the makerspace compounds their feelings of ownership that already grow through open opportunities for making. At these workshops or other events, makers of any age can take on the responsibility for and contribute to the "planning, leading, teaching, or hosting" of the workshops or events (Sheridan & Konopasky, 2016, p. 45). These workshops and events transform into another open opportunity for making.

Mount Elliot Makerspace, the site studied by Sheridan and Konopasky, plays host to several open opportunities for making. Openshop, the most common learning opportunity, is an arrangement in which any maker can work autonomously on any project they choose. Outside of Openshop, Mount Elliot Makerspace hosts workshops and events, developed by makers, that introduce new methods of making, materials, and concepts based on makers' interests and what makers or community partners are willing to teach. One such workshop,

BreakMake involves dissecting old electronics, harvesting functional parts from them, and recycling those parts into a functional project. This open opportunity for making has just two steps: break and make. Outside of these two directions, hands-on instruction occurs as needed during the construction phase of the learning opportunity, in processes such as soldering, wiring, or programming. Rather than providing a step-by-step set of directions in which makers all produce the same or a similar end product, BreakMake offers makers "skills, tools, and materials to generate project ideas," not just a final product (Sheridan & Konopasky, 2016, p. 39). During these workshops, facilitators keep makers engaged in their making and learning "not by prescribing solutions, but by asking questions" (Sheridan & Konopasky, 2016, p. 40). MakeBreak also serves as a group process for makers to practice ideation by working through several iterations of a design. By developing the processes for their individual projects as a group, makers work together at Mount Elliot Makerspace to work through their goals and ideas toward different outcomes.

### 2.5.4 Tinkering Studio (Case)

Ideation and complexification are common occurrences for makers during the experimentation process. Facilitators at the Tinkering Studio, a makerspace studied by Wilkinson, Anzivino, and Petrich, specifically design their learning activities to encourage makers "to complexify their thinking over time" (Wilkinson, Anzivino, & Petrich, 2016, p. 165). Making sure to offer materials in a curated variety of complexity, the facilitators equip the makers with the ability to first achieve quick success with the less complex materials, and then alter their designs with more complex parts as their ideas grow and as they gain more knowledge of the parts and processes. Iteration — working on something over time, making small but important adjustments as you go — drives the tinkering process by testing a design and then altering that design. By noticing an unexpected result of their process, makers develop "a whole set of investigations involving constructing, testing, refining, observing, reflecting, remixing, or reimagining," building their iteration skills through experimental practice (Wilkinson, Anzivino, & Petrich, 2016, p. 165). By experimenting with ideation and gradually

working with more complex ideas, materials, and processes, makers build their confidence and expand their knowledge and interests. By enabling this experimentation through designed learning activities that involve open opportunities for making, facilitators guide intrinsically motivated makers through a full development process.

The full development process for makers can involve changes in outcomes and goals throughout the designed learning activity developed by the makerspace facilitators. The learning activities in makerspaces are often subject to constraints, from the available materials to the environment of the makerspace. These constraints can serve to inspire or frustrate the makers, depending on the intentional prompts from the facilitators. Wilkinson, Anzivino, and Petrich call these constraints that are designed towards a set of goals "the problem space within which participants operate" (2016, p. 166). Facilitators must achieve balance within the problem space with constraints that are open enough to encourage makers with different interests to get involved but closed enough to guide makers through a functional development process. These shifting goals allow the facilitators to keep makers on track in making something while still acknowledging the makers' goals within the problem space. Designing for shifting goals requires the facilitators to design for varied outcomes as well, acknowledging that tinkering or making rarely follows a prescribed set of steps that results in the same final product from every maker. To design for varied outcomes within tinkering or making, facilitators at the Tinkering Studio "create constraints that allow for tinkering to occur" and "introduce a palette of materials that are varied enough, but not so varied that the learners move outside the territory being explored" (Wilkinson, Anzivino, & Petrich, 2016, p. 169). In more formal learning environments where the action of making is not necessarily the goal, there may be less room for shifting goals and varied outcomes, but the essence of the Maker Movement can still exist as long as facilitators can design learning activities with creative constraints. To develop varied outcomes for a makerspace project, facilitators structure the project around the makers' interests, background knowledge, and identified problems.  Varied outcomes result in shifting goals and more developed ways to achieve those goals, as well as more interest and reliability

from the makers. Starting with the makers' experiences and building from the makers' knowledge allows the facilitators to model the pedagogy that there is no linear path to a correct completion and build upon intrinsic motivation of makers who are involved and interested in the entirety of the design process, including the design of the constraints under which they make. Shifting goals and varied outcomes lead to open opportunities for making that are maker-driven.

Whether housed in a formal or informal learning environment, the facilitators within a makerspace are responsible for guiding the philosophy and pedagogy with the space. In making choices regarding the designed learning activities that are explored within the makerspace, the facilitators are charged with developing meaningful opportunities for making that engage makers in a flexible way. Facilitators can keep in mind the core learning practices while encouraging an open-ended exploration of materials, exposing makers to iteration and complexification. By guiding makers through questioning rather than directions, facilitators can design learning activities that stay true to the principles of the Maker Movement.

Both case studies referenced in subsections 2.5.3 and 2.5.4 influenced my understanding of maker-focused theories in practice and informed my process of researching makerspaces as case studies. The case studies of Mount Elliot and Tinkering Studio informed my methodology and development of observation practices in chapter 3.

## 2.6 Physical Space and Design

### 2.6.1 Design of Environment

Making in education can take place in a wide variety of learning environments, formal and informal. Therefore, makerspaces can take shape in a variety of ways, from maker carts that are wheeled into a classroom to a separate, dedicated space for making. The design of the environment proposed for making can impact the making that takes place within the space. Makerspace facilitators and designers need to consider several criteria that can influence the makerspace, including the physical space it occupies, the different needs for and among children, and what values they wish to impart through the space.

As a learning environment, makerspaces occupy a physical space, whether that is a dedicated space or a transformative space, and this occupation influences outcomes for makers within the space. As implied by the name, makerspaces "foreground the notion of space" (Sweeny, 2017, p. 355). Establishing a physical space is vital to creative educational practices, "as learning often takes physical form," especially in art education and making in education (Sweeny, 2017, p. 355). The physical environment of the makerspace has to take into account practical designs relating to layout, storage, and safety, as well as "conceptual ideas regarding space and representation" (Sweeny, 2017, p. 355). These designs may take place within schools, but "makerspaces can operate in any number of sites, including, but not limited to, public libraries, natural history museums, and science centers" and also community-based, stand-alone settings (Sweeny, 2017, p. 355). Within schools, makerspace facilitators and designers must consider the role of the makerspace when planning for its inclusion into the curriculum and into the physical space, making the design of environment a critical component of research surrounding makerspaces. My recommendations for practice include design recommendations in chapter 5.

### 2.6.2 Makerspace Environment and Design Philosophies

The development of the makerspace environment depends on the philosophy of the designer, incorporating design factors that influence making within the space. The choices made by the facilitators range from "1) individualization vs. standardization in learning environments; 2) formal vs. informal education divide; and 3) technology vs. hands-on making in learning environments" (Peppler, Halverson & Kafai, 2016, p. 6). Whether introducing maker projects within a classroom, a maker cart that can be used in any classroom, or a dedicated makerspace, facilitators and designers must make decisions regarding the visibility of the space and the projects taking place within the space. Featuring visible access to tools, materials, examples, and resources, makerspaces can promote accessibility through visibility, "coupled with high-quality learning outcomes" (Peppler, Halverson & Kafai, 2016, p. 5). This visibility promotes learning by encouraging makers to "ask questions, to take things apart and

put them back together again, to try out new solutions, and to think in a concerted way about the intentions of the designer as well as the makers' ability to hack new solutions" (Peppler, Halverson & Kafai, 2016, p. 5). In some cases, the construction of the makerspace is a chance for makers to hack new solutions, as they even participate in the building of the space (Sheridan & Konopasky, 2016, p. 36-37).

A makerspace facilitator who intends to promote resourcefulness can organize tools and materials openly, allowing anyone in the space to identify what they need, "with boxes of supplies and tools that are organized, visible, and clearly labeled" (Sheridan & Konopasky, 2016, p. 37). Organizing the tools and materials visibly allows makers to readily find what they need, and identify what projects they can complete depending upon what materials are available to them. Even if they don't know about all the available tools and materials, learning that they exist affords them the ability "to perceive the possibilities in the space" (Sheridan & Konopasky, 2016, p. 37). The organization of the tools is an important choice for the facilitator and designer to consider in a makerspace, but the tools themselves need consideration as well. The amount, quality, and technological level of the tools should be a important choice for the facilitators' philosophy and pedagogy. The implementation of 3D printers or the encouragement to use hand tools can be decided upon through the design of the makerspace environment. Expensive technology is not "a prerequisite for innovative and useful making," but can serve as a tool for learning valuable skills (Sheridan & Konopasky, 2016, p. 38). The makerspace facilitator at Mount Elliot community makerspace describes his choices as having "designed the space with just enough constraints so that participants must draw on their own and their community's resources" (Sheridan & Konopasky, 2016, p. 38). The values imparted by the design of the makerspace environment should align to the philosophy and pedagogy of the makerspace facilitators, who design the physical space according to the needs of the makers, and I consider this in my analysis of observations in chapter 4.

### 2.6.3 Dedicated Space or Mobile Resources

While a dedicated makerspace isn't necessary for a school to build in order to support a maker program, a makerspace can positively influence the implementation of the maker program. Serving as a central meeting point, a makerspace can provide a space dedicated to participation in making. A dedicated makerspace can provide a visible promotion of making "as a learning innovation through classroom-based and personally motivated projects" (Wardrip & Brahms, 2016, p. 104). By not confining making to individual classrooms, a dedicated makerspace allows for "the collective sharing of resources such as materials, tools, ideas, and staff for making" as a "shared endeavor of the school community" (Wardrip & Brahms, 2016, p. 104). Integrating making within a school community can have diverse approaches, however, including forming a dedicated makerspace or hosting classroom-based making experiences. Making can take place in elective classes, after school programs, or as a component of traditional curriculum. Making can be introduced by a variety of facilitators as well, such as a dedicated facilitator, teachers, teaching artists, instructional coaches, or other students. Making can be introduced and implemented as professional development or initiated by the teachers in their classrooms and then expanded into a makerspace. (Wardrip & Brahms, 2016, p. 104). While a physical environment is often a core part of the Maker Movement, the physical space is not "fully constitutive of the practice of and participation in making," overlooking the Internet's role in support of making (Litts, Halverson, & Bakker, 2016, p. 190). Online communities can support making within physical makerspaces by providing an open place for engaging, sharing, and discussing making. I analyze instances of designing a makerspace that fits within its necessary context in chapter 4.

## 2.7 Making in Education

### 2.7.1 Making as Designed Learning Activities

Making in education requires designed learning activities that not only incorporate making, but do so in a meaningful way. These learning activities can range from making as a smaller step-by-step aspect of a larger project, but also as an open-ended opportunity for

students to explore different materials and processes of making. In *Makeology: Makerspaces as Learning Environments* (2016), researchers Peppler, Halverson, and Kafai have identified core learning practices that contribute to meaningful making processes in learning activities. These core learning practices enable educators to use the foundation of making as a means of encouraging students to learn and explore materials, processes, and concepts. Among these core learning practices is the goal for educators to engage in complexification and to shift their intentions for their students, maintaining an open-ended mindset regarding the end goal and end product of their lessons. Educators and researchers identify the potential for open opportunities for making, recognizing the importance of varied outcomes for a project. While the Maker Movement often involves open opportunities for makers to choose exactly what they want to make, taking into account nothing more than their own skills and interests, making can manifest as designed learning activities that advance step-by-step making processes through shifting goals and varying outcomes into open opportunities for making within a formal or informal learning environment.

### 2.7.2 The Educational System

One of the major influences on making in education is the expectations for student learning housed in the educational system in the United States. There are differing models for informal learning environments, such as after-school programs, and formal learning environments, such as classrooms within the public education system. The public education system has waxed and waned in its support of hands-on making in schools, and the emphasis on standardized testing has increased the need for students to find one right answer to an assigned problem. With these limitations facing makerspaces, their implementation is rarely a top-down process, instead inspired by the teachers. Injecting making into education can be easy or difficult, depending on the support from the educational system.

In *Makeology: Makerspaces as Learning Environments (Volume 1)*, Kylie Peppler, Erica Rosenfeld Halverson, and Yasmin B. Kafai recognize the differences between learning and schooling as well as formal and informal learning environments. These differences have an

impact on makerspaces' acceptance in the educational system. Practitioners and policy makers separate formal and informal learning environments, naming schools as formal learning environments and "anything outside the school day is informal" (Peppler, Halverson, Kafai, 2016, p. 7). Peppler, Halverson, and Kafai (2016) acknowledge the Maker Movement's ability to "stretch across the formal/informal divide," by "encouraging formal spaces to think informally and informal spaces to think like formal learning environments" (p. 7). Bridging the gap between these learning environments requires that teachers, administrators, and policy makers accept the differences between learning and schooling. While school leaders are interested in new ways of promoting student engagement with STEM disciplines, and the Obama administration enthusiastically promoted the Maker Movement as a pathway to educational reform, policies, both federal and local, "continue to push for accountability and standards-based curricula which are a mismatch with the pedagogical practices of making," limiting the abilities of teachers to implement making in their classrooms (Peppler, Halverson, Kafai, 2016, p. 6). The disconnect between formal and informal learning environments and between learning and schooling contributes to challenges facing the Maker Movement in schools, and I analyze makerspaces that grew from grassroots means and top-down implementation in chapter 4.

### 2.7.3 Challenges to School Implementation

Making has regularly faced challenges in being implemented in school. Mark Hatch, founder of TechShop, compares his experiences as a student and as a making-focused adult:

> *"From an educational perspective, we live in a sad time for making. When I was growing up, wood shop and metal shop were required courses for middle schoolers. Every middle school I was aware of had a woodshed instructor. I still have the things I made in middle school wood shop, and many of you do too. Today, it can be hard to find a shop in an entire school district. This makes no sense at all. In our 'race to the top,' school systems tend to focus only on the students who are headed to college, ignoring the 50 percent of those who aren't, depriving all students of skills that they could use the rest of their lives"* (Hatch, 2014, p. 21).

It is not only the secondary students who have seen limitations in their opportunities to make, but early childhood students as well. Wohlwend, Keune, and Peppler (2016) focused a study on early childhood making, and found that while engagement with technology has increased in early childhood classrooms, making with this new technology is limited. Technological tinkering is rare in early childhood classrooms, especially compared to how often they are encourage to play with arts and crafts materials. There are few opportunities in schools for early childhood students to create with mobile technologies or electronic tool kits. Engagement with technology is usually limited to viewing, listening, or practicing skills on a computer. Wohlwend, Keune, and Peppler also describe an “app gap” in which affluent children have more access to mobile technologies at home, while children in poverty do not, limiting their base knowledge in terms of technology engagement in schools (2016, pp. 84-85). Schools have faced varying support from policymakers for the implementation of making throughout history, challenging those who have an interest in providing meaningful educational making opportunities for students.

One source of the challenges is the focus on finding one right answer, as is common on the standardized tests on which accountability is placed. Hatch addressed this issue in *The Maker Movement Manifesto*, writing:

> *“We were born to make. If you were to enter a kindergarten class in your local school and ask the kids, ‘Who likes to make things?’ every child would raise his or her hand. Everyone has ideas, though most stop fantasizing about them by the time they hit middle school. By then, they have learned that there is a single right answer to every question. That their art is either good and looks like the thing they are trying to draw, or not—and, therefore, they are not artists”* (Hatch, 2014, p. 144-145).

Moving beyond the one right answer sought after by the standardized test model is a challenge for teachers and administrators within the educational system, as their accountability often hinges on the results of those standardized tests. Making in education relies on an open-ended system of questioning and exploration that requires a shift in educational accountability if it is

to be implemented successfully, and I analyze questions asked and answered and levels of exploration within makerspaces in chapter 4.

### 2.7.4 Reliance on Top Down Implementation

The infusion of making in education relies on a movement away from top-down implementation towards a more grassroots approach starting with the teachers or even the students. This approach is common, as Peppler, Halverson, and Kafai (2016) noticed at a forum of educators, when a participant remarked that “teachers were the driving force behind the change” towards making in education (p. ix). The educator continued, describing the “informal nature of the change because it has not been driven by large, well-funded initiatives from foundations or governments,” instead building in a “bottom-up fashion with ‘open source’ strategies rather than closed or proprietary approaches” (Peppler, Halverson, Kafai, 2016, pp. ix-x). In the past, attempted changes to the educational system have mostly been top-down, expert-driven hierarchical changes, which often led to “standardizing what teachers should teach and testing what students recall” (Peppler, Halverson, Kafai, 2016, p. x). This structure of educational system changes differs greatly from the exploratory concept of making. It becomes a challenge to “blend the two spaces and adapt and adjust experiences in educational makerspaces without losing that which is intellectually stimulating and culturally engaging” (Sweeny, 2017, p. 355). Blikstein and Worsley (2016) call on teachers to remain the frontrunners in makerspace implementation, writing that “The Maker Movement will only survive and fulfill its educational goals if the decisions are being made by teachers, education researchers, and education policy makers—professionals that really understand schools, teaching, and learning,” calling for maintained connections with partners in the movement and other educational system stakeholders (p. 76-77). The influence of the educational system on making in education can be greatly influenced by the teachers within it, moving away from the top-down hierarchical style of implementation towards open-ended learning.

## 2.8 Art Education's Relation to Making

### 2.8.1 A Historical View of Art Education

Historically, art education has been primarily composed of making art. Through the industrial drawing movement's standardized technical approaches, to the open-ended creative self-expression, to today's emphasis on 21st-century skills and Teaching Artistic Behavior's choice-based artmaking, making art is the focus of art education, regardless of the media or pedagogy (Sweeny, 2017, p. 352). Throughout the history of art education, making has been "centralized, emphasized, reconceptualized, and criticized" at different points, from John Dewey's influence promoting process over product, to Discipline-Based Art Education, in which "making was de-centralized and placed into a larger set of practices that included art history, art criticism, and aesthetics" (Sweeny, 2017, p. 354). Bridging artmaking with making within a makerspace is a feasible next step in the history of art education.

### 2.8.2 What Makers Can Learn from Art Education

On the other side, "those in the Maker Movement should become more familiar with the longstanding, academically sound traditions of critical reflection and aesthetic analysis that are an important part of the history of art education, if the claim that art is a part of what is produced in the makerspace is to be made" (Sweeny, 2017, p. 355). Peppler and Hall discovered that youth engaged in making self-report elements of craftsmanship as insights they gained through making (Peppler & Hall, 2016, p. 146-148). The expectations of activities that take place within a makerspace and within the realm of art education may differ, but the relation between the two will continue to strengthen as technology is more widely used and creative aspects of making are embraced.

With the development of makerspaces on the rise, the philosophy and pedagogy surrounding makerspaces can be positively influenced by the philosophy and pedagogy surrounding art education. Art education can be used as an example for "the many forms that making can take in the art classroom, museum space, or community center," providing a glimpse into the many techniques that can be considered making (Sweeny, 2017, p. 354). Art

education can be a complement and a component of making in education. Lisa Regalla describes making as “an inherently inclusive activity that combines art, science, technology, music, math, theater, craft, engineering, and beyond in seamless ways,” noting how makers valued craftsmanship and facing challenging obstacles creatively (Regalla, 2016, p. 261). Regalla references Leonardo Da Vinci, Albert Einstein, Hedy Lamarr, and George Antheil as makers who were well-known, even better known, as artists (Regalla, 2016, p. 261). Valuing art education as a component of making in education can expand and enhance what is considered to be making within a makerspace.

Another way to strengthen the bond between making in education and art education is to reassess the expectations and requirements of the results of both art and making. While the expected product of creation in an art class is a piece of art, that expectation is not held in a makerspace, even when the activities in the makerspace may emphasize design concepts (Sweeny, 2017, p. 355). To balance the expectations of both the art education aspect and the making aspect of activities that take place in a makerspace, “art educators can learn to suspend judgment regarding the products derived from art educational practices, as is often the case in the makerspace” (Sweeny, 2017, p. 355).

#### 2.8.3 Use of Technology

The use of technology is a common theme among makerspaces, and its use is growing among art education. While art education’s roots lie in low-tech, “makerspaces draw equally from high-tech and low-tech traditions, with the hope that the variety of ways of making can meet the needs of the users” (Sweeny, 2017, p. 354). Although many art educators emphasize the importance of learning longstanding traditional methods of artistic creation, “in the makerspace, there does not seem to be any particular reverence for traditional techniques, media, or concepts as there is in many art educational sites” (Sweeny, 2017, p. 354). Makerspaces have achieved their current level of attention partially due to the growing incorporation of new, easily accessible technology. In education, arts standards reflect this attention to technology, adding a framework of standards that relate to new media (State

Education Agency Directors of Arts Education, 2014). The art education side and the making in education side both “evaluate technology for its functional and expressive purposes” (Peppler, 2016, p. 206). However, “media art places a great emphasis on visual culture and linear media, whereas computational media factors more prominently into the broader Maker Movement” (Peppler, 2016, p. 206). This value difference mimics the history of art education being wary of an over dependence on technology. Sweeny suggests that, “art educators should maintain the tradition of scrutinizing what it means to be an artist, even as materials change and new techniques are created,” relying on the examples of traditionally analog art and new contemporary artists who infuse technology into their work (Sweeny, 2017, p. 356). Infusing technology into makerspaces and art education further will inevitably strengthen the bond between art education and making in education.

