**Making learning: Makerspaces as learning environments**

By

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A dissertation submitted in partial fulfillment of

the requirements for the degree of

Doctor of Philosophy

(Curriculum and Instruction)

at the

University of Wisconsin-Madison

2015

Date of final oral examination: 11/25/2014

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Abstract

The maker movement is fundamentally changing the way educators and educational researchers envision teaching and learning. This movement contends *making* — an active process of building, designing, and innovating with tools and materials to produce shareable artifacts — is a naturally rich and authentic learning trajectory (Martinez & Stager, 2013). Makerspaces are places where *making* happens in *community*. I craft my dissertation to explore these two defining characteristics of makerspaces through a comparative case study (Stake, 1995) and a design experiment (Brown, 1992). In the comparative case study, I investigate three youth makerspaces as learning environments and the communities within as learning communities. I employ the design experiment to examine making as an activity that demonstrates learning. With these two complementary studies, I seek to answer the question: *how is learning demonstrated in makerspaces?* I ground my study in the convergences of new literacies and constructionist learning theories. From the intersections of these two learning theories, I develop an activity-identity-community framework, which I use as my analytic frame. My goal is threefold: 1) to compare three types of youth makerspaces (museum, afterschool, and mobile/library), highlighting design affordances and constraints of each; 2) to build a comprehensive understanding of how experienced young makers approach and complete activities in makerspaces, and 3) to realize implications for design and assessment of makerspace-inspired learning environments (e.g., classroom making activities). Findings expand the limited empirical research connecting making and learning by directly informing our understanding of youth makerspaces as learning environments and assessment of making activities — two key gaps identified earlier this year at the National Research Meeting on

Learning and Making. I discuss implications for practitioners and designers of informal learning environments, the emerging field of making in education, and learning scientists more broadly.

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**Acknowledgements**

This dissertation was only made possible with the support of the personal and professional communities with which Jesus has blessed me. First and foremost, I would like to thank Dick and Debbie Smith, my Wisconsin parents, for their prayer and generosity throughout my entire journey here in Madison, including completing this doctoral program. I would also like to thank Kay McMahon, Brittany Lewin, and Meagan Rothschild who have kept me anchored during the most challenging and, at times, excruciating season of my life — dissertating.

To my advisor and friend, Erica Halverson, I express my deepest gratitude. Not only am I grateful for her academic mentorship and guidance, but also for her steadfast friendship. Together we have grown personally and professionally in expected and unexpected ways. Her exceedingly abundant generosity has made an outstanding mark. I must also thank Rich Halverson who has been a reliable source of wisdom and has constantly pushed and challenged my thinking making me a stronger academic. Erica and Rich, while it is time for my utfart, I look forward to the adventures and collaborations that lie ahead. I thank the remaining members of my dissertation committee, Kim Sheridan, Matthew Berland, and Cathy Compton-Lily for your insight, feedback, and support in crafting this dissertation. Each of you has played a significant role not just in my doctoral program, but also in establishing and shaping my academic career. A special thanks to Alecia Magnifico and Lisa Brahms, who have become valued mentors. My appreciation extends to the countless members of the UW-Madison family and my academic community more broadly who have contributed immensely to my training as a researcher.

I would like to dedicate this dissertation to my dear friend, Emily Rose Olvera, whose tenacious battle with leukemia inspired me to grit through every word.

Above all else, Jesus wins.

# Introduction

The maker movement is fundamentally changing the way educators and educational researchers envision teaching and learning. This movement contends *making* — an active process of building, designing, and innovating with tools and materials to produce shareable artifacts — is a naturally rich and authentic learning trajectory (Martinez & Stager, 2013). Even more, learning through making intuitively "makes sense" to educators, parents, researchers, and kids, but we lack empirical evidence to demonstrate its effectiveness and, even more, how the maker movement is impacting education. Recent books about making (e.g., Anderson, 2012; Honey & Kanter, 2013; Martinez & Stager, 2013; Sousa & Pilecki, 2013) describe examples of making activities in various learning environments and offer instructional methods for implementing making activities into classrooms. Thus far, much of the effectiveness of making, as described through these stories, stands on a foundation of common sense and anecdotal evidence. There is minimal, if any, empirical research connecting making with learning.

The *Learning in the Making*[1] research team was tasked with conducting some of the first empirical studies investigating the learning that happens in makerspaces — places where makers come together — and how we can leverage this to design learning environments that achieve specific learning outcomes (Sheridan, Halverson, Litts, et al., 2014). Here, I discuss my own project, which complements the existing efforts of *Learning in the Making*, yet focuses specifically on youth makerspaces and how experienced young makers learn through making.