## 2.9 Conclusion

My literature review establishes the connections between the Maker Movement and the philosophies and pedagogies held by makerspace facilitators as well as its influence on education, thus shaping my conceptual framework. As my focus is on analyzing how facilitators transfer a philosophy of making, develop a pedagogy for making, and design an environment for making, I investigated literature describing how the Maker Movement has influenced education and how art education is related to making. I also explored the Maker Movement’s influence on the philosophies and pedagogies developed by makerspace facilitators, and I recognized how facilitators design makerspaces to be communities of practice and promote a maker mindset.

In the next chapter, chapter 3, I deliver a methodology that incorporates case studies of two individual makerspaces. The methodology is informed by knowledge gained from my review of related literature.

# Chapter 3. A Methodology for Researching Museum- and School-Based Makerspaces

## 3.1 Introduction

The methodology for my thesis research changed as my understanding of both participating makerspaces grew. In this chapter, I outline the constructivist paradigmatic assumptions that influence my research, note the evolution of my methods through the design of the study, and describe the participants in my study. While describing the settings in which my research took place and the methods of data collection I used, I reveal my role as the researcher within both makerspace settings. I also indicate how I analyzed the data I collected and state the tactics I used to ensure the validity and reliability of my analysis.

## 3.2 Paradigmatic Assumptions

As I am operating under a constructivist paradigm, I acknowledge that what I am observing and studying is not an objective truth, but instead is a collection of contexts and individual world-views projected through decision-making processes that impact makerspaces.

As a researcher interested in understanding decision-making, my views fall within a constructivist paradigm. I consider the social and contextual influences that drive decision-making on practices in makerspaces, why these decisions are made, and how they construct environments for learning, philosophies of creative making, and curriculum and pedagogical practices.

I appreciate that makerspaces do not exist in a vacuum, and I recognize that the facilitators in the makerspaces are subject to internal and external pressures and contexts that are constantly acting on their decision-making processes. School-based makerspaces and museum-based makerspaces must act in the best interests of many parties, from the makers to the funders, and function within social and cultural context of place. Therefore, the decisions the facilitators make may not fully represent the values they hold or their intentions when it comes to pedagogy, curriculum, or environment.

### 3.3 Design of the Study

This thesis presents two case studies, in which I observed makerspace facilitators instruct and interact with young makers and with and within the space at both sites. My study is designed to get a multifaceted view of the contexts surrounding the decisions made by makerspace facilitators in a museum-based makerspace and a school-based makerspace, and the impact of those decisions. To gain an understanding of how I might approach both cases, I looked to Robert Stake's *Multiple Case Study Analysis* (2016) to design a study that can take into account the different contexts in which making can occur. As a result, my sources of data include observations of the facilitators and a semi-structured interview with a facilitator. I mapped the physical space, including facilitators' movements throughout the space. In the space, I also observed and documented artifacts within, including posted signs, posters, words of encouragement, and the like.

This thesis aims to answer the question: how do makerspace facilitators design an environment, transfer a philosophy of making, and construct a curriculum and pedagogy that engages children in making, and for what purposes? I began my research hoping to complete a comparative case study between a school-based and museum-based makerspace, but the differences between the two makerspaces became more apparent and more vast, signaling that a direct comparison of the two would be ill-advised. Switching to completing two separate case studies allowed me to focus on all the different aspects of each makerspace rather than the few aspects that could be compared.

I chose to do two case studies, because case studies are designed for understanding complex issues and determining how or why things happen in real life situations. Collecting data through field experiences, my case studies are designed to determine patterns of behavior that point to use of environment, philosophy of making, and construction of curriculum and pedagogy. The behavior I focus on is the decisions made by the facilitators regarding the

makerspaces' designs and operations. Completing case studies allowed me to understand the context surrounding the complex issues concerning the decisions facilitators make in their makerspaces, as facilitators' decisions are subject to a variety of influences.

The case study format also further revealed the set of decisions and practices that go into developing and operating makerspaces. To further study the full decision-making process, my case studies involved a semi-structured interview with a facilitator and one of the initial developers of the space. A semi-structured interview allowed me to guide the line of questioning, but it also allowed the interviewee to express what they feel is important to address, about which I might not have necessarily planned to ask. As case studies require studying an all-encompassing view of the studied arena, my research focus on makerspaces needed to include a full view of the operations of the physical makerspace and the implications of the philosophies or theories surrounding the Maker Movement for learners. Operating with the opinion that makerspaces are about allowing makers to explore materials and guide their own learning, I performed the observation portion of the case study to recognize and understand the motivations of the facilitators, within everyday actions, at that makerspace. As a participant-observer, I noted and mapped the actions by the facilitators occurring in the makerspace, as well as participated in the action by following along with direct instruction, asking questions during the actions, and actively participating alongside the makers. By analyzing interviews and observations of the facilitators, I was able to make a determination about the reasons they made the decisions that were made, how those decisions changed throughout the process, for what reasons changes were made, and the results of the decisions.

### 3.4 Research Locations and Settings

My research took place in both a museum-based makerspace and a school-based makerspace. The school-based makerspace, as part of a new effort towards creative Project-based learning, was started by a midwestern suburban school near Milwaukee, Wisconsin. The

district aims to provide a liberal arts education that prepares students to embrace future challenges. The school district holds values that revolve around the beliefs that all children want reach their potential; rich, nurturing experiences and real world learning experiences promote the ability to reach that potential; and a high-quality education prepares children to work together and to be positively engaged citizens of a democratic and global society. These examples of guiding principles indicate that the makerspace installed within the school district was built to enhance student learning through place-based pedagogy and Project-based learning.

The museum-based makerspace is housed as part of an urban children's museum. The children's museum promotes hands-on learning experiences for children with the goal to help children build fundamental cognitive, social-emotional and physical skills. Designed with the intent to build children's reading, science, technology, engineering, arts, and math skills and knowledge, the participatory exhibits promote the development of problem-solving and planning skills, collaboration, and physical coordination. One could argue that the entire museum could be a makerspace, because visitors are participating in hands-on learning activities throughout the museum. Adding a dedicated makerspace aligns with their encouragement of hands-on activities to promote learning. This space hosts workshops, but also acts as a drop-in space for children, primarily younger children, to experiment with materials.

Figure 2 summarizes the differences between key components of each makerspace setting and provides basic information about the spaces.

| | School-based Makerspace (operated by school district recreation department) | Museum-based Makerspace |
|---|---|---|
| **Location** | Suburban | Urban |
| **Size** | Large classroom | Small part of larger Museum |
| **Features** | 3D printers, vinyl cutters in fixed locations | 3D printers, art supplies, gardening tools, air compressors, hand tools as parts of movable stations |
| **Average Age of Participants** | High school-aged | Pre-school- or elementary school-aged |
| **Number of Participants** | <6 per day average | 15 per day average |
| **Number of Facilitators** | 1 per workshop | 2 per day average |
| **Availability** | 2-3 hour workshops once a week, requiring pre-registration to participate | Twice daily 2 hour open-making sessions with additional guided workshops approximately monthly |
| **Dates Visited** | 2/27/17, 3/6/17, 3/20/17 with 4 additional workshops scheduled and cancelled due to no pre-registered participants | 3/31/17, 4/14/17, 4/21/17, 4/28/17, 5/5/17, 5/12/17, 5/19/17, 6/9/17, 6/16/17, 7/7/17 |

**Figure 2. Makerspace Site Comparison Chart**

### 3.5 Research Participants

Participants were chosen based on their involvement with the makerspace. I taught art in the school district that housed the school-based makerspace. I had previously worked with some of the museum-based makerspace facilitators in developing content for an educator-focused conference on making. Previous involvement with both spaces' developers led to their involvement as participants in this study. Preference was given to facilitators who had been on board with their project since the beginning stages of development, offering insights into the spaces in practice, that have resulted from long-term decision-making.

Working with the museum-based makerspace allowed me to observe a makerspace that was well-established and interact with facilitators who had played an integral role in the design and development of the space. The school-based makerspace was chosen as a new makerspace that was still in development. Although, at the time, the school-based makerspace

was used to after-school workshops, the intentions of the school district were to build a school-based makerspace that would be open to students during school hours. The facilitators in the museum-based makerspace had varying levels of input into the initial design of the space, while the school-based makerspace was in development as a part of a top-down implementation, limiting the facilitator's input as to the initial design of the space, enabling me to analyze the impact of facilitator involvement in the conceptualization of a makerspace.

At the school-based makerspace, I observed the same facilitator during all sessions, as he was the only facilitator in the makerspace during the sessions held for teachers, students, and community members. At the museum-based makerspace, I observed all of the active facilitators in the space, mapping their movements and recording notes about their actions. I interviewed the facilitator that had the most impact on the space, through the design of the environment and activities for the makers. The facilitator that served as the lead facilitator and influenced the decisions of the other facilitators. The race or ethnicity of the facilitators in both makerspaces was overwhelmingly white, reflecting the demographic make-up of both larger groups of staff encompassing the makerspaces.

Participants were chosen based on their involvement with the makerspace. Preference was given to facilitators who have been on board with their project since the beginning stages of development, offering insights into the spaces in practice, that have resulted from long-term decision-making. Participants in this study include facilitators, makers, parents of makers, and teachers of makers. In both makerspaces, makers could include parents and teachers. The school-based makerspace hosts workshops and slots of time for open making through their recreation department, making them open to all members of the surrounding community. This includes students and teachers from the school district and nearby residents who live in the area. The earliest workshops hosted by the school district's recreation department were designated for the district teachers, designed to familiarize the teachers with the capabilities of the makerspace for their students' future learning.

As the school-based makerspace is new and still developing, teachers who would have access to the makerspace for their classes need training to understand the equipment operation and the potential for their usage in their lessons. Teachers were also welcomed to the after school workshops to learn the basic fundamentals of 3D printing, 3D scanning, and vinyl cutting. First, I observed the training sessions, where I noted the questions asked, the activities practiced, and the technology introduced. I hoped to determine their pedagogical goals for their students that work in the makerspace and how their teaching philosophies might align with the philosophies surrounding making. Next, I observed workshop sessions that were held for students and members of the community, mapping the movements of the instructing facilitator, and recording notes about the actions of the facilitator.

At the museum-based makerspace, I observed all of the active facilitators in the space, mapping their movements and recording notes about their actions. I interviewed the facilitator that had the most impact on the space, through the design of the environment and activities for the makers. The facilitator that made the most decisions regarding the space design, curriculum, and atmosphere had the most insight for me regarding the decisions they made, why they made them, and the results of those decisions.

Figure 3 summarizes demographic information about makerspace facilitators in this study.

| | **Facilitator R** School-based Makerspace | **Facilitator B** Museum-based Makerspace | **Facilitator J** Museum-based Makerspace | **Facilitator V** Museum-based Makerspace | **Facilitator BY** Museum-based Makerspace |
|---|---|---|---|---|---|
| **Demographic** | White male | White male | White male | White female | Asian/White female |
| **Time spent in the makerspace** | 3 hours per weekly scheduled session | Approximately 10-12 hours per week | Approximately 10-12 hours per week | Approximately 10-12 hours per week | Approximately 5-10 hours per week |
| **Involvement in the Makerspace** | Facilitator only | Helped to design and develop the space | Helped to design and develop the space | Facilitator only | Helped to design and develop the space |
| **Background** | Full-time college student majoring in Computer Science | Full-time making-focused museum educator, MFA holder | Full-time making-focused museum educator and exhibit developer | Museum volunteer, BFA student | Full-time making-focused museum educator and exhibit developer, BFA holder |

**Figure 3. Makerspace Facilitator Comparison Chart**

### 3.6 Role of the Researcher

At both sites, my intentions as a researcher were to remain an observer and interact with the facilitators, makers, and the makerspace itself as little as possible. I believed that if I were to act solely as an observer who did not act within the space, my research would yield observations that were representative of what happens in the makerspaces every normal day, which would be a day without a researcher present. However, as I began my observations in the school-based makerspace, I quickly realized that maintaining my role as a silent observer would likely not be sustainable. As the workshops in the school-based makerspace began, I became a participant observer as the facilitator would direct questions to me or ask me for assistance, as he knew that I had background knowledge of the technology and software in use. I answered any questions that I was asked, and I assisted when requested to solve technological problems that arose. I adjusted my research protocol to include participating in the instructed activities because to not participate would likely have influenced the

participation of the makers. By participating alongside the makers, I could also gain a deeper understanding of the activities the makers were participating in.

At the museum-based makerspace, my presence was more noticeable, as the area of the space is smaller than the school-based makerspace. Because of the limited space, tables housing activities are closer together, leaving less room for makers to maneuver around the activities. Makers had to move around me to engage with different hands-on stations. Facilitators were always present during the times that the makerspace was open, but they were sometimes working behind the scenes, gathering supplies for current activities, developing new activities, working on exhibit components for the rest of the museum, or completing other tasks. At times when there were no facilitators visible or directly in the makerspace area, makers often looked to me for direction. I recognized that remaining a silent observer in the museum-based makerspace would not be possible, but I worked to limit my influence on the space, facilitators, and makers. I tried to pick a space within the makerspace where I could sit and observe with minimal interruption to the paths traveled by the makers within the space. Whenever makers looked to me for direction, I would only smile or say hello; I did not explain or introduce the stations in the makerspace or make any other conversation.

### 3.7 Methods of Data Collection

To compare practices between the school-based makerspace and the museum-based makerspace, I took field notes during my observations, mapped the physical space, including the movement of facilitators within the space, and interviewed the makerspace facilitator. I recorded written instructions that are posted or distributed to makers. With these methods, I collected data that enabled me to determine the impact of the facilitators' pedagogies and curriculum on the makers' outcomes in the makerspace, as well as the impact of the makerspace environment and the philosophy of making. The following sections describe each method in detail.

### 3.7.1 Interview

At both the school-based and museum-based makerspaces, I attempted to interview the lead facilitator, the facilitator who had the most impact on the space. I was able to interview the facilitator at the museum-based makerspace, but I was unable to reconnect with the facilitator at the school-based makerspace, due to changes made by the school district administrators regarding the use of the space. I was able to ask questions of the school-based makerspace facilitator at points during my observations in the space, which informed my data analysis. The facilitator I selected to interview at the museum-based makerspace had the most input on the initial design of the space and the most influence over the pedagogy enacted within the space. I was able to complete a semi-structured interview with the facilitator at the museum-based makerspace who had contributed to the environmental design and curriculum production of the makerspace. This was a semi-structured interview, in which I asked predetermined questions, shown in Appendix A, but allowed the interviewee to guide the conversation. Questions posed in the interview were informed by aspects of my literature review and my observations in the makerspace.

### 3.7.2 Observation

I performed a set of observations in each makerspace, where I recorded notes and maps in a sketchbook. Also using my iPhone camera enabled me to also include pictures of set activities, settings, and signage in my notes, without having to carry around more equipment. During each observation, I first attempted to refrain from being a participatory observer, but I did follow along with direct instruction and answer questions directed at me regarding the material, when I knew the answers, because not doing so would have interrupted or disturbed the process the facilitator was enacting. While observing the surroundings, I drew maps of the layout of the makerspace when empty. I also drew maps of the makerspace in use, in which I included the movements of one or more facilitators within the space, including what they were doing in certain areas and the paths they took around the space.3.7.3

### 3.7.3 Mappings

My map-making was partially inspired by David Turnbull's (2003) exploration of maps in *Masons, Tricksters and Cartographers: Comparative Studies in the Sociology of Scientific and Indigenous Knowledge*. Turnbull (2003) presents two sides of the use of maps: internal and external. Internally, maps enhance connectivity "through the spatial arrangement of information" and externally, maps "allow for the assemblage of information at centers of calculation" (Turnbull, 2003, p. 91-92). My hope for the maps while documenting facilitators' movements was to identify patterns of movement by overlaying the drawn representations of the facilitator's movements to display any matching paths with the intention of identifying areas within the space the remain empty and areas most frequently inhabited by facilitators.

By mapping the physical design of the makerspace and the facilitators' movements through it, I was able to determine the effects of the design of the space on the outcomes of the curriculum and pedagogy. I used mapping by drawing a top-down view of the makerspace, including textual indicators of what activities, materials, or equipment existed in each component of the space that I drew. To monitor the movements of the facilitators, I drew a circle for their starting position within the space, a line for the path they took to reach their next position, and a circle at their destination. These circles were numbered and corresponded to a list of the facilitators' actions that I wrote next to the drawn map. By locating the places within the makerspace where facilitators positioned themselves or lingered, I was able to align their movements to their philosophy for facilitating making. The facilitators' movements indicated their intended purposes within the makerspace by identifying the areas in which the facilitators demonstrated a need for proximity. Facilitators used proximity to show their interests, exhibit necessary supervision, or guide makers to a process. Facilitators also used distance to encourage free exploration among makers. By mapping these movements within the space visually, I was able to recognize patterns of movement and observe how the physical design of the environment impacted the facilitators' movements throughout the space.

While the areas where congregation took place were identified, as I recorded the movements of the facilitators through the makerspace in order to identify patterns of movement and observe the flow of the space, I recognized two determining factors that often dictated the facilitators' movements: leading the makers or being led by the makers. A third type of movement did not fall into either category, which occurred when a facilitators simply needed to move through the space without any intentions for the makers. By comparing the paths of the facilitators' movements in the maps to the actions of the facilitators in my documented observations, I was able to identify which movements were guided by the makers, which movements were guiding the maker, and which movements were independent of the maker. Determining the influences on the facilitators' movements revealed more patterns of behavior than comparing the patterns of facilitators' movements. For example, I noticed that facilitators in the museum-based makerspace were more likely to be led to a place by a maker, while the school-based makerspace facilitator was more likely to lead a maker to a place.

### 3.8 Methods of Data Analysis

In order to recognize the philosophies, pedagogies, and environmental designs of both a school-based and museum-based makerspace, I looked for comparative data through observations, mappings, and an interview. I coded my data according to my research question, placing emphasis on data that aligned with philosophy, pedagogy, or the design of the makerspace environment. I coded my data for patterns, utilizing methods referenced in *An Introduction to Codes and Coding* by Johnny Saldaña (2016). I looked primarily for patterns in similarity, correspondence, and causation (Saldaña, 2016). I then categorized my coding according to my research question, identifying the codes that related to philosophy, pedagogy, and the design of the environment. For reliability, ensuring that I had a sound method for coding, my data coding was peer-reviewed by two other art education Masters students, who were provided with my data and research question.

To compare the pedagogies, environments, and curriculum in each makerspace, I looked for patterns surrounding how the facilitators enacted their own philosophy of making. Patterns indicating child-centeredness can appear through the interactions between makers and facilitators and through the movements of the facilitators throughout the makerspace, represented by the movements in which facilitators were led by the makers.

To determine how makerspace facilitators transferred the philosophy of making, I wrote notes of what kinds of questions from participants get answered by facilitators, and what kinds of questions the facilitators ask, and how those questions are answered. This analysis of the written notes and questions provided insight into the level of child-centered exploration that is permitted and encouraged by the makerspace facilitators, the style and focus of the facilitators' instruction, and the makers' actions within the makerspace.

To determine the impact of the physical environment on the makers' abilities and inclination towards making, I determined common patterns of facilitators' movements within the space. I looked to determine whether they are following the makers or the makers are following them. Informed by the literature, I expected facilitators to follow makers to materials or equipment that the makers are most interested in using, so analyzing the patterns of movement of the facilitators helped me determine how the physical design of the space can impact the makers' engagement and exploration. Analyzing the patterns of facilitators' movements through the space also helped provide insights into the pedagogy of the facilitator, because it allowed me to see if the aim of the design of the space is child-centered.

To analyze the most accessible interview with the facilitator, I focused on the patterns that emerged regarding curriculum and pedagogy. Although one makerspace facilitator implemented pedagogy and curriculum in a school-based setting and the other implemented pedagogy and curriculum in a museum-based setting, interviewing the facilitator revealed patterns of intentions and motivations that were applicable to facilitators of the two

makerspaces. The results of these intentions and motivations, through the decision-making processes, was apparent in observations of facilitators in the makerspaces.

During my analysis of the data, I expected to find emerging patterns in the interview and observations with the facilitators. These patterns would likely emerge surrounding the motivations and intentions of both the facilitators and the makers, which would guide the decision-making processes. The data indicated that the similarities and differences existed between the school-based and museum-based makerspaces. I sorted these similarities and differences into categories as they related to philosophy, pedagogy, and design of environment ranging from the planned activities to the use of the space. I based my findings in Chapter 4 on these categorical similarities and differences.

### 3.9 Validity and Trustworthiness

In quantitative research, validity “speaks to the credibility and trustworthiness of hte project and any assertions or conclusions” (Leavy, 2017, p. 154). Although my research is qualitative in nature, I value the use of validity in qualitative inquiry to ensure that the information yielded from the study is a solid foundation on which to build high-quality findings and recommendations for future practice, which are based on rich data that takes into account the context that surrounds the settings and participants being studied. To enable valid and trustworthy research practice, I gathered data through several different methods, studied each space multiple times, built rapport with the participant facilitators, and involved peer researchers and the participant facilitators in the review of the data.

Ensuring that I had rich data from which to interpret my findings and develop my recommendations for practice, I gathered data through four different means: direct observation, interview, visual documentation of the makerspaces’ physical environments, and visual mapping of the facilitators’ movements through the spaces. Triangulating these data sources and observing multiple sessions in each makerspace enabled me to compare my findings across sources, eliminating the potential for an abnormal day of observations to

completely redirect the patterns of data I analyzed. This was especially important as there were no “normal days” in the makerspaces, especially the museum-based makerspace, requiring multiple observations. By layering data, I am able to present contextualized findings from my data analysis.