Makerspaces are places where *making* happens in *community.* I craft my dissertation to explore these two defining characteristics of makerspaces through a comparative case study

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[1] An NSF supported collaboration between the University Wisconsin-Madison, George Mason University, and the Children's Museum of Pittsburgh with growing partnerships across the maker movement.

(Stake, 1995) and a design experiment (Brown, 1992). The comparative case study offers a "thick description" (Geertz, 1973) of *community* as a hallmark of makerspaces; I study three youth makerspaces as learning environments and the communities within as learning communities. This deep investigative dive yields a cross-site comparison of the three makerspaces highlighting characteristic features of youth makerspaces. Moreover, the design experiment examines *making* as an activity that demonstrates learning. Using the idea of *design stances* — makers' perspectives toward their making — I consider how the learning exhibited in makerspaces compares to and expands our existing conceptions of learning rooted in disciplines like Art, Engineering, and Architecture. Through these two complementary studies, I seek to answer the question: *how is learning demonstrated in makerspaces?* I ground my study in the convergences of new literacies and constructionist learning theories. From the intersections of these two learning theories, I develop an activity-identity-community framework, which I use as my analytic frame. My goal is threefold: 1) to compare three types of youth makerspaces (museum, afterschool, and mobile/library), highlighting design affordances and constraints of each; 2) to build a comprehensive understanding of how experienced young makers approach and complete activities in makerspaces, and 3) to realize implications for design and assessment of makerspace-inspired learning environments (e.g., classroom making activities).

Collectively, findings expand the limited empirical research connecting making and learning by directly informing our understanding of youth makerspaces as learning environments and assessment of making activities — two key gaps identified earlier this year at the National Research Meeting on Learning and Making. Practically, this study sheds light on how we manage resources (e.g., tools, materials, and people) in youth makerspaces. Findings also challenge educators to rethink present disciplinary-based perspectives toward making opening the door to developing new assessment tools for making, like design stances. I discuss implications for practitioners and designers of out-of-school learning environments, the emerging field of making in education, and learning scientists more broadly.

In response to President Obama's call to design learning environments that "encourage young people to create and build and invent — to be makers of things, not just consumers of things" (The White House, 2009), educational researchers and learning scientists are considering makerspaces as viable alternatives to traditional STEM learning environments. As a result, making and makerspaces have gained traction in more formal and public contexts, and this has materialized as "the maker movement" (Anderson, 2012). This movement is defined by the mobilization of makers around the world through venues like World Maker Faire, MAKE magazine, and the Internet. In this section, I describe this movement and discuss its undeniable impact on education and educational research.

## Makerspaces

Tinkerers and makers around the globe are meeting and collaborating in makerspaces to create, hack, and innovate with various tools and technologies. But, even as this movement gains traction in schools, libraries, museums, and community centers, a crucial question remains largely unanswered: what *is* a makerspace? Despite the growing attraction to makerspaces as learning environments, there are actually very few resources defining or documenting them; they even lack their own Wikipedia entry. Recently, the Institute of Museum and Library Services (2012) made what is likely one of the first meaningful efforts to define makerspaces: "Makerspaces are part of a growing movement of hands-on, mentor-led learning environments to make and remake the physical and digital worlds. They foster experimentation, invention, creation, exploration, and STEM learning" (p. 1).

Makerspaces emerged out of the same tinkerer, do-it-yourself (DIY) movement that birthed *hacker*spaces. Wikipedia offers this definition of hackerspace: “a community-operated physical space where people with common interests, often in computers, technology, science, digital art or electronic art, can meet, socialize, and/or collaborate” (“Hackerspace,” n.d.). Some trace the roots of the hacker/DIY movement back to countercultural groups like “hippies” (Grenzfurthner & Schneider, n.d.) or “punks” (Triggs, 2006) of the 1970s. Others, like Nick Farr, founder of the Hackerspace Foundation and blogger on hackerspaces.org, describe the hacker movement as happening in three successive waves:

> **First wave** spaces date back to the early 1990s and “showed us that hackers could build spaces”; Farr refers to these spaces as “the stuff of legend” and, thus, continue to shape the movement.
>
> **Second wave** spaces were sparked by hackers in Europe who paved the way for a more sustainable and official approach to building hackerspaces by gaining recognition from the government and credibility from the public.
>
> **Third wave** spaces are those popping up all over the world today, and Farr claims these spaces are tasked with providing us with a “critical mass” or will fade out altogether. (Farr, 2009)