To establish rapport and trust between participant facilitators and myself as the researcher, I built upon the previous relationships that already existed between us and leveraged those relationships to serve as introductions to participants who I did not know prior to beginning this study. Before beginning observations, I explained the premise of the study to the participants to help them understand and feel comfortable with my presence and actions within their space. To establish trust and accuracy in my findings, I allowed the facilitator I interviewed to review my transcription of the interview, enabling him to correct any misinterpretations. Providing transparency in the interview process by allowing him to review the transcription ensured that the facilitator was able to explain his decision-making process or give me further information that may explain outside forces that influenced his curriculum, pedagogy, or physical design of the Makerspace that was not visible during my observations.

During the process of coding the data I gathered, I involved two fellow graduate researchers to peer-review my coding. This allowed me to gain additional insights into the themes that I identified, as well as identify different emerging patterns.

### 3.10 Conclusion

Changing during the process, my research methodology developed as limitations were navigated and my understanding of both participating makerspaces grew. Operating within a constructivist paradigm, I designed my methodology to keep in mind the settings and participants within those settings. I adjusted my role as the researcher to gather rich data, which I collected and analyzed through coding techniques that were reviewed by my peers. My methodology produced recognizable patterns that contributed to solid findings. In the following chapter, chapter 4, I analyze the data that I gathered using the practices outlined in my methodology.

## Chapter 4. Data Analysis

### 4.1 Introduction

In this chapter, I offer examples from narratives composed through field notes from direct observation and mappings in both the school-based and museum-based makerspace. Figure 4 provides an overview of my data sources as they align with research questions and emergent themes. I layer the data and organize examples of patterns that emerged, which offer insights into the choices made by the facilitators in both makerspaces and how those choices relate to the facilitators' philosophy and pedagogy and the design of the makerspace environment. While the two different makerspaces cannot be directly compared in every way, I offer reasons why they cannot be directly compared alongside the differences that became apparent between them during my research. Recognizing these differences advances the idea that there is no one correct model for a makerspace and that the choices made by facilitators in regards to the design, philosophy, and pedagogy of the makerspace must along with in the context surrounding the makerspace.

| Facet of the Research Question | Data Sources | Codes and Emergent Themes |
|---|---|---|
| **Philosophy of Making** | Observations<br>Interview | Parental Involvement<br><u>Production</u><br>Complete Product Made by Makers<br>No Complete Product Made by Makers<br>No Product Expected to be Made by Makers<br><u>Makers' Actions</u><br>Reactions to Being Unable to Work with a Facilitator<br>Looking for Direction<br>All Doing the Same Thing<br>Choosing What to Do<br>Working Independently<br>Not Following Directions |
| **Pedagogy** | Observations<br>Interview<br>Mappings | Questions Asked<br><u>Planned Activities</u><br>Flexible or Inflexible Plan<br>Pre-register for Programming or Drop-in<br>Imperfectly Designed Stations<br><u>Style of Instruction</u><br>Allowing Deviation from Directions<br>Offering Guidance<br>Direct Instruction<br>Encouraging Collaboration<br>Approachable<br>Interactive Instruction<br><u>Focus of Instruction</u><br>Experimentation<br>Makers Choose<br>Skill/Technique |
| **Design of Environment** | Observations<br>Interview<br>Mappings | <u>Use of Space</u><br>Attracting Makers<br>Multipurpose Space<br>Designed for Makers<br><u>Movements through Space</u><br>Maker Leads Facilitator<br>Facilitator Moves Independent of Maker Influence<br>Facilitator Leads Maker |

**Figure 4. Chart of Data Sources as they Relate to the Research Question and Emergent Themes**

### 4.2 Makerspace Settings

Gathering data involved observing multiple workshops and open making hours held at each makerspace. In order to provide a sense of the space and the context in which the space

exists, I describe how I enter the location of each space, describing the setting that surrounds each space through the following vignettes.

### 4.2.1 School-based Makerspace

On February 27, 2017, I pulled into a free parking lot in a suburb that touches Milwaukee. The parking lot is for teachers at the high school that houses the school-based makerspace, as well as other school administrators who work in the high school buildings. The high school is made up of several buildings, including the Arts and Science Building, which was where the makerspace was located. After parking my car, I walked between two buildings to reach the entrance of the Arts and Science Building, which was unlocked. School had just ended, and students were filtering out to attend after school activities or walk or bike home, as the suburb is small enough that students are not bussed. I knew from previous communications that the makerspace was contained in Room 240 in the Arts and Science Building, but there were no signs indicating where that room was located. If I had not been a teacher in this school district and not attended trainings in this building, I likely would have struggled to find the room. With previous knowledge of the building layout, I ascended a staircase to the second floor of the building and read the room numbers posted as I walked down the hallway until I reached Room 240.

Upon entering Room 240, the makerspace, a Project Lead the Way class had just ended in the science classroom. Some students were still finishing projects from the Project Lead the Way class as students began to arrive for the makerspace workshop operated through the community recreation department. The facilitator arrived shortly after I did, and the science teacher, who was working on his computer, began packing up his things to leave. The students and makers were quietly talking to each other, and there was no other noise in the space. The room was relatively large for a science classroom, with windows facing the north. The room did not contain items from a science laboratory, but did feature laboratory-style tables, which were arranged to all face the front of the room. I took a seat at a table towards the middle of the room, while the makers filled in the seats toward the front and the facilitator

stood at the front of the room. I began to sketch a general map of the room, which was used to create Figure 5.

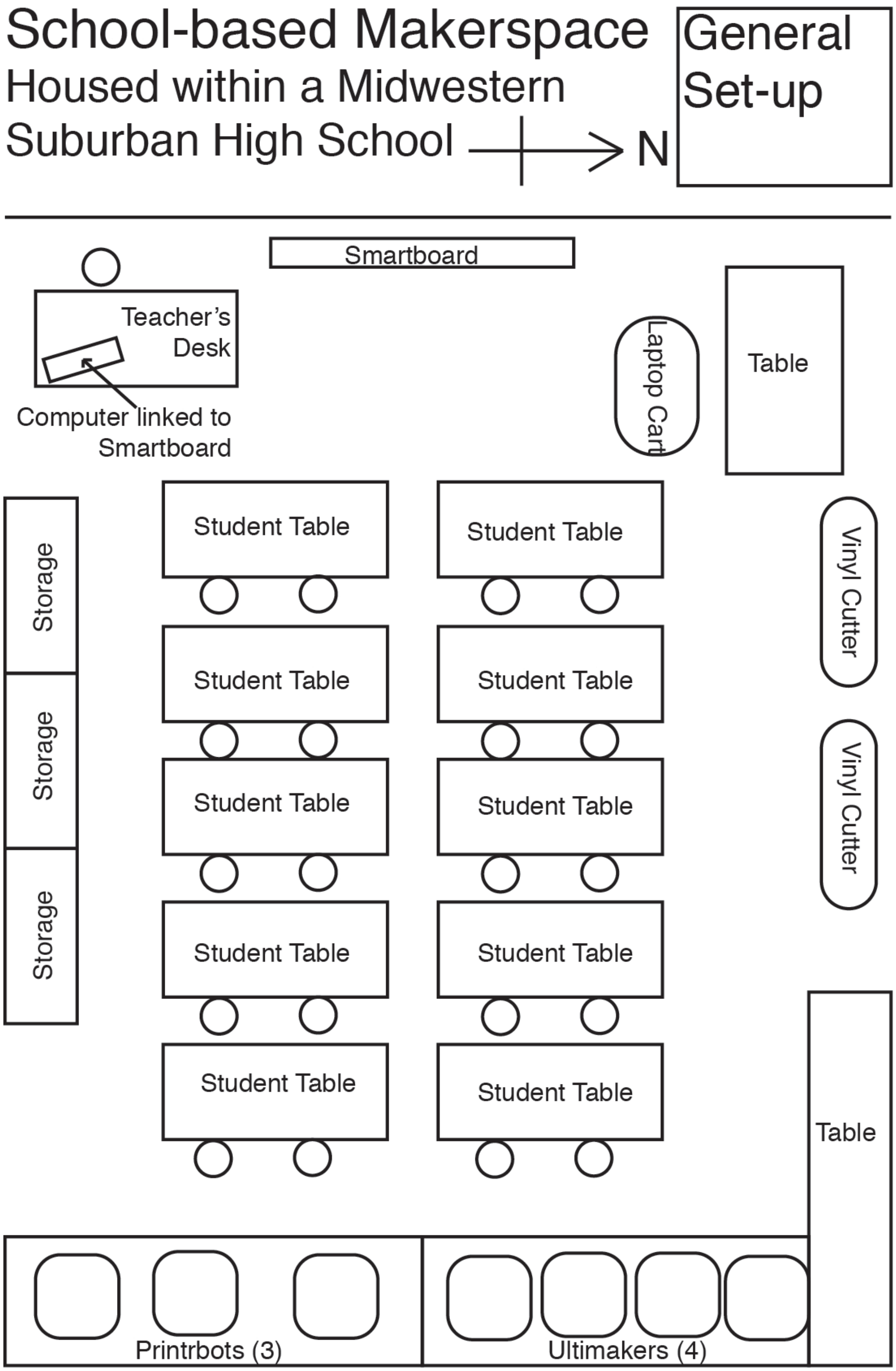


**Figure 5. Map of the School-Based Makerspace**

#### 4.2.2 Museum-based Makerspace

On March 31, 2017, I pulled into a paid parking garage beneath the children's museum, taking a ticket and driving up to the second level, closer to the elevator. I knew parking in this location usually cost me between $5- $7. I took an elevator up to the first floor, walking through a hallway to an atrium. I walked up a staircase to the second floor, reaching the front desk of the children's museum. The museum was full of children engaging with the interactive exhibits, and the atmosphere was relatively loud and energetic. As adults are not permitted in the museum without a child, I was required to sign in at the front desk and receive a visitor badge. Parents and children pay $8 in admission for the museum, but there are several ways to reduce that cost. Visitors may purchase a museum membership (starting at $75 per year) or receiving museum membership through an outreach program for families in need. Use of the makerspace during open making hours is included in the cost of admission. I already knew where the makerspace was located from previous meetings held there, but the visitor assistant at the front desk directed me the correct way. After signing in, I walked through a hallway amongst exhibits towards the makerspace, which was built primarily out of what appears to be repurposed wood. The feel of the construction emphasized its handmade quality. Visitors must step up into the makerspace, but there was a ramp that makes the space wheelchair accessible.

I had arrived just before the open making hours began, so the makerspace was locked and dark. Unlocking the space was as simple as reaching through a pane-less window and undoing the latch, so I let myself in and waited for a facilitator to open the space for the scheduled block of open making. Almost every main piece of furniture in the makerspace had the same handmade wooden quality as the space itself, which makes sense as almost all of it was handmade by museum staff. The space was located behind the clock face of a large clock tower, which visitors could look through, but so many materials, tools, and equipment were packed into the smaller space that the clock face was barely visible unless you know it's there. The main space in the makerspace was for makers, but a moveable fence blocked off a

secondary area for facilitators and two small office-focused areas. Children were playing with the exhibits surrounding the makerspace, but they did not seem to notice the space or want to enter it when it is dark. When a facilitator arrived in time to open up, he slid a large door open, exposing most of the space, and turned the lights on. Stations for making had already been set up on the tabletops, so the space was ready for makers. Makers slowly trickled in for varying amounts of time once they saw the lights on and the doors open, and I began to sketch a map of the space, which informed Figure 6.

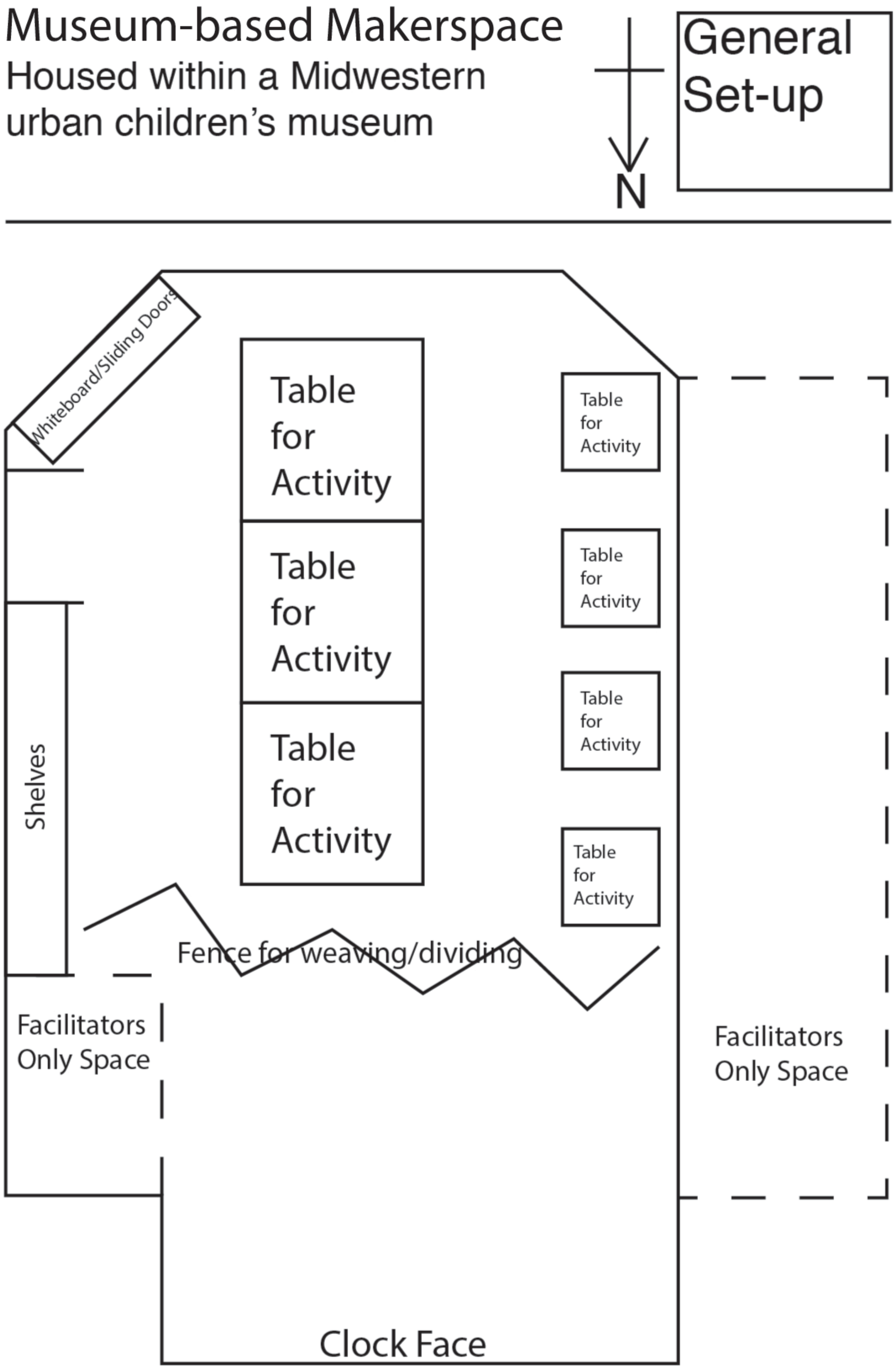


**Figure 6. Map of the Museum-based Makerspace**

## 4.3 Design of the Makerspace Environment

The physical design of the makerspace environment is the most noticeable difference between the museum-based and school-based makerspaces. The facilitator in the school-based makerspace had no input into the design and layout of the makerspace, as it existed in a longtime science classroom in a high school, rather than a dedicated room for making. Some of the facilitators in the museum-based makerspace, on the other hand, were instrumental in the design, layout, and even construction of the makerspace. Due to these drastic differences, it was apparent that the design of the makerspace environment was secondary to the room housing the school-based makerspace, while the facilitators in the museum-based makerspace were involved in the design of the makerspace from the beginning, as the primary use for the space within the museum.

### 4.3.1 Use of Space

The facilitators' design and use of the makerspace's physical environment depends on their level of involvement during the inception of the space, because the facilitators may or may not have participated in the original design process or construction of the space. The original design of the makerspaces varied from a classroom altered for use as a makerspace to a designated makerspace designed for makers. These differences in design of the space indicate the intentions for the use of the space.

The school-based makerspace was held within a science classroom that was outfitted with additional technology, like 3D printers and industrial vinyl cutters. The facilitator in the school-based makerspace did not have any input in the design of the space or the arrangement of equipment in the space. As a multi-purpose room, the school-based makerspace contained additional technology, like 3D printers and vinyl cutters, housed in the back and side of the room, out of the way of the traditional classroom set up. The facilitator faced problems stemming from the multi-purpose use of the makerspace in that he could not enter the makerspace outside of his workshop times to inspect and prepare the technology for use. This resulted in the vinyl cutters not being prepared for makers to use and the makers

being unable to reach the intended goal. While the facilitator demonstrated a technique, using the Smartboard to present his directions to the group, a new piece of equipment intended for use in the science classroom was delivered to the makerspace, quite loudly, distracting the makers and making it harder for the facilitator to explain his directions. While the back areas of the museum-based makerspace, blocked off from makers, housed other materials facilitators used to complete other projects, prototype, test, and do behind-the-scenes support for the makerspace, the facilitators in the museum-based makerspace did not face the challenges of a multi-purpose space.

The museum-based makerspace was designed for makers to make, with other uses for the space not taken into account during the design and construction of the makerspace. The makerspace's design is aimed at engaging makers in making activities. While the school-based makerspace is housed within a science classroom that is designed as a formal learning environment during my observations, no changes take place to make the room more suitable for makers yet. The museum-based makerspace is designed for making only, with many aspects of the space serving multiple purposes, such as tables that can fold down, counters with wheels that can be moved, even a divider that also serves as an activity. The museum-based makerspace is designed to be enticing and welcoming to attract makers. Facilitators at the museum-based makerspace will open two large sliding doors, making the inner workings of the space more visible to the rest of the museum, when there are few or no makers in the space. Their goal is to make the activities and space look interesting and exciting to draw in curious makers. Focused on the makers, the museum-based makerspace is designed for adaptability. Stations can be moved in or out to accommodate crowds or new interests. An outside balcony is available for agricultural-focused activities on days with good weather. Makers' experiences are the main priority for the facilitators, and they were able to design and construct a space that serves makers.

### 4.3.2 Movements through Space

I originally intended to map the facilitators' movements in the space in order to observe the flow of the design of the space in order to develop recommendations of practice related to the physical lay-out of a makerspace. However, while I was able to notice the facilitators' patterns of movements in terms of the design of the space, I began to notice that the makers were more of an influence on the facilitators' movements than the design of the environment. Facilitators moved through the space in relation to the makers. The facilitators would lead the makers, the makers would lead the facilitators, or the facilitators would move independent of the needs of the makers. The facilitators' movements through the space in relation to the makers reveal how child-centered the activities are by comparing the number of movements were the result of makers leading the facilitators or the facilitators leading the makers.

Some of the facilitators' movements were independent of makers' influence. Their movements did not take into account any makers' actions or needs. Facilitators' movements are not entirely dependent on the makers, because other things happen in the makerspace that are not directly related to the makers. Facilitators need to get supplies for another project, help someone outside of the makerspace, or work on another project, as evidenced by the green and red lines representing facilitators' movements in Figure 7. When new equipment arrives, facilitators needed to explore their options, moving through the space independent of the current makers, as evidenced by the green and red lines representing facilitators' movements in Figure 8. Facilitators sometimes move through the space, often times away from the makers, to achieve a goal that does not relate to the makers.

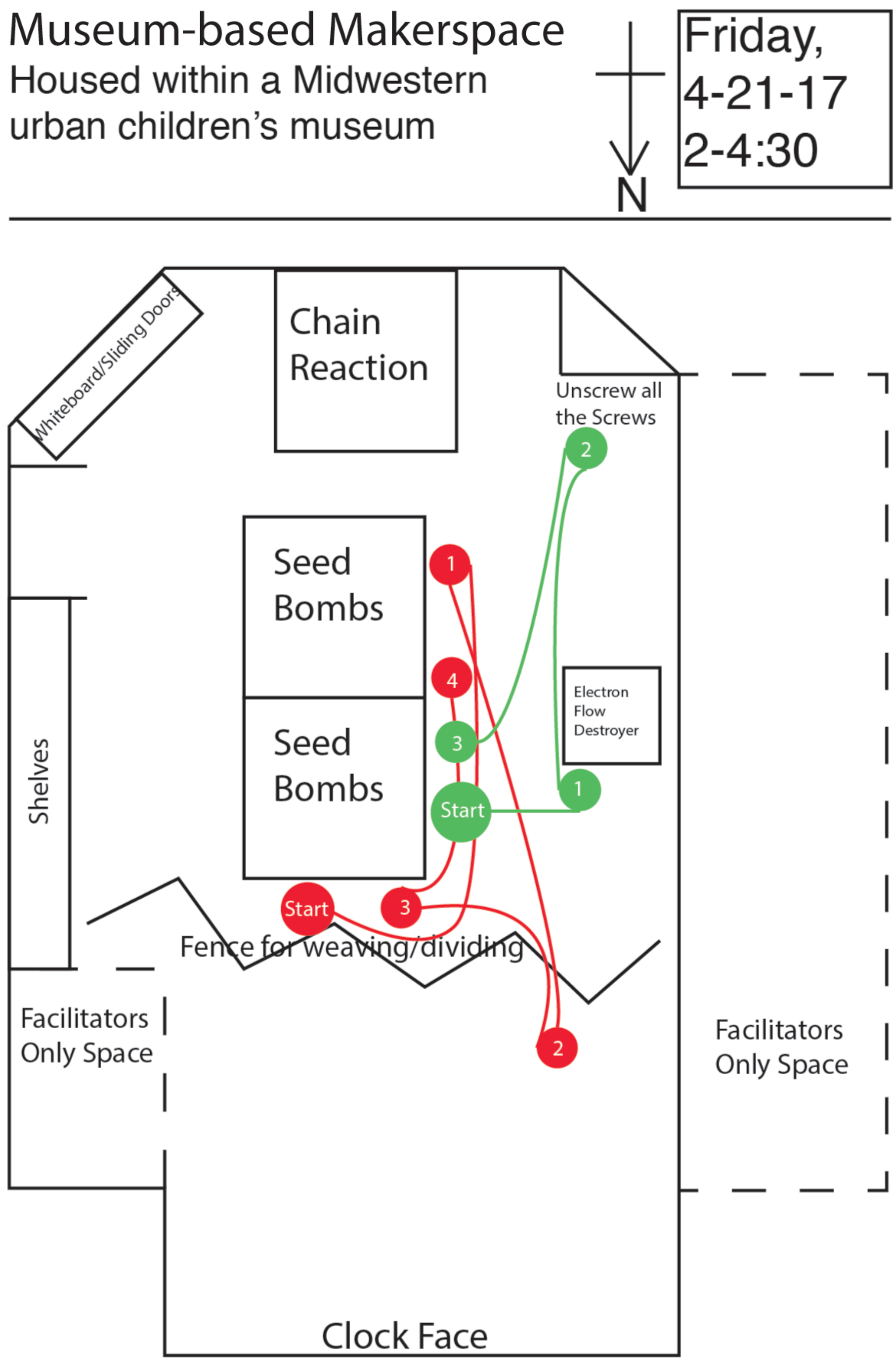


**Figure 7. Facilitator Movements within the Museum-based Makerspace, April 21, 2017**

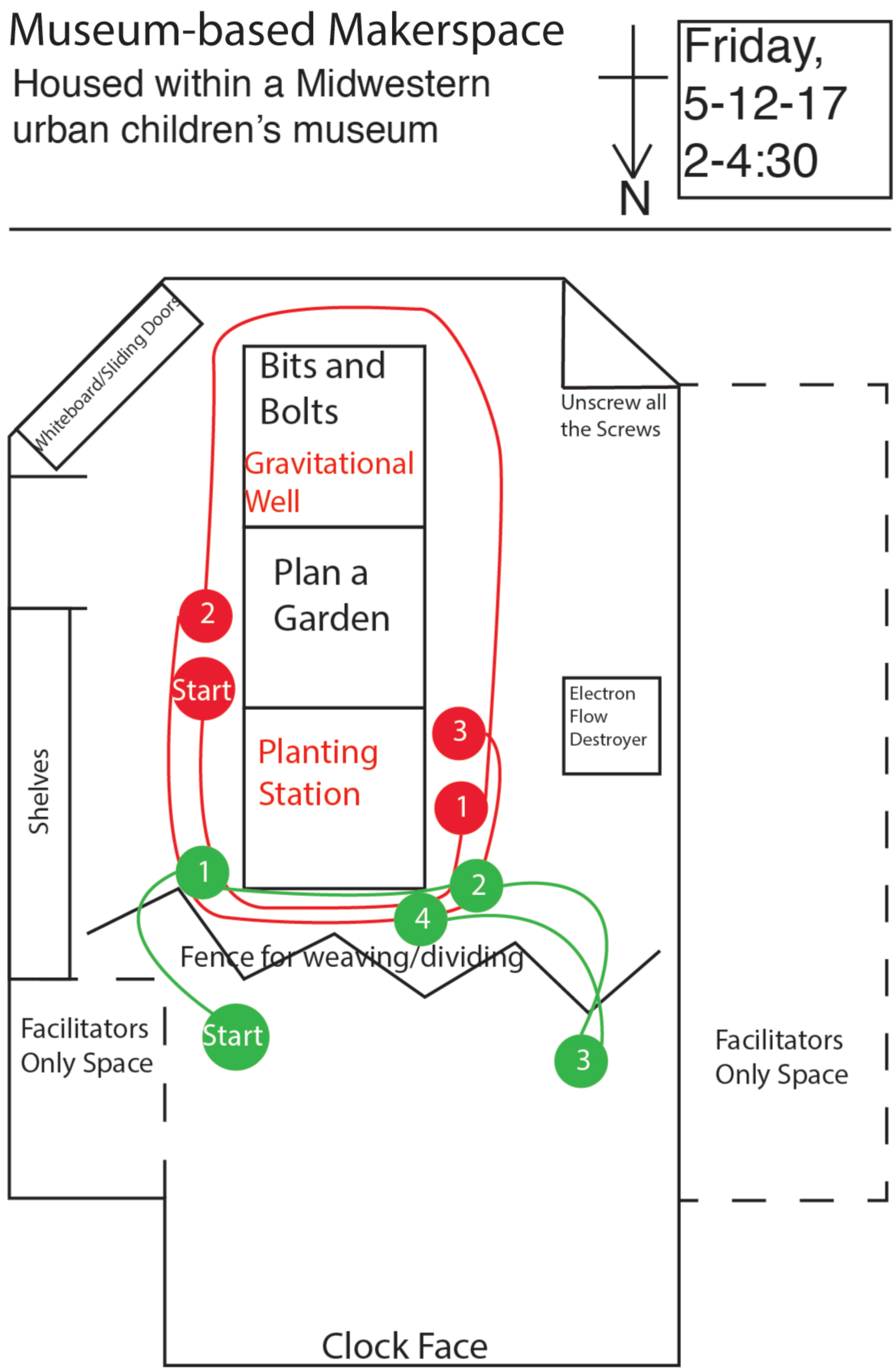


**Figure 8. Facilitator Movements within the Museum-based Makerspace, May 12, 2017**

Other movements by the facilitators were used to influence, direct, or instruct the makers. When the facilitator is leading the maker, their movements are directive to makers' actions or needs. When the facilitator's instruction is focused on building a specific skill or technique, there are often more movements that occur by the facilitator leading the maker. If the facilitator is leading the maker, it generally means that the facilitator is making the decision of what or how the maker will be doing what they are doing. As shown in Figure 9, a movement of the facilitator leading the maker could still be a child-centered process, however, because the maker could have asked the facilitator a question (while the facilitator occupied position 4), which the facilitator needed to demonstrate (moving to position 5). The maker could initiate the process of moving through the space by asking a question.

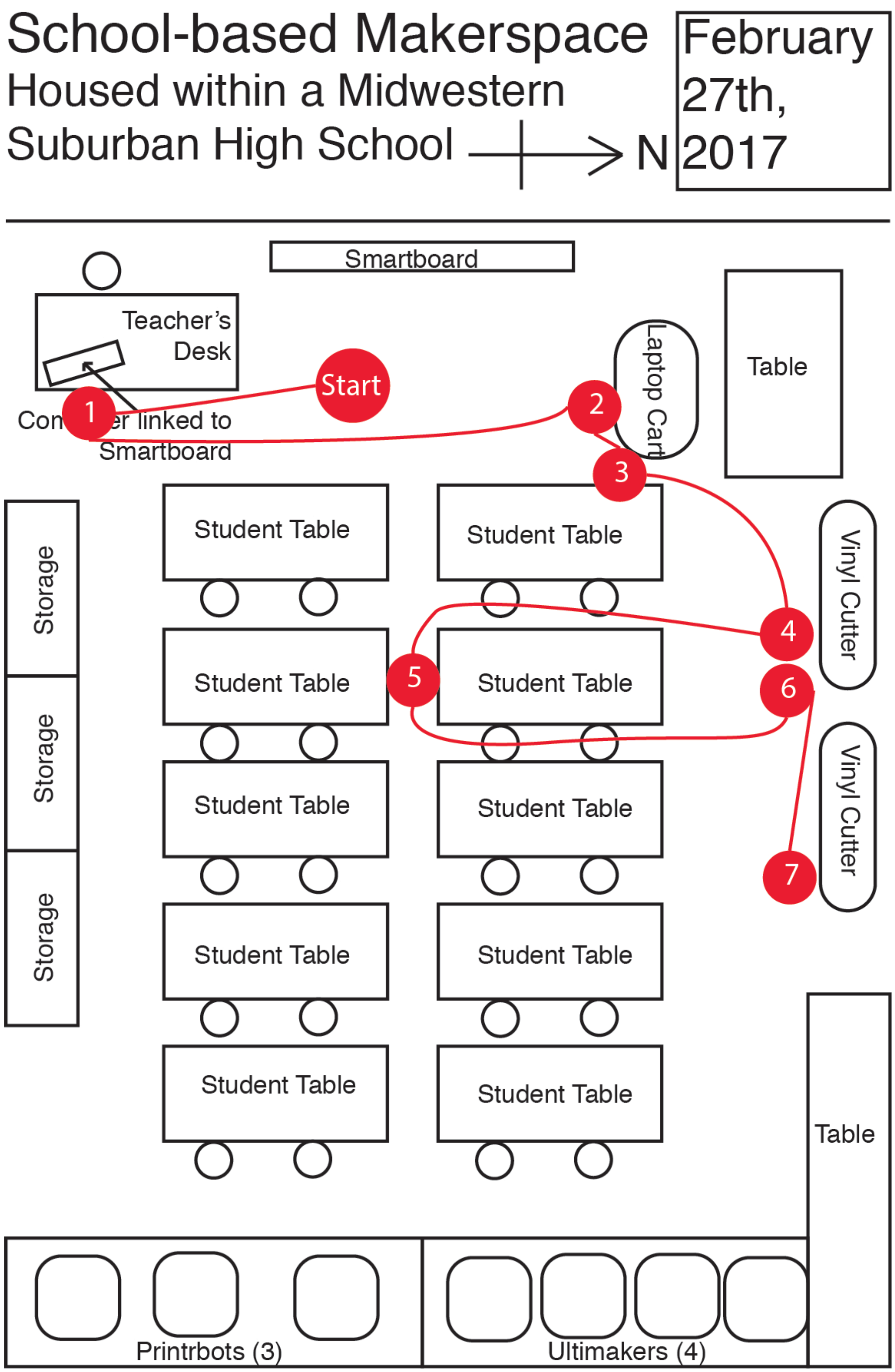


Figure 9. Facilitator Movements within the School-based Makerspace, February 27, 2017

In a more child-centered approach, the maker leads the facilitator through the space. The facilitator may not physically follow a maker through the makerspace, but the facilitator's movements result from the maker's actions or needs. When makers are leading the facilitator, it generally means that the makers are deciding what they want to do and how they want to do it. When makers want to try a different activity, trading Bits and Bolts for drawing, the facilitator, while not physically led by the makers' movements but led by the makers' ideas, gathered supplies and reformatted the space to meet the makers' needs, as shown in Figure 10.

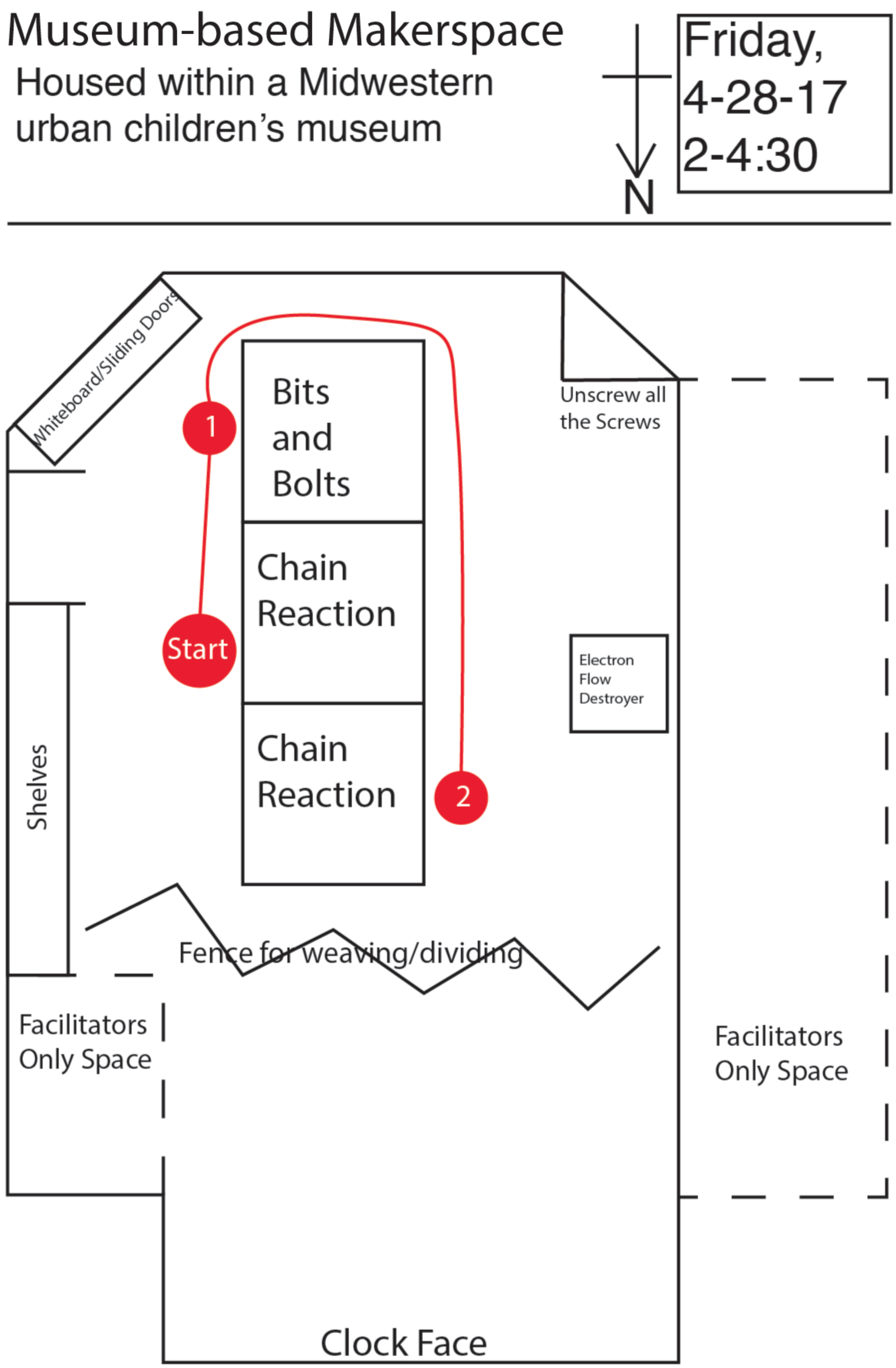


**Figure 10. Facilitator Movements within the Museum-based Makerspace, April 28, 2017**

The number of times facilitators lead makers or makers lead facilitators demonstrate whose choices are valued in the makerspace. When the facilitator led the makers, the facilitator is making the choices that dictate what the makers will be doing. When the maker is leading the facilitator, the maker is making their own choices about what they will be doing. While no workshop or set of open making hours featured solely maker-influenced or facilitator-influenced movements, a pattern emerged regarding the focus of instruction in each makerspace. When the focus of instruction was to build a specific skill or technique, far more of the movements were facilitator-driven. When the focus of instruction was for makers to experiment with concepts, tools, or equipment, far more of the movements were maker-driven. The movements of the facilitators in relation to the makers revealed a child-centered focus in the design of the environment and in the philosophy and pedagogy of the facilitators.

### 4.4 Philosophy of Making

A philosophy of making is a collection of ideas and beliefs held by a makerspace facilitator that relate to their interpretation of making's definition. What facilitators define as making will influence the philosophy they transfer to the makers. For example, if a facilitator consistently presents making activities that use a high degree of technology, they are transferring a philosophy of making to the makers that presents high-tech strategies as the procedures that "count" as making.

The philosophy of making varies by facilitator as each facilitator exists in a different makerspace environment and has a different background and skillset. Facilitators develop and transfer a philosophy of making to makers through the activities they design for makers within the makerspace. Considering what activity constitutes making is a critical component of the philosophy; comparing production and making is necessary to develop activities that achieve the goals facilitators have for makers or align with the goals set by others in the context surrounding the makerspace, such as school administrators or a Board of Directors. Transferring a philosophy of making requires understanding and influencing makers' actions in the makerspace. Setting the level of parental involvement is also an indicator of the facilitators'

philosophies for making in education. The level of parental involvement in the making activities also indicates the philosophy of making held by the parents of the makers, whether making is valued or encouraged. The value of making is apparent in facilitators' philosophies, but the choices they make in acting on their philosophies varies depending on their circumstances. In the sections that follow, I analyze the facilitators' use of production during their designed learning activities, how makers' actions are influenced by the philosophy of the facilitator, and the level of involvement of parents allowed or encouraged by the facilitators.

### 4.4.1 Production

Production is generally considered a result of making, as makers are generally thought to produce an object during their making process. However, my observations uncovered that the production of a complete product is not necessarily guaranteed during making activities. I define a complete product as an object, digital or tangible, that makers design and construct from start to finish, collaboratively or individually. Making and production do not have to mean the same thing. In a makerspace, makers can make objects do something. Makers can make predictions about what will happen to objects within the makerspace. Makers can make a giant mess. But makers may or may not produce something while acting in a makerspace. During my observations, I recognized that there were times that makers produced a complete product, times when makers did not produce a complete product, and times that no product was expected from the makers, depending on the choices made and activities planned by the facilitators. The level of production encouraged by the facilitator indicates the value of a final product to the facilitator and influences the makers' interpretations of what can be considered to be making.

In my literature review, I gathered literature that supported learning through hands-on means. For example, in subsection 2.3.3 references project-based learning, which encourages production as a means of applying and demonstrating knowledge.

During the situations in which makers did not produce a complete product while working in the makerspaces, there were times that a complete product was produced during

the making activities, but it wasn't produced by the makers, and there were times that no complete product was produced at all. In both of these sets of situations, making did occur, but no complete product was produced. During my first two-hour observation of an after-school workshop for students in the school-based makerspace on February 27, 2017, the facilitator was instructing makers in the use of the industrial vinyl cutter. He began by teaching makers about the software used to produce a vector image through a visual presentation, explaining the concept of vector art to them and why vector art was required for the vinyl cutting process. Using a sample image he had previously prepared, the facilitator then showed the makers how to turn on the vinyl cutter, load a roll of vinyl, and set up the machine to begin cutting. During this instructional process, the makers experimented with the prepared image, but did not produce their own image. Once the vinyl cutter was ready to use, which the facilitator demonstrated but did not involve the makers in doing, the facilitator demonstrated the use of the software required to produce a file that the vinyl cutter was able to plot and cut. The vinyl cutter, however, had the blade loaded incorrectly. After some fruitless troubleshooting, the facilitator moved to the second vinyl cutter to try that one, but the second vinyl cutter had the same problem. Attempting to adjust the blade height manually was unsuccessful, leaving the makers unable to use the vinyl cutters. As the makers were unable to use the vinyl cutter, they did not make the intended sticker. Having brought samples of cut vinyl, the facilitator demonstrated weeding a sticker, which is the removal of vinyl pieces that are not meant to be part of the final image. He also demonstrated tips for using Adobe Illustrator to create vector images suitable for cutting on a vinyl cutter, in order to fill the time allotted for the workshop and impart knowledge to the makers that was at least relevant to vinyl cutting. This situation demonstrates an occurrence in a makerspace that hindered the intended production of a complete product by the makers, but other intended situations result in makers not producing a complete product.

In the school-based makerspace, the general intent was for the facilitator to teach the makers a specific skill or technique, so makers often did not produce a complete product from

start to finish or did not complete a product that they designed themselves. During workshops focused on 3D printing, the makers often left with a 3D printed object, but that object, the same object for all makers, was not designed by the makers, nor was it set up to print on the 3D printers by the makers. The facilitator demonstrated software to repair and alter 3D models to make them printable, and he demonstrated the use of two different 3D printer models to the makers. The makers were then able to make changes to 3D models and set up sample models to be 3D printed, but the were not involved in the actual design or production of the objects that they were able to take home from the school-based makerspace. Similarly, in the museum-based makerspace, Drawbots or RobARTs, shown in Figure 11, made by facilitators were sometimes set up in a sort of arena in which markers attached to the rotating machines made marks on the paper-covered table beneath them. Makers could place paper underneath a specific Drawbot and take home the resulting drawing, but the makers did not produce the object taken home. In situations like these, a complete product was expected as a culmination of the workshop, but the makers themselves did not produce the complete product.

**Figure 11. Completed and In-Progress Drawbots or RobARTs**

In other situations, a complete product was not expected to be the end goal of a makerspace activity. In many of the stations designed by facilitators in the museum-based makerspace, makers did not produce a complete product. For example, Chain Reaction, shown in Figures 12 and 13, a large domino-style set of wooden pieces in various sizes designed to be arranged in rows and then knocked over, elicited applause when all of the pieces had fallen, with participants making a reaction, not a final product.