Currently, there are over 1000 hackerspaces worldwide listed on hackerspaces.org with varying statuses (e.g., active, building, planned, closed, or unknown). This list includes organizations that self-identify as hackerspaces, makerspaces, Computer Clubhouses, and/or FabLabs. Additionally, there were over 50 makerspaces worldwide listed on makerspace.com[2],

[2] This domain was recently bought out by the Make organization, so this information may no longer be available.

which includes a similar mix of identification. While for some there are meaningful differences between these types of spaces, the present boundaries between them are extremely blurred, because they are woven together by a common ethos. Midsouth Makers (n.d.), a hackerspace in Memphis, Tennessee, attempts to describe this ethos and the tension around it:

> A Hackerspace is defined as a location where hacker minded individuals can gather to share interests, typically in science, mathematics, electronics, art, and/or crafting. Hackerspaces are as unique as the cities they are located in. No two spaces are alike. Often referred to as a makerspace, hackerspaces are often hard to describe. (Midsouth Makers, n.d.)

Some (http://mentor.makerspace.com/) have attempted to distinguish makerspaces from hackerspaces and claim that makerspaces are more specifically targeted at engaging *young people,* whereas hackerspaces are traditionally dominated by "white male nerds" (Grenzfurthner & Schneider, n.d.). As a grassroots movement, it is particularly challenging to cohesively define makerspaces. For the purposes of this dissertation examination, I use *makerspace* as a broad term to describe spaces and organizations that ascribe to this common ethos of hacking, tinkering, and making.

**Community, Space, Tools**

Makerspaces are primarily made up of community, space, and tools. The Library as Incubator Project (2012) explains that, "makerspaces are not necessarily born out of a specific set of materials or spaces, but rather a mindset of community partnership, collaboration, and creation." Collectively, designers of makerspaces seem to agree that *community* is ultimately what molds and sustains them (Baichtal, 2011; Britton, 2012a). In many cases, makerspaces are born when groups of like-minded tinkerers are drawn together to make, create, and hack. For example, Sector67, a makerspace in Madison, Wisconsin, evolved from a small group of undergraduates who wanted a space to work together. Cultivating community is at the core of the maker movement, as illustrated by Maker Faires, MAKE Magazine, Hackathons, and online spaces (e.g., hackerspaces.org or DIY.org), which all serve to connect makerspaces around the world. Communities of makers range from young children up to retired adults; some spaces target specific age groups while others remain open to the general public. Regardless of age, the key is that *people* are the heart of makerspaces.

Another foundational component of makerspaces is *space*. Naturally, a group needs a common space to build their community. As the "third wave" (Farr, 2009) of the hacker movement has grown, the types of buildings and organizations housing maker communities have expanded significantly. Nowadays, it is not uncommon to find a makerspace in a public library, museum, or afterschool program, in addition to its more traditional environment of garages and warehouse-like buildings.

Finally, *tools* are the resources present in makerspaces necessary to engage the community in making. Designers of makerspaces tend to have a *people first* rather than a *tools first* mentality toward implementing and growing makerspaces. More specifically, Lauren Britton, director of the Fayetteville Free Library, expounds, "the list of equipment and materials will naturally grow as specific projects and programs generate new ideas" (Britton, 2012b). Put differently, though there are tools usual for makerspaces (e.g., 3D printers, laser cutters, or CNC machines), typically these resources are informed and driven by the needs specific to the community.

**Third place**

Many makerspaces are like gyms where members pay a fee to have access to the space and tools provided within it. In some cases, though, makerspaces maintain a free drop-in structure to attract youth, as is the case with Computer Clubhouses who have turned makerspace (e.g., Lakewood, Washington and San Rafael, California locations). Despite varying member demographics, fiscal structures, equipment lists, and project portfolios, the overarching role makerspaces serve in their communities is as a “third place” (Oldenburg, 1989). Third places are spaces between work and home where people meeting informally and provide participants with a unique and meaningful sense of worth. The special blend of community, space, and tools that comprise makerspace has transformed them into critical third places for makers worldwide. With this broad understanding of makerspaces in mind, I look more deeply at makerspaces as learning environments throughout this dissertation by drawing from current research on making and using two constructivist-based learning theories.