**Figure 12. Chain Reaction in Progress**

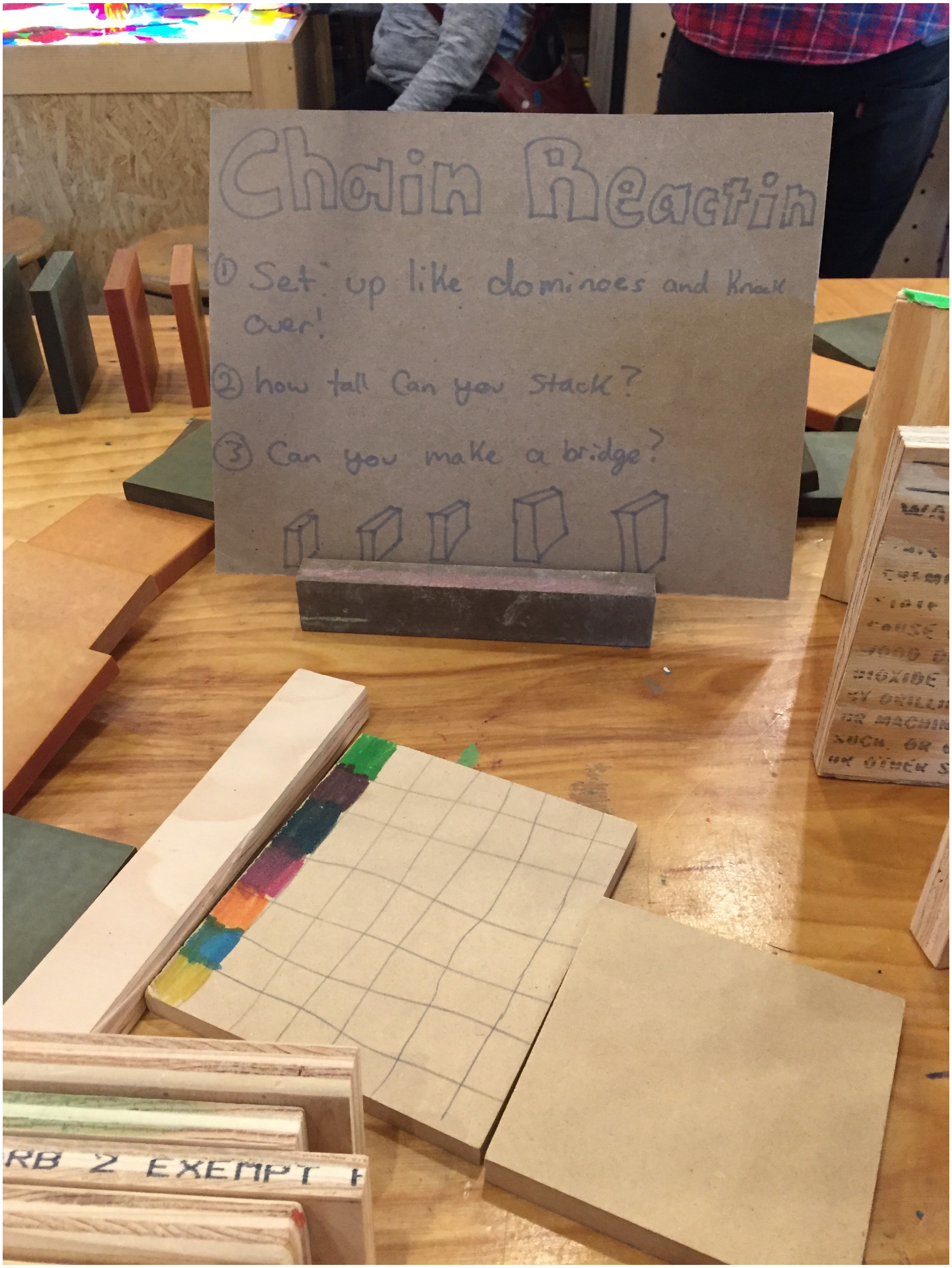


**Figure 13. Posted Directions for Chain Reaction**

Other more permanent fixtures in the makerspace included a large pegboard, shown in Figure 14, with screws at various levels, with instructions reading “Can you help us unscrew all the screws?” Screwdrivers and some battery-powered screwdrivers were available for makers to use, with the only final production being an image created by the design of the remaining screws. Makers usually focused their efforts on the process of screwing and unscrewing rather than the aesthetic result.


**Figure 14. Screw Wall**

A large light table sat next to the screw wall, with translucent colored tiles that makers could construct with, as the tiles had tabs cut out to allow them to intersect, as shown in Figure 15.

**Figure 15. Light Table with Translucent Tiles**

A magnetized table featured round pieces of metal that could stick to each other for makers to design and balance structures, featured in Figure 16.

**Figure 16. Magnetized Table with Metal Pieces**

A table with a television set facing the ceiling featured a large magnet that hung over the screen, called the Electron Flow Destroyer, shown in Figure 17.

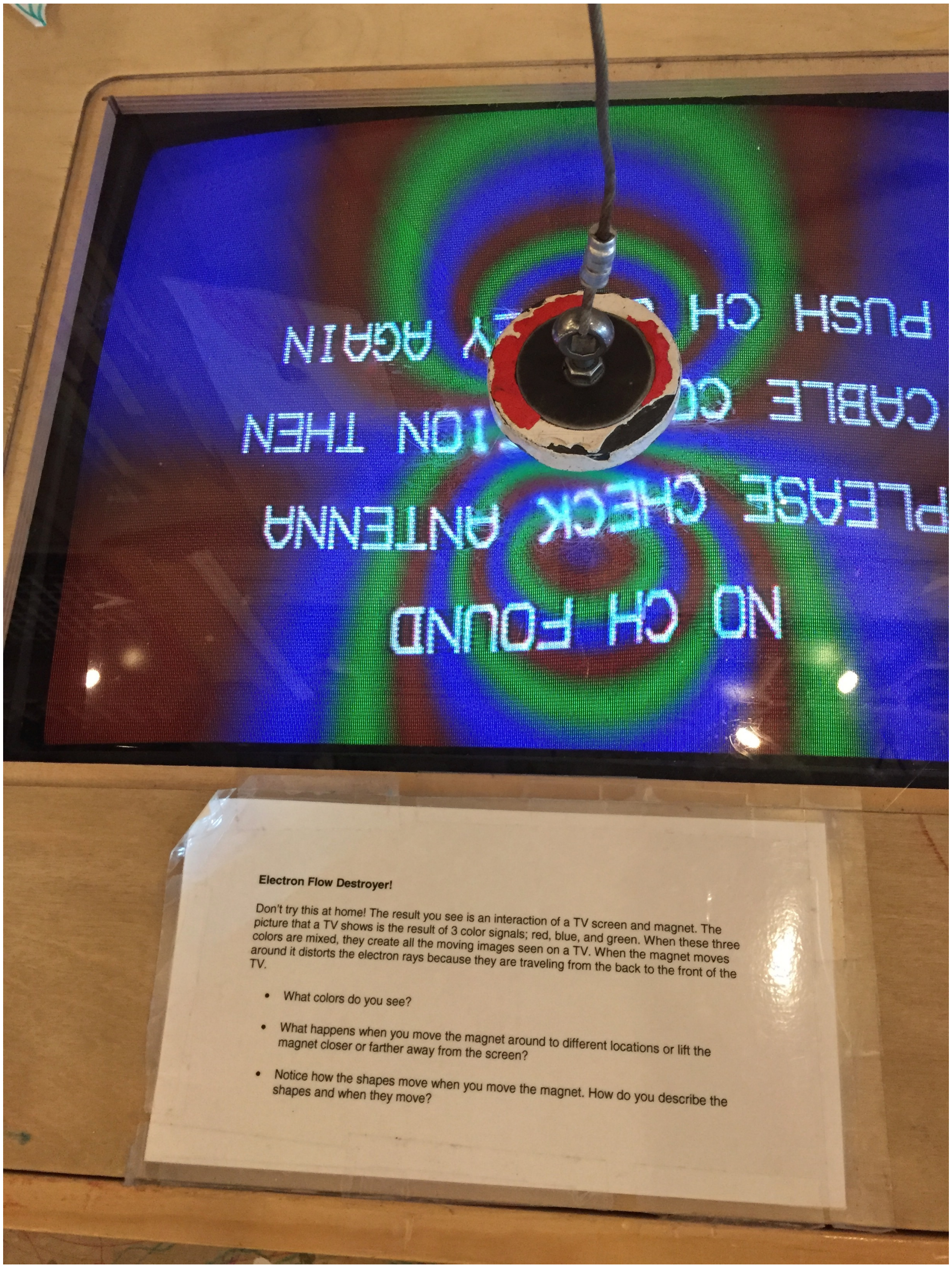


**Figure 17. Electron Flow Destroyer**

The magnet affected the image on the television screen, and was manipulated by the makers. Posted questions ask “What colors do you see?” All of these stations within the museum-based makerspace invited makers to make designs or make a reaction between materials, but

they did not involve the makers producing any sort of product that they would take home with them from the makerspace.

The museum-based makerspace also offered activities that did result in makers taking home a completed product of their design and production. During an Earth Day-inspired activity, two of the larger center tables were dedicated to a seed planting station, which involved makers rolling newspaper around a pre-made tube to make a container, scooping moistened dirt into that container, and planting seeds into that container. While makers made a planter, facilitators would ask them what three things a seed needs to grow, indicating that seeds needed water, sun, and dirt. Facilitators would also explain that newspaper is decomposable, meaning that the whole planting can be buried in the dirt at home because the newspaper would break down in the dirt. There was a two-week old sprout available to show what makers could expect from their planting. While this activity involved little opportunity to make design choices that influenced the results, makers were able to take home and use an object that they had produced from start to finish. With more options in terms of design, a related activity offered in the museum-based makerspace involved planning a garden on paper, shown in Figure 18. Makers could design their garden on a gridded paper, choosing which plants they wanted to include by coloring them, and then cutting and pasting them onto the garden plans. These activities and others like them culminated in a tangible product that makers could take home with them from the makerspace.

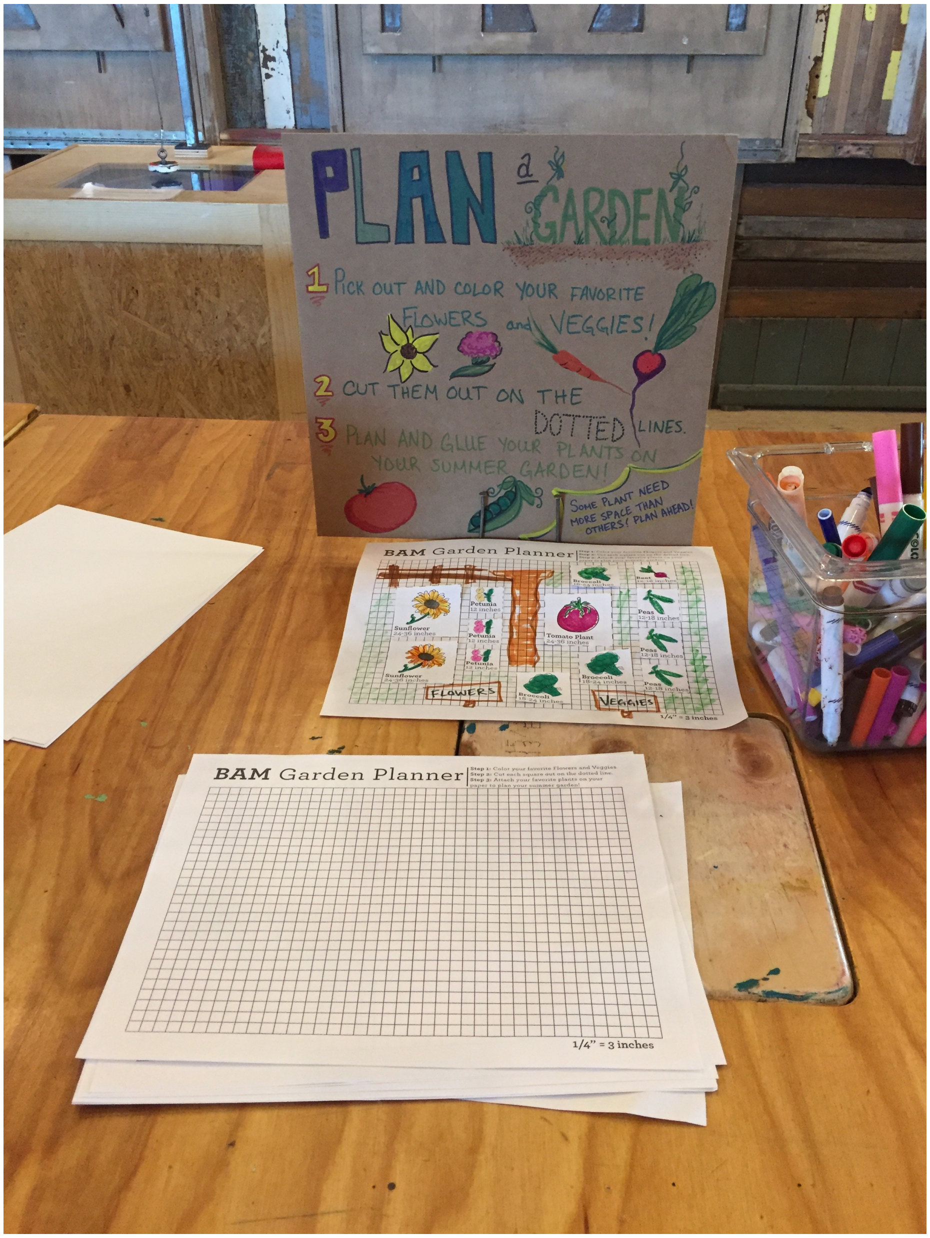


**Figure 18. Plan a Garden Station**

Tangible or digital products are not necessarily the end goal for activities within a makerspace, depending on the philosophy of the facilitator who designs the activities. Transferring a philosophy of making to the makers within the space depends upon the philosophy of the facilitators, because what the facilitators consider to be making influences what activities they design for the makers. Production can be a major component of maker activities, or making can look more like manipulation of materials with no end product.

### 4.4.2 Makers' Actions

In both makerspaces, results of makers' actions were on display as soon as they entered the makerspace. During my observations, makers' actions were heavily dependent on their environment, their interactions with the facilitators, and the expectations of the facilitators for the makers. When observing facilitators' actions and interactions in the makerspaces, I discovered that the philosophy of the facilitators influenced the expectations for the makers, which in turn influenced the actions of the makers within the makerspace. The philosophy of the facilitators indicated how facilitators would design making activities, develop expectations of end goals for the makers, and be available to makers as a guide, providing a context in which makers act according to their interpretation of that context. Makers' actions, whether directly influenced by even the presence of a facilitator or not, indicated how both the makers' and facilitators' philosophy of making contribute to expectations, level of interest, and outcomes.

Makers revealed their expectations for their time in the makerspace based on their actions in the event that they could not work with a facilitator within the makerspace. Being unable to work with the facilitator meant that the facilitators were not available to answer questions, direct, or interact with makers in the makerspace. The inability to work with the facilitator occurred in both makerspaces, but for different reasons and with different results. In the school-based makerspace, the facilitator was always present in the space, but was unavailable to makers in the event of a piece of equipment not working and needing his attention to troubleshoot the problem, such as when the vinyl cutters' blades were loaded incorrectly. In the museum-based makerspace, facilitators were often in the greater area of the space, but sometimes not in the area of the makerspace where makers were working. They sometimes worked behind the scenes, where makers could not reach them, testing, preparing, or developing makerspace activities or exhibit components. In one situation in the museum-based makerspace, staff were having a meeting behind the weaving fence, shown in Figure 19, because open making hours were scheduled to be held, so the Makerspace required staff

supervision, but schedules only permitted meeting during the open making time. The requirement for the makerspace to be staffed came partially from a safety standpoint, but also from a philosophy standpoint. The rest of the museum was not staffed in the same way, mainly relying instead on parents or caregivers to supervise their children, but the makerspace was expected to be staffed in order to provide interested makers with guidance and encouragement from a knowledgeable source. Stations were set up to be independently interacted with while the facilitators and other staff members were meeting. The activities were set up in order to ensure that makers could interact within the space with self-sufficiency.


**Figure 19. Weaving Fence**

A common action of makers who were unable to work with facilitators was to look for direction upon entering both spaces. Especially in the museum-based makerspace — compared to the school-based makerspace where makers were more comfortable in the setting likely because they had prior experience there — many makers initially hesitated upon entering the space if they were not welcomed by a facilitator. Many makers looked to me, as an adult in the area, for direction in the museum-based makerspace, but when they did not receive direction from me, they would interact with the stations that were set up for them. According to the museum-based facilitator, there are a variety of possible reasons for their hesitation: unfamiliarity with the concepts addressed in the stations, lack of confidence, lack of interest, or concern over what is allowed in the makerspace (personal communication, April 28, 2017).

Concepts from my literature review — section 2.4, specifically — suggest that children who enter makerspaces may not yet view themselves as makers and require guidance and encouragement to take on the identity of a maker.

The philosophy of the facilitator regarding the choices for which makers should be responsible is apparent in several situations: when makers are all doing the same thing, when makers are not following given directions, when makers work independently, and when makers choose what to do. In the school-based makerspace, the workshop modeled instruction led to makers following along step-by-step with the facilitator to learn a specific skill or technique.  In several scenarios within the school-based makerspace, the facilitator issued step-by-step directions accompanied by demonstrations, with which makers were expected to follow along on their own. When makers are all doing the same thing at the same time, as when makers are following along with directions given by the facilitator, they are likely not involved with the design process of whatever object they are making, nor do they get to make as many choices during the process.

The situation that often goes hand-in-hand with makers all doing the same thing at the same time is makers not following the given directions. When makers do not follow along with

the directions, they may not meet the expectations set by the facilitators in terms of the skills they are building or the product they are completing. As expected in an informal learning environment for youth, makers did not always follow the instructions provided to them by the facilitators. In the school-based makerspace, the facilitator used direct instruction, with the expectation that makers would follow along with his directions. Makers who were not interested in the 3D modeling concept he was instructing sometimes started doing other things on the computers, even in small groups where the facilitator was likely to notice that they were not following along, often within the same software that the facilitator was demonstrating. For example, during a presentation on repairing meshes for 3D printing in the school-based makerspace, many makers were experimenting with Cura or other 3D modeling programs, such as Meshmixer, which some makers had been taught to use during the previous 3D Printing 102 workshop. The facilitator walked around the makers to ensure that they had understood his directions, and he did not address the makers who had not been following along with his directions. In the cases when the facilitator noticed that makers were not following along with his instructions, he did not correct the makers, allowing them to continue experimenting outside of the parameters set by his directions. He explained that they were likely still building the skills in 3D modeling through that practice. The makers' actions of not following along step-by-step did not necessarily reveal a disinterest in the subject matter, as their straying from the directions still involved the concept the facilitator was teaching in those directions (personal communication, March 7, 2017).

The way makers interact socially while working within the makerspace reveals their intentions for collaboration, which can be influenced by the facilitator. When makers are working independently, they are not collaborating with others, focusing on their own version of the activity taking place. In the school-based makerspace, makers worked on the same thing at the same time, but generally did not work together. In the school-based makerspace, the makers were instructed to begin a print of a model previously loaded onto SD cards, which involved the facilitator demonstrating how to turn on the printer, insert the SD card, and use the

click wheel to select “Print.” The makers replicated the process on the other two operational 3D printers, with each maker at their own 3D printer. As the makers got their prints started, the facilitator explained the best practices for 3D printing. During this process, one of the makers explained that he actually had his own 3D printer at home. Another maker asked if it was possible to change the color of the prints. These makers, although interested and willing to ask questions and provide feedback, worked independently with the 3D printers. In the school-based makerspace, most of the makers in the workshops were students at the school or teachers at the school, so they often knew each other beforehand.

In my literature review, subsection 2.4.3, I reference how collaboration is an integral part of makerspace culture, which was encouraged by facilitators in the museum-based makerspace to limited degrees of success. In the museum-based makerspace, as a drop-in program, makers only knew the people they arrived with, like their siblings, parents, or friends who came to the museum with them. This led to makers working more independently, as they were less comfortable with the makers working alongside them. Facilitators in the museum-based makerspace often tried to encourage collaboration among makers by working to unite makers who are working on the same activity independently, but there was generally resistance, indicated by the makers’ unwillingness to work with another maker they did not know. At a station featuring simple robots that could make drawing marks, the facilitator explained the circuits to a maker, using the demonstrative tool, shown in Figure 20, in an in-depth way due to the maker’s age and level of understanding. As the maker gained more understanding, with help from the facilitator explaining that “electricity needs to be in a circle; it wants to get back home,” the facilitator asked, referencing another younger maker in the makerspace, “Can you teach her how to do it?” The older maker, who had been practicing with the practice circuit board, was hesitant to teach the younger maker, so the facilitator continued to connect with the maker. “How about you teach me about it?” the facilitator suggested. Sensing more hesitation, the facilitator joked with the maker, “I’m going to quiz you! Is that the motor? What am I supposed to do here? I don’t get it.” Once the maker was more comfortable

explaining how circuits work, the facilitator demonstrated how to reverse the wires, changing the direction the motor spins, but the anticipated collaboration with the older, more experienced maker teaching the younger maker never occurred. Makers working independently reveals their comfort level with the concepts, other makers, and the climate of the makerspace.

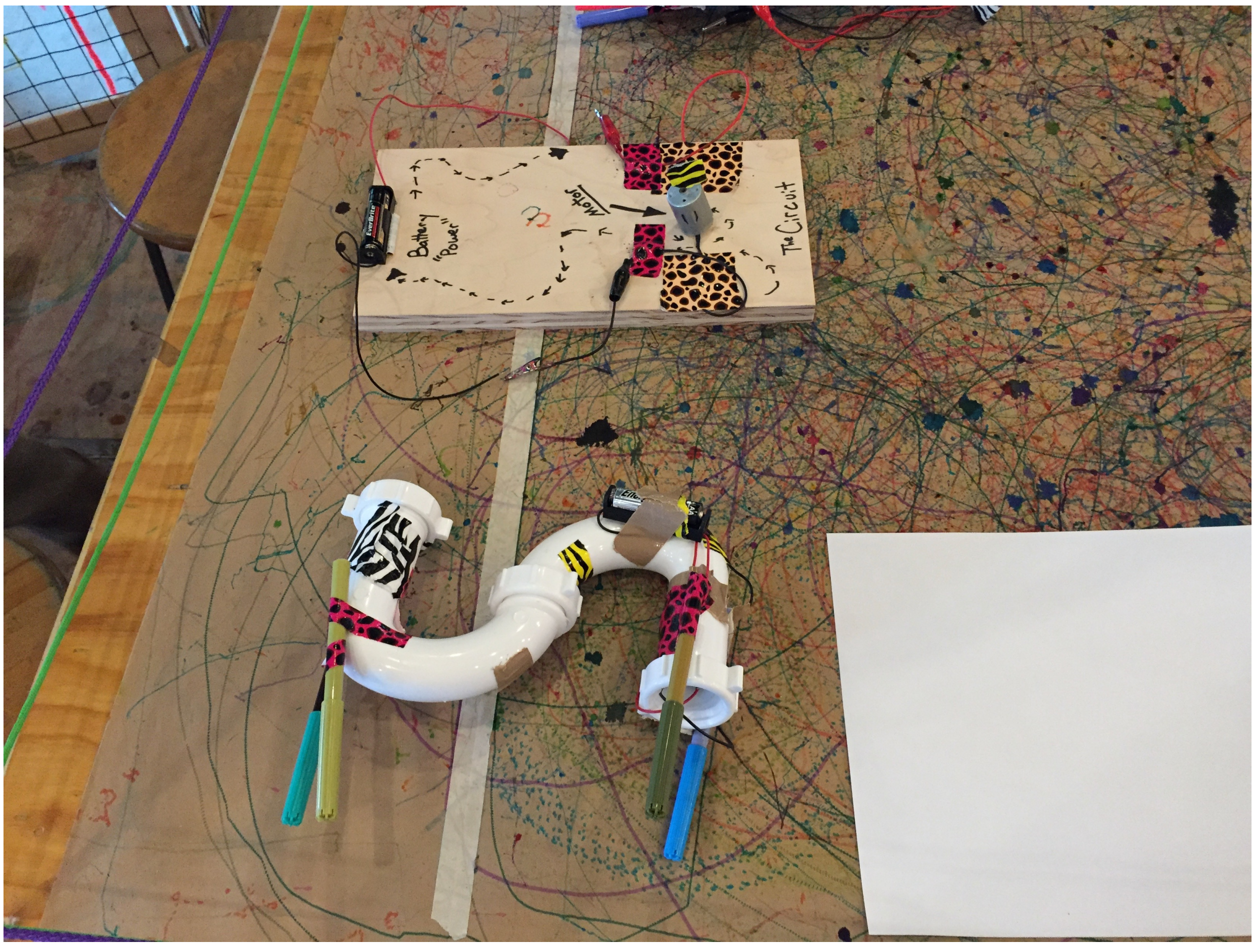


**Figure 20. Drawbot and Circuitry Example**

Makers choosing what to do in the space can greatly increase their comfort level, as they can make what they are interested in and remain engaged in learning new skills. As it is used as a setting for after-school activities, in the school-based makerspace, predominantly highschool-aged makers chose which workshops they wanted to sign up for, because they knew based on the workshop description whether they would be interested in the topic of that

day’s workshop. Once they arrived to the workshop, however, there were very few choices left up to them, as they generally all work on the same concept, same production, and same skills and techniques. In the museum-based makerspace, as a drop-in program, makers’ first choice was whether or not to enter the makerspace at all. As the younger, preschool to middle school-aged makers often did not know the activities offered in the museum-based makerspace ahead of time, they could choose from the activities within the space upon their arrival. Facilitators set up a variety of activity stations for makers to participate in. Makers could even choose how they wanted to do the activities, not having to adhere to posted or explained directions. With Chain Reaction, makers used the wood pieces to build towers, instead of setting them up like dominos to make a chain reaction. A facilitator noticed this but did not redirect the makers to follow the posted directions. The posted directions were more like suggestions of the intentions of the station, but makers were not required to follow the suggestions. Allowing makers choices lets them make what they are interested in and promotes their engagement in learning a new skill.

The makers’ actions within the makerspace display the outcomes of the facilitators’ intentions for the makerspace. The makers’ actions are directly related to what is allowed and encouraged by the facilitators within the makerspace. Makers’ comfort levels with the makerspace environment and skill or techniques being taught are revealed through their actions like working independently, not following directions, choosing what they want to do, and looking for direction.

#### 4.4.3 Parental Involvement

Parental involvement in a youth-oriented makerspace can range from not being present in the makerspace to being an active collaborator with their children to being an active maker individually. The inclusion and treatment of parents in the youth-focused makerspaces included the philosophy of the facilitators by revealing how the facilitators used and valued the parents’ presence and interaction with their children.

In the school-based makerspace, only one parent came to any of the workshops offered, though the workshops were open to community members ages 13 and older. Her son had more previous experience with 3D printing than she did, so she actively participated in the 3D Printing 101 workshop. She remained in the makerspace after the end of the planned workshop and spoke with the facilitator. She explained that she was interested in designing her own product: a frame with clips on the four corners to hold a dishcloth, to be washed in the dishwasher and reused. The facilitator gave her ideas of how her son could help her design her model, as her son also had previous knowledge in 3D modeling, and explained that now she knew how to print the design, based on the knowledge she had gained from this workshop. The maker's mother entered the space and acted as a maker within the space, working independently from her child, with her own motivations, indicating that parental involvement can be encouraged other than as assistance for the youth maker.

In the museum-based makerspace, parents were a regular fixture, as children required accompaniment by an adult while inside the museum. Children were predominantly pre-school- or elementary school-aged. Many parents actively made alongside or with their child and served as another facilitator in their making and learning process within the makerspace. Parents' involvement in the makerspace was exemplified during an activity in which makers could plant a seed in a portable container that could then be planted and grow at home. Although the area featuring the seed planting station had many printed directions, the facilitators often remained close to the makers at that station to help. When the facilitators were not nearby, a mother and two girls made seed plantings on their own, by following the posted directions. The parents of an unenthused maker made a planting themselves, with guidance from the facilitators. Another set of parents arrived with makers, who checked out the various projects. The parents suggested that they save making the plantings for the end of their museum visit, so that they would not have to carry the plants around through the rest of the museum's exhibits.

The range of parental involvement indicates the philosophy of both the parents and facilitators in the space, revealing the interest level of the parents and how much they value the learning activities taking place in the makerspace. Parents offering guidance and participating in the activities demonstrate more value placed on the activities for their children.

The philosophy of making held by the facilitators influences the level of production carried out by the makers, including what level of production is valued as important for the makers to participate in. The philosophy of the facilitators is also on display through the actions of the makers within the makerspace and the level of parental involvement. When the facilitators enact their philosophy of making in the makerspace, influencing the actions of makers and parents, they are also imparting that philosophy in to the design of the learning activities they develop for makers and how they teach them, developing a pedagogy of making in education.

## 4.5 Pedagogy of Making in Education

The pedagogy of making depends on several factors ranging from the facilitators' personal interests to the level of autonomy granted to the facilitators by others who may have more of an influence on what happens in the makerspace. Facilitators in both the school-based and museum-based makerspaces indicated that they were striving to introduce makers to new concepts in a way that would inspire a lasting interest and curiosity. Their pedagogical interpretations of this motive varied based on the differences of the environments and audiences, over which their control was limited, and focus and style of instruction, which was left up to the facilitators.

### 4.5.1 Focus of Instruction

The focus of instruction in a makerspace is what the facilitators intend for the makers to learn during the course of their time in the makerspace. The focus of a facilitator's instruction displays which parts of making the facilitator values. During my observations, the facilitators' pedagogical beliefs were on display when they set expectations for what the makers should do and achieve within the makerspace. The focus of instruction also directly relates to the

expected production from the makers, because what facilitators expect makers to produce in the makerspace depends upon the focus of their instruction. Understanding the focus of facilitators' instruction is key to developing makerspace activities that can align with outside expectations while maintaining the authenticity of the making experience. Facilitators can focus on maintaining a open environment for experimentation, allowing makers to choose what they want to do, and imparting specific skills in a skill or technique.

Creating an open environment for experimentation involves providing opportunities for makers to experiment with tools, materials, and equipment without a focus on a specific end product as a goal. As noted in section 4.4.1, the production of a complete object is not the goal of experimentation. In the school-based makerspace, there was very little room for experimentation during the set times of the workshops. There had been open making hours scheduled, but they required pre-registration to attend. When no one signed up to attend the open making hours, the head of the recreation department canceled them, in order to save the facilitator's time and costs related to hosting the open making hours, leaving only the skills-focused workshops. The cancellation of open making hours points to a level of rigidity in the school-based makerspace's practice, emphasizing that the focus of instruction is on the set skill being taught during that time. If a potential maker is not interested in that skill, they do not sign up; if no one signs up, the workshop is canceled.

In the museum-based makerspace, many stations for makers were designed for pure experimentation, such as Bits and Bolts. Bits and Bolts used thin wooden pieces with holes drilled into them. Makers could use 3D printed plastic nuts and bolts to assemble constructions. Makers sometimes needed assistance loosening nuts from bolts to assemble something new, but Bits and Bolts was generally independent, as they were entirely open-ended. Facilitators encouraged the naming of creations made with the Bits and Bolts, but otherwise did not intervene. In fact, oftentimes the facilitator would move away from the Bits and Bolts to another area to allow makers more free experimentation and to discourage the makers from looking to the facilitators for answers. Incorporating experimentation indicates a

child-centered focus, because they are choosing what to do within the makerspace, but facilitators still play a strong role in designing the situations that allow and encourage experimentation.

Allowing makers to choose what activities they want to do is another child-centered approach to makerspace facilitation, taking into account the interests, skills, and background knowledge of the makers. The workshop model in the school-based makerspace did not encourage makers to choose what they wanted to do once they got into the space, but makers could sign up for a workshop that interested them, choosing between vinyl cutting or 3D printing or another topic. The museum-based makerspace was built on makers' choices, including the first choice of whether or not to even enter the space. When inside the makerspace, makers could choose which stations they want to interact with or if they want to do an activity beyond the stations that are set up, the facilitators encourage and help them do so. During a garden activity one day, one maker at the Plan a Garden station wanted to make a Hawkeye mask, and was using the paper intended for that station to try to make the mask. A facilitator offered a paper plate for the mask-making process, instead of the drawing paper, and brought it to the Plan a Garden station. As that maker began making their mask, more makers wanted to make their own masks. Although mask-making was not a station set up by the facilitators that day, they assisted makers with mask-making by answering questions, finding space for them to work, and getting supplies for them. Many makers had questions for the facilitators about mask-making, ranging from tips and tricks, what supplies they'd need, to just permission to make the masks. Allowing makers to choose what they do in the makerspace is also representative of a child-centered approach.

Focusing the instruction on one specific skill or technique of making encourages makers to develop a specific skill or practice a specific technique during their time in the makerspace. Each workshop in the school-based makerspace focused on one specific skill, and the direct instruction from the facilitator lead to an understanding of the steps necessary to complete a product using the skill they learned during the workshop. In a situation similar to

the situation presented in section 4.4.2, a workshop-style class entitled 3D Printing 102 intended to expand on the basic 3D printing techniques makers were assumed to have learned in the 3D Printing 101 workshop. The facilitator demonstrated ways to repair a faulty mesh within the program Meshmixer. As makers were all using the same model on their own computers, they quickly identified the holes in their model as the same holes in the demonstrated model through the use of the Inspector tool. The facilitator demonstrated the three different kinds of fills that Meshmixer is capable of using to automatically fill holes: minimal, flat, and smooth. He also demonstrated the use of the Autorepair tool. While demonstrating the tools, he allowed makers the time to try out repairing the holes in the mesh, moving among them to assess any questions they might have. From within the makers' seating area, the facilitator demonstrated the next step to ensuring a mesh will print successfully, adjusting the first layer of plastic that the 3D printer will lay down. He advised the makers to cut off the bottom layer of the mesh they are all working with to ensure that it will lay flat while printing on the printer bed. He demonstrated this process after letting them try it, importing a new model to show just that step. He then loosely showed the makers the availability of the other tools, which are designed more for sculpting and creative use than the technical tools he has demonstrated so far. After makers had explored these tools, that was the completion of this workshop. The focus of the facilitator's instruction was to teach basic ways of improving 3D printing outcomes by using Meshmixer to repair and improve the digital files. With a focus on building a specific skill, the facilitator used direct instruction and demonstration to enable makers to practice the skill. With the extra time remaining, the facilitator headed back to the 3D printers to show makers the models he had set up to print before the workshop had started. He gave them an overview of the 3D Printing 101 workshop, as many of the makers had not actually taken that workshop before signing up for the 3D Printing 102 workshop. At the end of the workshop, students had not made a physical product or a digital product. Instead, they manipulated pre-made digital models, in order to learn technical processes. Makers in the

museum-based makerspace also learn technical processes, but the focus of the space is rarely to teach makers a specific skill or technique.

The focus of instruction is an important indicator of how the facilitators in each makerspace value the makers' choices and interests. Focusing on a specific skill or technique places the value on the production aspect of making. Focusing on makers' choices and experimentations places the value on makers' backgrounds skills and knowledge. The pedagogy that the facilitators subscribe to dictates how much choice they will allow the makers and how they will focus their instruction.

### 4.5.2 Style of Instruction

The focus of instruction directly influences the style of instruction, which is how the facilitators direct makers' activity within the makerspace. Facilitators' style of instruction could adapt depending on various factors, such as how many makers are in the makerspace at one time, what activities they have designed and available during that time, what the makers reveal their interest in, and how makers act to the ongoing instruction. The style of instruction that accompanies the focus of instruction reveals the pedagogy guiding the instruction of the makers by indicating how facilitators decide to teach the skills or concepts that are important for makers to learn. Dependent on all these and many more factors in a makerspace, facilitators' style of instruction can include many tactics: allowing deviation from directions, offering guidance, using direct instruction, encouraging collaboration, maintaining an approachable demeanor, and using interactive instruction.

When facilitators allow makers to deviate from their instruction, they are promoting makers' choices within the structure of their designed learning activities. The directions within the space could be given verbally by the facilitator staffing the space or exist by posted signage within the space. In the school-based makerspace, the facilitator had a set plan and set of directions that makers were expected to follow during the skill-specific workshop sessions. During one of the school-based facilitator's demonstrations and lectures on 3D printing, many makers were experimenting with Cura or other 3D modeling programs, such as

Meshmixer, which some makers had been taught to use during the previous 3D Printing 102 workshop. The facilitator walked around the makers to ensure that they had understood his directions, and he did not address the makers who had not been following along with his directions. Makers were still involved in the 3D modeling process, just adapting the instruction to their own interests. In the museum-based makerspace, there are very few directions at all, leading to deviation from the directions or even the activities in general. In both makerspaces, allowing deviation from directions promoted the interests and choices of the makers by letting them decide what they want to do.

When facilitators offer guidance to the makers, as opposed to giving them direct instructions, they offer suggestions to help makers as they work. During the workshops in the school-based makerspace, the facilitator gave a lot of direct instructions, but would interject tips and tricks during his instructions or while makers were working. During a 3D printing workshop in the school-based makerspace, as the makers got their prints started on the printers, the facilitator explained some of the best practices for 3D printing, which involve watching the first layers of plastic go down to make sure that the plastic adheres to the print bed properly. He suggested that if adhesion proves to be a problem, applying glue stick to the print bed can help. He also explained how to pause or stop a print if there are troubles during the printing process. When one of the makers explained that he had his own 3D printer at home, the facilitator adapted his instruction to offer guidance related to the makers' background knowledge and interests. In the museum-based makerspace, the facilitators rarely directly answered questions that the makers asked, instead letting the makers take the lead in experimenting to achieve what they wanted and offering suggestions while working alongside them. When facilitators offer guidance instead of instruction in a makerspace, they are valuing the makers' choices, interests, and the direction that they want to take. Guidance is not correcting or redirecting, but encouraging and furthering makers' ideas.

Direct instruction is establishing a set of steps for makers to follow to achieve an end goal. In the school-based makerspace, most of the instruction was direct instruction, as

makers were all expected to follow a set of directions to reach the same end goal. In the museum-based makerspace, there was very little direct instruction involved in the stations. Some activities, like the seed planting did involve direct instruction, as there was no room for variation in the end results. Relying heavily on direct instruction can limit makers' ability to make their own choices, as direct instruction is facilitator-led and facilitator-focused.

Encouraging collaboration is an intention of the facilitators for makers to work together toward a shared goal. In the school-based makerspace, makers worked predominantly independently, and the facilitator did not encourage them to work together. In the museum-based makerspace, makers usually worked with the groups that they entered the space with, like their friends or siblings and parents. As referenced in section 4.4.2, facilitators would encourage a more experienced maker to help or explain something to a less experienced maker, which was only sometimes successful. Working with Drawbots, the facilitator explained the basics of circuits to a maker, using the demonstrative tool shown in Figure 20. The facilitator encouraged the older maker to teach the younger maker what he had just learned. Despite the facilitators' encouragement collaborate with the younger maker, the older maker was not comfortable with teaching the maker that he did not know prior to working in the makerspace. Encouraging makers to collaborate and teach each other allows the makers to take charge of their work. Allowing makers to teach one another also builds a sense of community among makers who often enter the makerspace as strangers. Facilitators can explain a concept to one maker who can then teach others, practicing their skills and understanding.

When a facilitator is maintaining approachability, they are not directing makers' activity, but staying close to the activity so that they are available to the makers if help is needed. In the museum-based makerspace, if makers were set in what they were doing, the facilitator would work next to them, but not interact with what they were doing. She would just be available for them to ask questions or for them to solicit help if needed. On a large table, origami papers were available, along with markers, hole punchers, scissors, and glue sticks. Various origami

directions were printed out and laminated, so makers could follow along. A facilitator had skills in origami, so she helped makers make their own origami objects and made her own origami designs next to makers who did not request her help. Being approachable meant being available to the makers, and it resulted in the makers generally leading themselves through the activities.

Interactive instruction is a type of direct instruction in which makers can actively participate by following along with the facilitators' directions. In the school-based makerspace, makers were expected to follow along, step-by-step, with each direction. In a 3D printing workshop, the makers were instructed to begin a print of a model previously loaded onto SD cards. The process of beginning a print involved the facilitator demonstrating how to turn on the printer, insert the SD card, and use the click wheel to select "Print." The makers replicated the process on the other two operational 3D printers. In the museum-based makerspace, most of the few directions given by facilitators could be interactive, but some activities that required a facilitator's assistance could not have interactive directions for safety reasons. As part of one activity, facilitators used an air compressor to blow bubbles with soap and paint in a bucket. Makers could then press a paper onto the bucket or scoop paint bubbles onto a sheet of paper with a spoon to make a print. The directions for using the air compressor could not be interactive, only informative, as it would not be safe for young makers to use the air compressor. Direct instruction that is interactive is more engaging for the makers, as they can actively participate in the step-by-step processes.

The style of a facilitator's instruction within a makerspace likely relates to their focus of instruction and how much they value the makers' ability to make choices within the makerspace. The facilitators' styles of instruction are adaptable, and can depend on the planned activities that they design for the makers as well as influence the planned activities they design.

### 4.5.3 Planned Activities

The activities planned by the facilitators for the makerspace vary based on the goals of the facilitators for the makers. Facilitators in both makerspaces planned activities before opening the makerspaces to makers, but they differ in how closely they adhered to those plans, based on their intentions for the style and focus of their instruction. The school-based makerspace facilitator focused on teaching makers one specific skill or technique at a time, so his plans were more rigid, because makers were only expected to be doing one kind of activity during each workshop. The museum-based makerspace facilitators designed more open plans, providing more options for makers, so the options of activities were the main plans they developed. The flexibility of the facilitators' plans and well as the flexibility of the program in which the activities exist depend on the philosophy and pedagogy of the facilitators.

Before makers even enter the makerspace, they must interact with the activities planned by the facilitator, whether the the program requires registration beforehand or is a drop-in program. To participate in activities in the school-based makerspace, even the sessions designated for open making, the makers must have signed up for a selected makerspace program before the time the activity takes place. When selecting programs, the makers knew the planned activity before they decided to join the session. The facilitator then knew how many makers to expect in each session, so that he could tailor his planned activities to the audience. In the museum-based makerspace, makers did not have to sign up for the makerspace program before participating. Makers may or may not have known what planned activities were taking place before entering the makerspace or joining in, but makers were welcome to come and go as they pleased, meaning they only had to participate in a makerspace activity if they wanted to and if one of the activities interested them. Facilitators in the museum-based makerspace were required to estimate how many makers would attend open making hours and then adapt their planned activities to the audience that then actually participated.

In the museum-based makerspace, some of their planned activities seemed as though they were not completely planned out, as the makerspace included stations for maker exploration that were known to facilitators to not function as designed or as produced. One such station was the Chain Reaction Wall. The Chain Reaction Wall was a tall box with pegboard material on the exterior walls. Facilitators provided PVC pipes cut in half, clamps, and other assorted materials with the intentions of makers developing their own vertical maze for a ball to roll down. The newness of the station was apparent, as the half pipes and other pieces did not fit well in the pegboard, but a few makers gave it a try for a short time. They quickly got frustrated and moved on to stations that they are more comfortable with. Many makers avoided the Chain Reaction Wall entirely, and I did not see the Chain Reaction Wall set up in the makerspace in the four following visits I made after that day.

The facilitators in both makerspace developed both flexible and inflexible plans for the activities that took place in their makerspaces. A flexible plan is one in which planned activities adjust to changes that occur during the workshop or makerspace programming. In the school-based makerspace, plans for each session were decided upon ahead of time, with makers signing up for sessions that they were interested in. Open making hours were intended to be available, but required makers to sign-up for attendance ahead of time, which no one did, resulting in their cancellation, like the workshops referenced in section 4.4.2. In the museum-based makerspace, plans for the day were decided upon ahead of time, but as a drop-in program, if makers were interested in other activities, the facilitators would alter the activities to suit the makers' interests and goals. Flexible plans were still planned out ahead of time, but could adapt to the situations that arose, based on the makers' participation in the activities. An inflexible plan is one in which planned activities are not responsive to changes that occur during the course of the workshop or makerspace programming. The pre-planned activities that took place in the school-based makerspace were set up to be reliant on the technology on which they focused, as in the scenario in section 4.4.1 in which the vinyl cutter had the blade loaded incorrectly, leaving the makers unable to use the vinyl cutters. The facilitator explained

that this predicament was the downfall of facilitators not being able to always be in the space to test the equipment before the scheduled workshop. As the makers were unable to use the vinyl cutter, they did not make the intended sticker. Inflexible plans in makerspaces can backfire when technology does not cooperate, when makers are not interested in the plans, when no makers sign up, and in countless other situations.