## Current research on making, makerspaces, and learning

Over the last few years, making and makerspaces have proliferated our ideas of learning and education and have garnered attention from policymakers, practitioners, and scholars. Most notably, President Obama put the maker movement on display at the first-ever White House Maker Faire earlier this summer and implemented policies to equip schools and entrepreneurs to pursue hands-on innovation and manufacturing (Fried & Wetstone, 2014). Through the maker movement, President Obama argues that we are changing the world “not by buying stuff, but by building stuff — by making stuff, by tinkering and inventing and building” (Fried & Wetstone, 2014). The power behind the maker movement is the “DIY citizenship” it encourages; we change the world through our ability to make it rather than consume it (Ratto & Boler, 2014). With support of policymakers and funders, the grassroots maker movement has exploded into a national, even international, phenomena; making is integrated into classrooms and makerspaces are popping up in communities around the globe. Practitioners and scholars are feverishly working to grow our understanding of how making connects with learning and how makerspaces function as learning environments.

### Making learning

Alongside policymakers, practitioners from formal to informal learning environments are experimenting with making as a learning trajectory. Maker Education Initiative (makered.org), a non-profit organization that seeks to expand learning through making, has led the way to equip practitioners and designers with knowledge and resources to implement making activities in a variety of contexts. The Maker Ed website hosts a collection of information from “making the case” for making to example projects and curricula. Moreover, other resources serve as platforms for practitioners to tell their stories to equipping other practitioners through lessons learned and best practices. Honey & Kanter (2013) offer a series of cases demonstrating how making is integrated in school and out-of-school learning environments and outlining design implications based on these testimonies. Museums like the Exploratorium (Petrich, Wilkinson, & Bevan, 2013) and the Children's Museum of Pittsburgh (Brahms & Werner, 2013) share how they design for disciplinary practices and/or design processes in their making-based exhibits to support learning. Specifically, the Exploratorium focuses on designing for tinkering as an entry point for STEM learning and the Children's Museum of Pittsburgh leverage a more general iterative design process to support cross-generational learning (Brahms & Werner, 2013; Petrich, Wilkinson, & Bevan, 2013). Martinez & Stager (2013) take a similar practitioner-based approach to connect making with learning and equip teachers with tools to integrate making into their classrooms, particularly in engineering disciplines. As these resources continue grow, the case for making as learning strengthens.

In the effort to substantiate making as a learning trajectory, scholars are scrambling to provide empirical evidence of the assumed intrinsic learning value of making. Learning theory such as Papert's (1980) constructionism, New London Group's (1996) multiliteracies, and Lave and Wenger's (1991) situated learning support the spirit of learning through making, but development of and access to new technologies have fundamentally expanded the types of learning that are possible. Through fabrication, for example, learners are able to concretize abstract ideas by 3D printing a tangible rollercoaster to explore with physics concepts (Blikstein, 2014). Other new tools like laser cutters and tangible interface construction kits and microcontrollers — for instance, Makey Makey (Silver, Rosenbaum, & Shaw, 2012) and LilyPad Arduino (Buechley, Eisenburg, Catchen, & Crockett, 2008) — coupled with more accessible programming languages like Scratch (Resnick, et al., 2009) also capitalize on learning at the intersection of physical and digital making. Lee and colleagues combined Scratch programming with Makey Makeys and Play-Doh to teach game design workshops illustrating the value of making across multiple interfaces (Lee, Kafai, Vasudevan, & Davis, 2014). The rise of these new technologies has expanded our understanding of how learning happens.

Researchers have also latched on to the disciplinary value of making by connecting these new technologies to our existing schemata of disciplinary-based learning. Building with 3D printers and laser cutters, programming, and even crafting Play-Doh into circuits have obvious connections with STEM disciplines. Scholars have noted that new technologies like paper computing (Qi & Buechley, 2010), Squishy Circuits (Johnson & Thomas, 2010), and electronic textiles (e-textiles; Kafai, Fields, & Searle, 2012) make complex STEM problems tangible and transparent. In paper computing, makers use conductive tape or paint in place of wires to make their circuits; with Squishy Circuits they use Play-Doh; and with e-textiles they use conductive thread. Making with these technologies builds learner's circuitry skills, programming practices, and engineering thinking (e.g., Eisenberg, Eisenberg, & Haung, 2013; Fields & King, 2014; Kafai & Burke, 2014; Peppler & Glosson, 2013). With learning through making, scholars have begun to reconceptualize what it means to learn STEM concepts. Before the maker movement, we weren't using Play-Doh to make circuits, but now low-cost Squishy Circuit kits are available to the public.