Developing the planned activities for the makerspace is the main responsibility for the facilitators. Adapting those plans for the actual occurrence in the makerspaces requires forethought, experience, and access to and an understanding of the makerspace facility. Makerspace facilitators' pedagogies are reflected in the flexibility or inflexibility of their plans, as well as the planned activities themselves.

#### 4.5.4 Questions Asked

The questions asked by facilitators and by the makers and the answers they receive indicate the philosophy and pedagogy of the makerspace. Makers ask questions to achieve the goals that are set either by themselves or by the facilitators. Facilitators ask questions to gauge the understanding of the makers and to get makers to think further about what they are making. Facilitators answer questions to further makers' understanding of the concept they are wondering about. Asking and answering questions is a vital component of teaching and learning, and in an informal learning environment like a makerspace, questioning is key to developing an interest in the activities.

When a facilitator answers a question asked by a maker, they are solving a problem for them, imparting the maker with additional knowledge, but with little involvement from the maker following asking the question. Makers in the school-based makerspace did not often have questions, because the direct instruction offered by the facilitator was very straight forward and because there was little room for variance from the designed activity's demonstration. The questions that did arise from makers were generally just questions stemming from a general interest in the technology with which they were working. The facilitator answered these questions directly and moved on in the step-by-step process he was

teaching. In the museum-based makerspace, simple, straightforward questions were answered directly by facilitators, but questions with a more in-depth answer were generally answered through demonstration or other interactive ways. While in the museum-based makerspace, a maker noticed a sign behind the dividing weaving fence that read: Ask me about hydroponics. As expected, he asked the facilitator about hydroponics. Pointing to some hydroponics set up beyond the fence, the facilitator explained the basics of hydroponics, pointing out some plants as well, satisfying the maker's desire to learn about hydroponics.

Questions that could be answered through a demonstration were regular occurrences, and the facilitators in both makerspaces would demonstrate answers to technical questions posed by the makers. As the focus of instruction in the school-based makerspace was for makers to develop a specific skill or technique, few questions requiring demonstration were asked, because each step of the technical process was a demonstration. When one maker in the school-based makerspace asked if it was possible to change the color of the prints, the facilitator explained it was possible by changing the filament. If there was time at the end of the workshop, he said he would show the maker how to change the filament in a 3D printer. While there ended up not being time at the end of the workshop, the intention was to demonstrate the answer to the question for the maker. Questions answered by demonstration rose more organically in the museum-based makerspace, as makers tried the activities that interested them, and facilitators answered with demonstrations if the question related to a step in the skill or technique the activity aimed to develop. When a maker grew frustrated with a non-functional Drawbot in the museum-based makerspace, another facilitator intervened, using a demonstrative tool to explain the basics of circuits, then pointed out a loose wire on the Drawbot. He asked the maker, "notice anything?" The maker indicated that the wire was loose. The facilitator asked, "What should we do?" The maker responded, "Connect it." The facilitator showed the maker how to connect the loose wire with an alligator clip, explaining "They're called alligator clips because they chomp, chomp, chomp the wires." The maker connected the wire with an alligator clip, and the Drawbot was functional again. Demonstrating the answer to

a question most often follows a question that is focused on building a skill or technique that is being taught in a way to solve a problem presented in the makerspace. Demonstrating the answer is a direct way of answering the question to the maker's satisfaction.

In an effort to gauge makers' previous experience with a concept, facilitators sometimes ask questions of the makers to which the facilitators already know the answer. In both makerspaces, facilitators would occasionally "quiz" the makers by asking them questions about what they were doing as they were working. In the school-based makerspace, makers were almost always able to correctly answer these questions, while in the museum-based makerspace, the makers were usually unable to answer these questions. Makers in the school-based makerspace had previous experiences with the concepts, enabling them to answer the questions, while the makers in the museum-based makerspace were more often trying new things, lacking the previous experience to answer questions about what they were doing.

The answering and asking of questions is a valuable construct in the development of philosophy and pedagogy in a makerspace or any formal or informal learning environment. Responses to questions reveal the facilitators' intentions for learning within the makerspace, as well as the style of instruction in play.

### 4.6 Conclusion

The data gathered through observations, mappings and an interview in the makerspaces revealed patterns of behavior and choices made by the facilitators of both spaces. Analyzing the facilitators' philosophies and pedagogies, along with the design of the makerspace environments, allowed me to draw conclusions based onto behavior and intentions of the facilitators. These findings accompanied with the research compiled in my conceptual framework helped me to develop recommendations of practice for makerspaces. In the following chapter, chapter 5, I discuss and develop recommendations for practice based on this data analysis and its relation to my conceptual framework.

## Chapter 5 Discussion and Recommendations for Practice

### 5.1 Introduction

Through my research, I observed patterns in the makerspace facilitators' actions and intentions. These observations helped me understand the many factors that influence makerspaces and develop recommendations for practice that take into account the greater context surrounding the makerspaces, the facilitators, and the makers. These recommendations for practice revolve around my research question, offering advice for transferring a philosophy of making, constructing a pedagogy for incorporating making into education, and designing a physical environment of a makerspace. Key points and recommendations are italicized within the following discussion.

### 5.2 Integrating a Philosophy

Especially when making with youth, makerspace facilitators need to transfer a philosophy of making to the makers in order to inspire and motivate them. This can be accomplished by integrating a philosophy of making into the pedagogy and design of the space. There is no specific philosophy required of a makerspace facilitator to operate a successful makerspace, as success will look different for every makerspace. All makerspaces exist within a context, whether they are school-based or community-based, and the facilitators' philosophies must adapt to these contexts in order to ensure that the space provided to makers is what the makers really need. The philosophy of the facilitators is evident in the focus of the makerspace: what end goals the facilitators encourage makers to reach and how they guide them in reaching those end goals. The end goals for makers in the museum-based makerspace were different than the end goals for makers in the school-based makerspace. Neither end goal was wrong; they just require different philosophies to guide the approaches taken by the makerspace facilitators. The strategy of transferring a philosophy of making depends heavily on the intentions of the facilitator for the makers in terms of their end goal: experimentation or a final constructed product. Combining focuses, a facilitator could teach an overview of all the equipment, tools, materials in the space (technical focus) like a woodshop

safety course, putting makers in the position of having enough background knowledge that they could actually learn enough through experimentation to produce an object of their choice. While most facilitators will integrate a philosophy that combines these strategies, some of the strategies to reach certain end goals focus on building technical skills, experimentation, or the final product.

### 5.2.1 Technical Focus

A technical focus involves focusing on skill-building, requires demonstrative instruction, and often follows a step-by-step process to learn a technique chosen by the facilitator. These methods of instruction can greatly benefit makers and equip them with the skills necessary to continue making. A technical focus can also stifle the depth of the knowledge that makers gain through a limited step-by-step process. *Balancing a technical focus with chances for makers to learn outside of the step-by-step process enables makers to gain the solid foundation of the technical skill that the facilitator teaches to them while still being able to mold the knowledge gained through the instruction with a technical focus to their interests and personal goals.*

With a facilitator following a technical focus, makers will learn the correct way to do things, when methods have a correct way. As in the school-based makerspace, when makers had to learn the basics of 3D printing, makers learn a set system of creation, giving them a strong foundation on which to build, boosting their confidence in their abilities to make. Learning by experimentation can sometimes lead to makers developing bad habits or learning less effective ways of achieving what they want to achieve with a new technique or piece of equipment. For many of the techniques taught in the school-based makerspace, experimentation would likely not have yielded any results for the makers, as they had no background knowledge to figure out their own first steps, such as knowing which software to use for the vinyl cutter or 3D printer. When makers follow along with a facilitator with a technical focus, they learn a standard way of operating that has been in use before they started experimenting with the materials.

When makers can learn from a facilitator with a technical focus, they gain an advantageous starting point from which to grow. While experimentation benefits makers with a prior knowledge of the tools or materials being introduced, many makers will arrive in the makerspace without any prior experience in making with the tools and materials that are presented to them. Providing all makers with a standard instruction can equalize the knowledge between those makers who have previous exposure to the equipment and those who lack that previous exposure. Following along with a process step-by-step can build makers' confidence as they achieve quick successes and are able to produce a desirable result.

While focusing on building technical skills can quickly ensure that makers have a general understanding of new technology, materials, or equipment, it can limit the depth of understanding the makers gain. Without involving experimentation or a focus on the final product, a technical focus does little to motivate makers to continue making, as there is little in the form of a tangible result that makers often crave. Incorporating a technical focus as a part of a makerspace pedagogy must be balanced with a focus on experimentation and a focus on the final product.

**5.2.2 Experimentation Focus**

An experimentation focus is open-ended, letting makers try new things. A facilitator who focuses on experimentation does not simply open up the makerspace and let makers run wild. They plan activities, source materials, and maintain equipment while guiding makers through the making process. Facilitators who focus on experimentation devote their attention to the makerspace environment, promoting skill-building by providing activities that are tailored to makers' development and interests. *Makerspace facilitators should allow at least some elements of experimentation in the makers' learning process in order to provide makers with choices.*

Focusing on experimentation allows the facilitator to help makers develop a deeper understanding of concepts. In the museum-based makerspace, in order to build a deep

understanding of agriculture, makers did not only plant sunflower seeds in a planter to take home. They also planned a garden through a drawing activity and could view a hydroponics system and grow sphere on the balcony. The sunflower seed plantings had a more technical focus, because the makers were following the step-by-step directions from the facilitators. The plan-a-garden activity had more of an element of experimentation, because makers could make more choices. Makers were able to investigate agriculture from a variety of angles, deepening their understanding beyond the hands-on activity they were initially presented.

A focus on experimentation helps to maintain makers' interest in the makerspace activities, because they can choose what to make. Working at a self-guided pace, makers can work on what interests them. In the community-based makerspace, the first choice that makers could make was whether or not to take part in any of the included activities. Beyond that first choice, they could continue making choices depending upon their interests.

Facilitators who focus on experimentation provide activities that can be adaptable to all makers, because maker can choose what to do. Makers who have differing interests and differing abilities can try many different methods of making to find what works for them. Makers can focus on their personal strengths as they make in their own ways.

While focusing on experimentation is highly encouraging and interesting for makers, it is limiting in terms of what makers can make. It builds on previous knowledge that the makers already have, but it may not build on that knowledge fast enough for makers to produce what they want to produce. Makers without any previous knowledge in a particular method or technology will likely not feel comfortable enough to begin experimenting with it to learn how to use it. Experimentation is a highly valuable focus for a makerspace, but facilitators must take into account the comfort level of the makers and the abilities they bring to the makerspace.

### 5.2.3 Final Product Focus

Focusing on the final product — the digital or tangible item produced by the makers — has a goal of producing an object, not necessarily entirely by the makers from start to finish. It evolves from a technical focus as a way to prove that the makers have learned a technical skill

well enough to produce an object. Many makers' first inclinations are to focus on the final product, making the final product an alluring end goal for them. *While a final product is not a necessary as a culmination of making processes, facilitators should carefully consider how the making project will end, ensuring that the project ends in a way that is motivating for makers.* Final products are intriguing for makers, and easy for them to envision as a finishing point. Building intrinsic motivation, makers who have a final product to focus on know what the end point is for the making activity they are taking part in. The challenge comes when the final product is distant, requiring many days, weeks, or even months to reach completion. Maintaining a level of interest from makers over the course of a long project serves as a difficult proposition for facilitators.

Makers want to have something tangible to take home with them at the end of the day. The motivation arises from confidence gained through completing something, especially from the beginning of the design process through the very end. Makers want to show parents, friends, and share with everyone online. When that object takes weeks to produce, makers may lose interest in the final product. Incorporating experimentation into the focus on the final product lessens the likelihood that makers will get bored with the final product they are striving to make, because they will have made more decisions throughout the design process surrounding the final outcome. With a final product focus, makers take ownership of the objects they produce, but they can also take ownership over the ideas they discover and enact during the process. Focusing on a final product as the ideal outcome may work in some makerspaces but not in others, depending on the context surrounding the makerspace.

#### 5.2.4 Integrating Technical, Experimentation, and Final Product Focus

The makerspace facilitators are rarely the only ones making the decisions in the makerspace. *In order to transfer a philosophy of making to makers within the contexts surrounding the makerspace, facilitators must tailor their approach to include aspects of technical focus, experimentation, and final product focus to fit within the context surrounding the makerspace.* The school-based makerspace and museum-based makerspace operated in

different contexts and faced different levels of outside influence. The school-based makerspace facilitator's ideas for workshops were subject to approval by school and recreation department administration, while the design of the space had to have the approval of the school administration, the school board, and others within the school environment that the facilitator did not occupy. The museum-based makerspace facilitators had much more control over the design of the environment and activities held in the makerspace, but were still influenced by museum administration and the board of directors.

In the school-based makerspace, and makerspaces with a higher level of influence from outside forces, the balance between technical focus, experimentation, and final product focus will likely involve more emphasis on the technical skill-building and final product. As students in school must demonstrate their knowledge through more tangible forms, like tests, essays, projects, and presentations, the outside influences of a school-based makerspace are likely to require tangible results that reveal specific knowledge that was learned during the making process. Learning activities must meet academic standards, and makerspace facilitators, as instructors, must take that into account when designing activities. Experimentation should certainly be included, but in order to meet the needs of the makers and the people who influence the context of the space, facilitators should integrate a technical focus and a final product focus more heavily.

In the museum-based makerspace, and other makerspaces outside of educational institutions, there are no academic standards that are required to be met, but there are standards held by boards, administrators, funders, and others that must be taken into account when designing learning activities. The facilitators' philosophical focus can be more flexible, including more experimentation that does not necessarily reveal a final product or mastery of a technical skill. Museum-based makerspace facilitators are able to focus on experimentation, but should still integrate a level of technical focus and consider promoting a final product in order to please parents, makers, and others who expect to learn a specific skill or take home some tangible thing that they have made.

Integrating a technical focus, experimentation, and a focus on a final product helps the facilitators to transfer a philosophy of making to the makers. Facilitators can also promote a maker mindset through the pedagogy they infuse within the learning activities.

**5.3 Promoting a Maker Mindset**

*Promoting a maker mindset within a makerspace involves developing a pedagogy that engages makers throughout the entire process of making, from start to finish, while making them feel comfortable experimenting with new techniques and using technology.* A maker mindset is the attitude that makers hold while working in the makerspace. Especially in environments in which making or Project-based learning is a new development, makers will be understandably cautious about their actions in a new space. The facilitator should be helping makers to understand their role in the space as an active participant in the learning process. Makers should also understand the role of the facilitator as a guide alongside them, not a traditional instructor. Makers should, and be given ample time to, participate in the making process from start to finish, including the choice of the problem to solve and cleaning and maintenance of the equipment. Makers should feel comfortable enough to experiment with new techniques, materials, and equipment. Makers should have access to adequate technology, but not be forced to use technology that is beyond the scope of their needs. Promoting a maker mindset through developing a pedagogy requires understanding the role of the maker and the facilitator within the makerspace, involving makers in the process from start to finish, encouraging experimentation from the makers, and knowing how to best utilize technology for making.

**5.3.1 Role of the Maker**

Establishing the role of the maker is a key component of promoting a maker mindset among makers in the makerspace. In order to take on a maker mindset, makers must understand their roles as makers: what makers should do, how makers should act, what makers should consider. *Facilitators can influence the role makers play in the space by treating*

*makers as active participants in their learning, encouraging makers to teach each other, and allowing makers to make as many choices as possible.*

Treating makers as active participants in their learning both encourages and inspires makers to try new things, because they can take more control over their learning. With more of a sense of agency, makers who are active participants in their learning want to continue learning new things, because they have engaged in the learning process in a hands-on way. Instead of treating makers as empty vessels to be filled with knowledge, facilitators should be involving makers in the learning process by incorporating as many hands-on learning opportunities as possible. In the school-based makerspace, the predominant form of instruction was lectures and demonstrations. While lectures and demonstrations will be necessary to teach new techniques and new technology, hands-on activities should outweigh passive forms of learning. Activating the makers' learning process requires them to actively engage with what they are learning.

One way to activate makers' learning is to engage the makers as teachers for each other. Ensuring that makers understand a concept that has been introduced, facilitators can teach select makers to use and maintain the technology, techniques, and methods that those makers need to create what they want to create. Rather than teaching all of the makers the same technique at once, facilitators can teach relevant skills to makers who need them. Those makers can then teach those skills to other makers once those makers need to learn those skills. Teaching skills are a way of practicing those skills, improving the makers' understanding of concepts they are taught. Teaching other makers also places makers in a place of authority, promoting their involvement in the makerspace and their sense of belonging. Embracing a teacher role in the makerspace will boost makers' confidence in their skills. Including teacher as a role for makers promotes the idea that makers are in charge of their learning within the makerspace.

Ensuring that makers maintain the ability to be in charge of their learning involves facilitators providing choices for the makers to choose. The things makers should make most

often in a makerspace are choices. Facilitators should ask makers: What problem do you want to solve? What do you want to make? What's the best way to make it? Makers should be able to choose the problems they want to solve, the materials they should use, the best tools for the job, and what to make. Equipping makers to make choices promotes the role of the maker as the decider of what is made within the makerspace.

Establishing the role of the maker depends on the facilitators' willingness to allow the makers to control as many aspects of their own learning as possible. Makers should be able to take on an active role in the makerspace, making their own choices and decisions. The role of the maker in a makerspace should be one of partnership, engagement, and confidence.

#### 5.3.2 Role of the Facilitator

*The role of the facilitator is to promote a maker mindset by tactfully teaching technology concepts and providing relevant challenges for makers to take the lead on solving.* Even if it is housed in a school, the makerspace is generally a more informal learning environment. The role of the facilitator in promoting a maker mindset among the makers in the makerspace is different than the role of a teacher in a classroom situation. A facilitator is not a teacher, but more of a guide for the makers within the space. The makers should be taking the lead in their learning, and the facilitators should be providing guidance to the makers while following their lead. Makers were more engaged in the making processes that they chose for themselves. Facilitators can fill this role by making sure that makers are in the position to make the best choices for their own making processes, by teaching relevant techniques and presenting them with relevant problems.

Facilitators should hold more knowledge about the tools and equipment within the space than the makers, and they should impart that knowledge in a way that is meaningful for the makers' growth in the makerspace. Any technology that is available for makers to use should be introduced to the makers, so that makers can take the lead on the production process using the tools. The facilitator can teach the technology in a way that engages the makers by teaching the technology when the makers need the technology. Introducing the

technology as the makers need the technology, depending on the projects they are interested in making, ensures that makers can choose technology that best fits their needs, rather than all learning the same technology at once that may or may not be the best means of making what they are interested in making. Facilitators should provide an overview of tools and equipment that is tailored to the needs of the makers.

Facilitators can guide makers' decision by presenting them with problems to solve that are interesting and engaging. To ensure that makers are leading the making process, facilitators should allow makers to choose a problem to solve and how to solve it. Completely open options can be overwhelming for young makers, so providing them a starting point can be better guidance than asking, "What do you want to make?" To start the makers on the right path, facilitators should present a variety of options of problems that are engaging to makers and relevant to real-world situations. facilitators should offer guidance throughout the process that is tailored for each maker.

Serving as a guide to makers, rather than an instructor, ensures that facilitators are allowing makers to be in charge of their own learning. Promoting a maker mindset means that makers must be engaged in the learning process through hands-on processes.

### 5.3.3 From Start to Finish

Building a maker mindset requires involving makers in the entire making process. *Makers should take the lead on, or at least be involved in, their making process and be included in the making process from start to finish.* The making process needs to include: identifying the problem, brainstorming (collaboratively or independently), designing a solution, prototyping the solution, producing the solution, and cleaning up after themselves, including taking care of the equipment.

In order to ensure that makers are involved in the making process from start to finish, facilitators should offer guidance throughout the process that is tailored for each maker. Facilitators should present problems for makers to solve that are relatable, interesting, relevant, and open-ended. The more choices the makers can pick from, the more invested they will be in

the making process. In the school-based makerspace, this would be possible with the smaller groups of workshop participants over several workshop periods. For a class of 30 students in a school-based makerspace, this would likely take weeks or months for a project that involved a complex technical skill. While fully engaging each student individually in a project of their choice would be ideal, practicality would likely dictate allowing students to complete projects that address one problem that they are interested in or projects on a much smaller scale that they are allowed to choose.

Facilitators should offer guidance, not direction, during brainstorming. Facilitators should not tell a maker that something will not work until it's been tried. In the school-based makerspace, the facilitator relied on direct instruction because of the technical focus, and the makers followed along step-by-step for the duration of the workshop. There were no chances for makers to make mistakes. In the museum-based makerspace, makers often made mistakes and learned from them.

Facilitators should encourage collaboration among makers who will benefit from working together to find a solution. Brainstorming should be an informal process that produces many ideas, and facilitators should guide makers in narrowing down the ideas to the best options to prototype and test.

Facilitators should help makers identify the best way to make the solution during the design process, including what the best tool for the process is. As evidenced in the school-based makerspace, many makerspaces offer new technology as a means of engaging curious makers, but not everything can be made with the 3D printer. Despite being one of the most popular choices for inclusion in a makerspace, 3D printers are generally not a useful piece of equipment. In the museum-based makerspace, the 3D printers were not used during open making hours, because they take too long to produce something to hold the attention of makers who dropped in. In 3D printing-focused workshops at the museum-based makerspace and in the school-based makerspace, 3D printing had to be introduced in the beginning of the workshop so that the prints would be finished by the time the makers had to leave the space,

despite the usual order of 3D printing, which starts with the digital design of the model. Helping makers choose the right tool for their job involves providing many different tools, materials, and equipment for makers' use and guiding them to the best fit for their project.