Further, researchers situate making as a representational discipline inherently integrating artistic practices (Halverson & Sheridan, 2014a, 2014b). Scholars have used e-textiles to illustrate how the aesthetic characteristics of making intersect with the arts and fundamentally shift the gender-imbalance of STEM fields (e.g., Buechley, 2013; Buchholz, Shively, Peppler, & Wohlwend, 2014). Rhetoric in the maker movement underscores that making is about STEAM (science, technology, engineering, arts, and math) — not just STEM — disciplines (Sousa & Pilecki, 2013). Much of the research about learning through making is still in progress, but these recent works highlight how the maker movement is inspiring policymakers, practitioners, and scholars to reimagine what it means to learn in and out of school.

## Makerspaces as learning environments

In the discourse around makerspaces, much of what's available are popular press articles sharing resources of how to build a makerspace and explaining what they are. Consider, for instance, the following article titles, "6 strategies for funding a makerspace" (States New Service article), "Three makerspace models that work" (Good, 2013), and "Here's how we did it: The story of the EPL makerspace" (Haug, 2014). The Maker Education Initiative has released a handful of resources as well, including multiple editions of a "Makerspace Playbook" outlining how to establish a makerspace. As a result of these efforts, makerspaces are taking several forms: libraries (e.g., Willett & Shuppy, in press), museums (e.g., Brahms & Werner, 2013; Petrich, Wilkinson, & Bevan, 2013), schools (e.g., Blikstein, 2014), and mobile or pop-up forms (e.g., Barniskis, 2014). Thus far, scholars have primarily focused on how the activity of making and how this intersect with learning. *Learning in the Making's* empirical investigate of makerspaces as learning environments is the first contribution to understanding making *spaces* — beyond just the making *activities*.

### Learning in the making.

The *Learning in the Making* research team began as a National Science Foundation funded, cross-institutional partnership between the University of Wisconsin-Madison, George Mason University, and the Children's Museum of Pittsburgh. In two phases, this team conducts some of the first empirical research examining makerspaces as learning environments. During phase one, *Learning in the Making* conducted ethnographic case studies at three makerspaces across the country (Sheridan, Halverson, et al., 2014). In the current phase, *Learning in the Making* is leveraging what we learned from our case studies to conduct design experiments with the goal of empirically substantiating design principles for makerspace-inspired learning environments. Since its inception, *Learning in the Making* has built numerous other partners across the maker movement, including: Maker Education Initiative, Common Grounds Publishing, Betty Brinn Children's Museum, and several makerspaces around the country.

As a member of *Learning in the Making*, I have drawn from and depended on much of our existing work on makerspaces. Specifically, I used our ethnographic work to conduct a pilot examination of *stances*, and I adopted two of the methodologies (comparative case study and design experiment) that have grown familiar throughout this project. Thus, it is important for me to acknowledge that this dissertation was conceived in and is supported by my participation in the *Learning in the Making* research team.

## Overview

Our understanding of making and makerspaces in education is still in its infancy, but policymakers, practitioners, and scholars are making progress. With this dissertation, I contribute to this growing effort by comparing youth makerspaces and investigating how makers relate to the artifacts they make. In the follow chapter, I outline my theoretical frame and introduce an activity-identity-community framework rooted in the convergences of constructionism and new literacies. I present in chapter three a comparative case study of three youth makerspaces providing insights to our understanding of these spaces as learning environments. Then, in chapter four, I expound a series of design experiments I conducted at each youth makerspace and illuminate how learning demonstrated in makerspaces. I conclude with a chapter discussing implications of this dissertation study for the emerging field of making and learning, practitioners and designers of informal learning environments, and education research broadly.

## Theoretical frame

I use constructivist-based situative-cognitive and sociocultural learning theories to theoretically contextualize the three facets of makerspaces (community, space, and tools). In its simplest form, constructivism claims that meaning is something to be made; and, this idea is a point of convergence for constructionist and multiliteracies theories. While the former leans more toward a Piagetian interpretation of constructivism and the latter toward a Vygotskian interpretation of constructivism, they both agree that new knowledge is built on previous knowledge. Yet, they diverge in their explanations of how meaning is made. Generally speaking, Piaget situates this sensemaking in individuals' experiences and Vygotsky distributes it across social interaction and practice.

Piaget (1956) proposes that learners gain knowledge through engaging in personally meaningful experiences. As Piaget puts it, knowledge "is actively constructed and reconstructed through direct interaction with the environment" (Kafai & Resnick, 1996 p. 26). Thus, despite its cognitivist leaning, Piaget's constructivism acknowledges that learning does not solely happen inside the learner's head; put differently, external factors affect knowledge building. Piaget explains that experiences enable the construction of schemata, and change and adaption of these schemata occurs through processes of assimilation and accommodation. In the end, the goal of learning is to achieve internal cognitive equilibrium (Piaget, 1956).

Vygotsky (1978), on the other hand, proposes a more socially-based constructivism. He claims that knowledge is socially and culturally constructed, particularly through language, and learners then internalize this knowledge. According to Vygotzky's theory of the Zone of Proximal development, learners overcome their respective developmental stages through processes like scaffolding and apprenticeship. Hence, social context and interaction can trump the general stages of knowledge and learning development to which learners would otherwise be tied (Vygotsky, 1978).

While Piaget offers a more cognitivist perspective toward constructivism and Vygotsky offers a more sociocultural perspective toward constructivism, they both directly influence constructionism and multiliteracies. The process and practice of making and the participation of members equally define makerspaces, so these two learning theories deepen and expand our understanding of learning through making. In this review of learning theory, I outline the natural collision between constructionist (Papert, 1980, 1991, 1993) and multiliteracies (New London Group, 1996, 2000) theoretical orientations, and use this collision to construct a viable framework through which we can interpret makerspaces as learning environments.

## Constructionism

Seymour Papert's (1980, 1991) curiosity to uncover the art of learning drove his conception of the theory of constructionism. Papert (1991) explains that constructionism takes constructivism's idea of building knowledge and adds to it "a context where the learner is consciously engaged in constructing a public entity" (p. 1). Constructivism's foundational idea is that learners construct knowledge via experiences, but Papert (1980) takes this a step further with constructionism by highlighting the necessity of making "public" artifacts. Ackerman (2001) thoroughly explores the similarities and differences between these perspectives, and explains that, "Papert's approach helps us understand how ideas get formed and transformed when expressed through different media, when actualized in particular contexts, [and] when worked out by individual minds" (p. 441). Thus, unlike Piaget's constructivism, Papert requires that learning happens when thinking is worked out through the making of external artifacts that "can be shown, discussed, examined, probed, and admired" (Papert, 1993, p. 142).

Another distinction is that constructivism is an epistemology and constructionism is "a theory of learning and strategy for education" (Papert, 1996, p. 1). Of course, constructionism has epistemological implications, but learning is the central focus. Since its conception, researchers (Papert, 1980; Peppler & Kafai, 2007; Peppler, 2010; Pinkett, 2000) have developed different strands and approaches of constructionism, but in this section I chiefly focus on the original roots of constructionism.

**The Art of Learning**

Even though Papert was particularly inspired by the challenges of teaching mathematics, he does not limit himself to any specific discipline or context. Papert describes that his exploration and development of constructionism began with a basic yet complex question: "why is there no word in English for the art of learning?" (Papert, 1996, p. 9). To instantiate his notion of constructionism, Papert offers the concept mathetics (Papert, 1980, 1996) to illustrate the important role that learning plays in the knowledge building process. He expresses a strong concern of and opposition to the disproportional nature of educational research and discourse; teachers are often either explicitly or implicitly defined as the active agent, while the learner is a passive agent (Papert, 1996). Essentially, his argument hinges on these two analogies:

a. pedagogy:teaching::________:learning

b. heuristic:problem solving:: _________:learning

To disrupt this asymmetrical relationship, Papert (1980) identifies a need to fill this gap and proposes "mathetics" as sensible candidate. Though this word has not really gained much traction in the academic community, the essence of the word has; constructionism fundamentally changes the way we talk about learning. A foundational concept for constructionism is Dewey's notion of "learning by doing" (1916, p.180), and Papert is pointing to the fact that learning itself is a viable option for doing. If one learns about reading by reading or about teaching by teaching, then shouldn't it follow that one learns about learning by learning? And shouldn't it also follow that learning is an equally worthwhile thing to learn about?

Since constructionism is built around the idea of doing (i.e. constructing, making, etc.), it follows that constructionists are largely concerned with the question of how we learn - the process by which we build knowledge. Papert (1996) reminds educators that there is an undeniable relationship between the 