Facilitators should help makers build their technical skills during the prototyping process. After helping the makers determine the best tools and equipment to use to make their particular solutions a problem, then the facilitators can teach the makers how to use that equipment. Rather than teaching all the makers to use a 3D printer together, when hardly any of them will need to use a 3D printer to make what they want to make, teaching the makers how to use what they will need to use is a more valuable use of instruction time.

Cleaning up is one of the most underrated ways to learn in a makerspace. Maintaining equipment is a valuable way to teach makers about it. Maintaining the equipment reveals more of the concepts behind how the technology works by learning how the parts work together to operate. The community-based makerspace sometimes offered a workshop dedicated to deconstructing electronics, in order for makers to learn more about how they work. The facilitator in the school-based makerspace offered technical information about the 3D printer during his demonstration, providing makers with a more in-depth understanding of how the 3D printers work and how to make them work. Similarly, cleaning up and maintaining equipment enables makers to more fully understand how the technology works.

In many cases, it can be difficult to fully engage makers throughout the entire making process. In the school-based makerspace, for example, makers did not produce objects of their own design, due to time constraints and the design of the workshops focusing on one technology at a time. By allowing makers enough time and enough freedom to choose what they want to make, they can actively participate in the entire process of making, promoting their understanding of the concepts they are taught and with which they experiment.

#### 5.3.4 Experimentation

Promoting experimentation in a makerspace is key to developing a maker mindset among the attending makers. Experimentation does not need to mean a complete free-for-all

approach to facilitating activities within the makerspace; it means developing a tailored approach to making that encourages makers to try new things on their own. *In order to encourage experimentation among makers, facilitators need to assure that makers feel comfortable experimenting and avoid a step-by-step protocol of making.*

A makerspace needs to be a place where both makers and facilitators feel comfortable experimenting. Technology needs to be approachable or taught in a way that enables makers to continue learning by doing, with a strong foundation of the basics of the technology. Facilitators should teach new technology just to the level that makers can make what they want to make but must continue working with the technology to continue achieving new things with the equipment. In the school-based makerspace, even when makers were unable to make the vinyl stickers using the vinyl cutter, they did not seem interested in cutting vinyl when the workshop was over, despite knowing all of the necessary steps. Had they been able to experiment with the vinyl cutter, to try out the skills they had seen demonstrated, maybe they would have been more interested in the process.

Materials should be approachable, but advanced. Makers should recognize materials, so they can build on their previous knowledge of those materials. Facilitators need to offer encouraging guidance. In a school-based makerspace, facilitators need to offer that guidance to both the students and the teachers who will be utilizing the space and the equipment therein. Posted signs should be both encouraging and informative, rather than rules and expectations. In the museum-based makerspace, each station had posted reminders, but they stopped short of being actual directions. Reminders for the use of the equipment posted close to the equipment allow makers to troubleshoot their own problems, encouraging their continued experimentation even after a point of confusion. The goal of encouraging experimentation is for makers to feel comfortable working independently or collaboratively without waiting for direction from a facilitator.

While the goal of a makerspace may solely be to provide an arena for makers to freely experiment with tools, materials, and equipment, there are likely to be more focused goals that

aim for set outcomes. Especially in school-based makerspaces, specific standards should be met that are designated for specific subjects. Even in situations in makerspaces that require a set outcome or product to be produced, experimentation should still be a component of the making that occurs as part of the overall project. Following a step-by-step protocol does not allow for experimentation, and it limits the makers' levels of participation in the process. Without experimenting or making their own decisions on how to try to make something, makers are limited to only learning the steps they are being directed to follow. Facilitators who must meet standards should tailor their facilitation to be a guide, allowing makers to meet the set standards by learning-by-doing. Facilitators should set standards-based goals that are broad enough to be met by a variety of making techniques, ensuring that makers are experimenting with techniques that are of interest to them. Ideally, makers should be able to set their own goals, with guidance and encouragement from the facilitators, that support experimentation as a means of learning. Facilitators can support this goal-setting by limiting their plans to use direct instruction to reach a set goal.

Experimentation is a valuable tool in an active makerspace. Makers can learn by doing and build upon previous knowledge while developing new skills with new tools, materials, and equipment. While setting makers loose in a makerspace with no guidance or intervention would likely not yield positive results, encouraging makers to embrace their previous knowledge and try new things without knowing exactly what will happen equips them with the confidence to keep trying new things. Experimentation is relatively easy to allow with inexpensive materials with which makers are likely familiar. The challenge of promoting experimentation grows with the expense and complexity of the technology.

#### 5.3.5 Use of Technology

The newest and most advanced technology is not required to design a successful makerspace. Makerspaces can be filled with all different types of tools, materials, and equipment. A 3D Printer and a Vinyl Cutter do not make a makerspace; making makes a makerspace. Infusing technology into a makerspace environment can be highly beneficial for

makers, as they discover new ways to make the solutions they design for the problems they want to solve. *In order to encourage a proper relationship with technology, facilitators should find the right technology for the job, let makers take the lead when working with technology, and teach the technology from start to finish.*

Choosing the right technology for the job requires identifying the problem makers want to solve, the previous knowledge makers have with the technology, and the interest the makers have for the technology. In developing makerspaces, 3D printers are often touted as a necessary piece of equipment, but very little of what is produced with a standard 3D printer is usable for any purpose other than practicing with a 3D printer. A good purpose for the 3D printer is to develop interest among the makers, but that goal must be balanced with a solutions-focused method and the prior knowledge that makers have on which to build. The technology should be interesting, intriguing to makers, so that they are motivated to learn it. The technology should be useful to makers as well, the goal of the makerspace should be to make things, not just learn techniques. The provided technology in the makerspace should be at a level beyond the makers' understanding, so that they can learn new techniques, but it should not be at a level so advanced that makers do not even know where to start with it. Helping makers choose the best tool for the job means making technology available, but not too available. Guiding makers to an older, more familiar method of making does not diminish their experience in the makerspace; it sets them up for success by limiting their frustration with a new technology that does not do what they need it to do.

In school-based makerspaces, students may not be the only makers in the makerspace. Teachers may also use the makerspace as a supplement to their lessons. The background knowledge of the teachers, in terms of the technology within the makerspace, may be just as limited or advanced as their students' background knowledge. When welcoming teachers into a makerspace, respecting how they want to the the space is key. Although the teachers would be makers, as the one teacher who attended the vinyl cutting workshop in the school-based makerspace, treating them like the young makers would not benefit them.

Student makers generally want to make something for themselves, while teachers would generally want to learn the technology well enough to use it with their students.

Despite the impending fear of broken expensive machinery, makers should take the lead in learning new technology within the makerspace. Makers should be permitted to experiment with the technology, once they have received basic safety instructions. Learning technology step-by-step is a quick way to get working with the technology, but limited in terms of the longterm knowledge and interest of the makers. If the makers only learn one way to use a machine, they are lacking an understanding of the full range of the possibilities of the machine. Once a maker has an expanded knowledge of the inner workings and possibilities of a new technology, that maker should be allowed and encouraged to teach others about the technology. Facilitators should step back from direct instruction and demonstration, instead encouraging collaboration and learning by teaching among the makers.

Ensuring that makers have a preliminary knowledge of a new technology is required before allowing them to experiment, and the methods to teach them the basics of the new technology require teaching them from start to finish. For example, in the school-based makerspace, 3D printing was taught, but 3D design and modeling was not included as part of the workshop offerings. Makers learned how to set up a print on the 3D printer, but they were printing pre-designed objects instead of their own designs. The 3D printer is not a first step in the learning process of producing a 3-dimensional object. Instruction in 3D printing should begin with an introduction to a simple 3D modeling software, allowing students to design their own object to print, and then learning how to print that object on a 3D printer, because the entire process is necessary to learn before makers can actually make something. Instruction in the makerspace should not begin with a particular piece of technology, but should instead focus on the goal decided upon by the makers. A 3D printer is rarely going to be the best way to make a functional object that serves a set purpose. Technology instruction should include the technology that is required to complete the task that makers want to complete.

## 5.4 Physical Environment

Designing the physical environment of the makerspace may not always be possible. A school-based makerspace often grows out of an existing classroom, as a portable experience that travels from room to room, or is part of a multi-purpose space that is only sometimes a makerspace. A community-based makerspace may face the same challenges in the design of the environment. The facilitators who most regularly use the space may or may not have a hand in the design of the physical space. Facilitators may be brought in to operate the space after the space has already been designed and constructed, or facilitators may represent all the teachers who intend to use the space, who have not been consulted on the design of the space. In the many situations that may surround the design of the makerspace environment, there are many ways to adapt to and influence the physical design of the makerspace. The physical environment of the makerspace is key to how makers operate within the space. *Overcoming the challenges of dealing with the physical context of the makerspace can be possible when facilitators design a space that is inviting to makers and acts as a multipurpose environment for learning.*

### 5.4.1 Inviting Atmosphere

*Creating an inviting atmosphere within the makerspace is a valuable means of inspiring makers to enter and work in the makerspace.* In the community-based makerspace, the space was constructed inside a popular children's museum, attracting the museum visitors through activities inside and outside of the space. The facilitators intentionally attract makers to the makerspace by hosting open making hours each day and performing actions and activities that make noises that are intriguing to passers-by. If the makerspace slows down, the facilitators will clean up and reorganize the stations, and open the larger sliding doors to entice more makers to enter. In the school-based makerspace, the environment was a science classroom that was open after school to those who pre-registered, even for the open making hours. Located on the second floor of a high school building, with only one classroom door to enter and exit, the space was not inviting to makers. Those who had not pre-registered for

workshops would not coincidentally pass by the space, nor would they be inspired to by visible activities or noises from activities.

Whether a school-based or a community-based makerspace, designing an inviting environment for a makerspace requires planning with the intention of attracting interested makers to the space. A portable makerspace that travels from classroom to classroom depends upon the inviting nature of the classroom in which it is housed during that time period; the intention is not to attract outside makers, but to engage the makers already in the classroom. A classroom that transforms into a makerspace during certain times of the day or year is limited in how the design can be inviting, as it must remain a functional classroom as well. It would be ill-advised to knock down walls to install sliding doors to attract makers to a science classroom. In the school-based makerspace, as a new makerspace still in the development stages, there was no transformation that occurred when the classroom became the makerspace during the after school workshops. The science classroom simply housed additional making-focused technology, like 3D printers and vinyl cutters. Makers who entered the makerspace behaved as though they were in a science classroom, not a makerspace. Configuring the room as a makerspace would have made a difference in the attitude of the makers. This can be achieved by rearranging desks or tables to promote group work and interaction, highlighting the equipment that will be used by centering it in the room, and ensuring that the lay-out makes every usable tool easily accessible. Locked cabinets, individual seating, and equipment pushed off to the side do not send makers an invitation to enter the space and make. If the room that houses the makerspace is not visible to the outside, develop signage that indicates the location of the makerspace, what equipment it houses, and its availability or how to sign up for workshops that require pre-registration. Some of the first makers to use the makerspace could be recruited for this effort, promoting their sense of belonging and encouraging them to engage their peers to attract more makers. An inviting space that encourages experimentation will likely be a more informal environment, as makers will not be intimidated by the space or the equipment in it, and the goal will not be a final

product, but a growth in development of skills and knowledge. Lounging around in the space may be permitted, and food and drink, depending on safety surrounding the enclosed equipment, may be welcome.

An inviting makerspace should be approachable, available, and advertised. Approachability depends on the equipment housed in the space and the makers' background knowledge. Ensuring that the makerspace is an approachable space requires that it be staffed with a facilitator knowledgeable enough to help makers use anything that is available for them to use, so that makers have enough training to use the tools in the space. Keeping the makerspace available for use is difficult, as it requires staffing with a qualified facilitator, but keeping the makerspace is available for maker use is important to ensuring that the makerspace is an inviting place for makers. The makerspace could be open for makers to drop in whenever they need to use the equipment, or the makerspace could be open for set periods of time, like the community-based makerspace. In a makerspace housed as part of a school, students should be able to use the equipment in the makerspace whenever it is relevant to what they are doing in their classrooms. No child should be dissuaded from making something because the makerspace is unavailable. The makerspace should also be advertised, either as a part of the school or as a part of the community. Prospective makers should know that the makerspace exists, what equipment is available to makers, and what they can do in the makerspace. Advertising is active encouragement of making. Creating an inviting environment through approachability, availability, and advertisement, is key to promoting a maker mindset among makers.

### 5.4.2 Multipurpose Space

Building a dedicated makerspace, whether part of a school or open to the community, enables facilitators to have more of an influence on the design of the space, but a multipurpose space can function as a makerspace, as evidenced by the school-based makerspace housed in a science classroom. Ideally, any school or organization with an interest in building and maintaining a makerspace would have the time, money, space, and ability to build a

makerspace. As most schools or organizations lack the means to build a dedicated makerspace, relying on a multipurpose space is often a necessity. Maintaining an identity of the makerspace within a multipurpose space ensures that makers can develop a maker mindset that permeates into the rest of their learning. *Developing a makerspace as part of a multipurpose space requires planning, flexibility, and efficiency.*

Makerspace facilitators need to put forth a great deal of effort towards planning the design of the space, including how the makerspace will be included as part of the multipurpose space and how makers will be able to access equipment that is presented as part of the makerspace. A multipurpose room could include a makerspace on one half and an classroom on the other, or the multipurpose room could transform from a classroom to a makerspace and back again. Facilitators may opt to always have the makerspace equipment reachable, but transform the space to emphasize certain pieces of equipment depending on the motivations for learning that day. Facilitators may also elect to store the makerspace equipment out of reach, even in a separate room, and only bring the equipment out during set times that are dedicated to making. If the entire space is to transform, facilitators need to take into account how the makerspace-specific objects will move within the space to become available. In a multipurpose space in which the makerspace component and classroom or other component do not require a physical transformation, the facilitator still needs to plan the transition between the two spaces in order to develop a maker mindset. Makers may be permitted to transition on their own. If a maker is overtaken by a sudden brilliant idea, they may be permitted to delve into making on her own terms. Facilitators may opt to divide some of the making steps between the two codependent spaces, having makers brainstorm and plan in a traditional classroom setting, then move to the makerspace when they are ready to prototype. In codependent spaces, facilitators need to take into account how the makerspace equipment will affect both environments within the space. For example, 3D printers take a long time to print objects, producing noise as they do so. As 3D printers must often be left on and operating for long periods of time, facilitators must determine if the noise they produce will distract

activities that occur on the other side of the room before it becomes a problem. Planning is a key step in designing a functional multipurpose makerspace.

Flexibility is a key attribute of makerspaces, especially those that must exist as a part of a multipurpose space. Building a makerspace that transforms as part of a multipurpose space would benefit from multipurpose fixtures. In the museum-based makerspace, the facilitators built signage that could fold down into additional table space and storage space on shelves behind them. Stations were on wheels to be easily moved, and drawers to provide more storage. A flexible layout is key to transforming the environment to a makerspace whenever it is a makerspace. Providing tools, materials, and equipment that is specifically reserved for making ensures that makers recognize what they can use during time dedicated to making. A flexible layout is key to transforming the environment to a makerspace whenever it is a makerspace.

As in almost every classroom, efficiency is a requirement for functionality. Facilitators must design for efficiency in time-management and storage. In an environment in which a space transforms into a makerspace, the length of time it takes to complete the physical transformation must be managed. Makers can be trained to help transform the space, speeding up the process. The makerspace could be scheduled to only change during lengths of time that the room is unoccupied, such as a lunch or recess period, eliminating any wait time on the part of the makers. One of the biggest challenges in any learning environment that is especially challenging in a multipurpose makerspace is the storage of in-progress creations. Makers require ample time to design, build, and test multiple iterations of what they want to make, requiring ample storage areas and creative storage solutions. Efficiency in time management and storage is a key component in avoiding frustration in a multipurpose makerspace.

Developing a makerspace as a component of a multipurpose space is not only a valuable means of being efficient with funding, but it also helps makers develop a maker mindset that exists in every space, not just a dedicated makerspace. If the end goal is to instill

a maker mindset that permeates through all activities in a larger environment, a dedicated makerspace, even as part of a flexible space, may not be advisable. In that case, making should be a standard part of every activity, allowing makers the flexibility to accomplish what they need to accomplish through making.

**5.5 Possibilities for Further Research**

Further research into makerspaces could investigate how to develop standards by which to assess the projects completed in makerspaces or the process of making as it relates to the integration of technical, experimentation, and final product focus referenced in subsection 5.2.4. In school-based makerspaces, makers are likely required to receive grades if they work in the makerspace as part of the school curriculum. Further research could help determine which subjects' existing standards could be applied to makerspace projects incorporating aspects of STEAM education, referenced in subsection 2.3.4. Researchers could also develop new, making-focused academic standards, based on focuses of instruction referenced in subsection 4.5.1.

**5.6 Conclusion**

Makerspaces exist and grow from a variety of contexts, within schools, museums, libraries, and other community settings. Makerspace facilitators play a valuable role in makerspaces, transferring a philosophy of making, developing a pedagogy, and designing an environment. My recommendations, stemming from the literature and my research, revolve around allowing makers to make as many choices as possible within the makerspace. When makers are empowered with choices, they can take ownership of their learning and the outcomes of that learning. Aligning with constructivist and constructionist practice, makerspaces are settings that should be designed with experimentation in mind, equipping makers with the technical skill to complete the final products that are relevant and interesting to them. By instilling a maker mindset within children, facilitators are in a position to impart knowledge, guide makers' directions, and instill a lifelong capacity for learning through doing

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## APPENDIX A:
## IRB Approval Notice

UNIVERSITY of WISCONSIN
UWMILWAUKEE

Department of University Safety & Assurances

**Melissa Spadanuda**
*IRB Manager*
*Institutional Review Board*
Engelmann 270
P. O. Box 413
Milwaukee, WI 53201-0413
(414) 229-3173 *phone*
(414) 229-6729 *fax*

http://www.irb.uwm.edu
spadanud@uwm.edu

**New Study - Notice of IRB Expedited Approval**

**Date:** February 21, 2017

**To:** Christine Woywod, PhD
**Dept:** Peck School of the Arts

**Cc:** Rebecca Johnson

**IRB#:** 17.186
**Title:** Community-based and School-based Makerspaces

After review of your research protocol by the University of Wisconsin – Milwaukee Institutional Review Board, your protocol has been approved as minimal risk Expedited under Category 6 and 7 as governed by 45 CFR 46.110. Your protocol has also been granted approval to waive informed consent as governed by 45 CFR 46.116 (d) for public observations of adults.

This protocol has been approved on **February 21, 2017** for one year. IRB approval will expire on **February 20, 2018**. If you plan to continue any research related activities (e.g., enrollment of subjects, study interventions, data analysis, etc.) past the date of IRB expiration, a continuation for IRB approval must be filed by the submission deadline. If the study is closed or completed before the IRB expiration date, please notify the IRB by completing and submitting the Continuing Review form found in IRBManager.

Any proposed changes to the protocol must be reviewed by the IRB before implementation, unless the change is specifically necessary to eliminate apparent immediate hazards to the subjects. It is the principal investigator's responsibility to adhere to the policies and guidelines set forth by the UWM IRB, maintain proper documentation of study records and promptly report to the IRB any adverse events which require reporting. The principal investigator is also responsible for ensuring that all study staff receive appropriate training in the ethical guidelines of conducting human subjects research.

As Principal Investigator, it is your responsibility to adhere to UWM and UW System Policies, and any applicable state and federal laws governing activities which are independent of IRB review/approval (e.g., FERPA, Radiation Safety, UWM Data Security, UW System policy on Prizes, Awards and Gifts, state gambling laws, etc.). When conducting research at institutions outside of UWM, be sure to obtain permission and/or approval as required by their policies.

Contact the IRB office if you have any further questions. Thank you for your cooperation and best wishes for a successful project.

Respectfully,

Melissa C. Spadanuda
IRB Manager

## APPENDIX B:
## Interview Questions for the Museum-based Facilitator

*Questions Related to Philosophy*
What processes do you consider part of “making”?

What thought processes do participants use in the makerspace?
What technical skills do participants use in the makerspace?

What choices do participants make while working in the makerspace?

*Questions Related to Pedagogy*
What are your goals for participants in the makerspace?
How did you develop these goals?

How do you envision participants succeeding in the makerspace?
What does success look like for makerspace participants?

What needs to happen within the makerspace for participants to succeed?

What can participants explore in the makerspace?

What do you consider when designing curriculum for the makerspace?

*Questions Related to Design of Environment*
What are participants drawn to within the makerspace?

How does this space differ from a classroom environment?

During the design process for the makerspace, what did you anticipate participants being drawn to?

How did you plan for participants to move through the space?

What were the most important aspects of the space that you envisioned?

# APPENDIX C:
# Recruitment Script

Recruitment Script for Interviews Becki Johnson

**Recruitment for Interviews**

Hi! My name is Becki Johnson, and I'm a graduate student at the University of Wisconsin-Milwaukee. I'm working on a research project about how facilitators design and implement curriculum in makerspaces. If you are interested in being interviewed for my thesis, I have a sign-up sheet and consent forms by me. Thanks!

**Recruitment for Observation**

Hi! I am beginning my research project for my thesis at the University of Wisconsin-Milwaukee about how facilitators design and implement curriculum in makerspaces. If you are willing, I would observe your work in the makerspace. I also have a consent form if you're willing to be interviewed afterwards. Thanks!

## APPENDIX D:
## Format Guiding Observations

Date:
Time Period:

Activities Offered: Time Spent at Each Activity:

Participant Information (ages, length of stay, etc.):

Time Periods without Makers:

Facilitator’s Movements & Actions: Facilitator’s Movements & Actions: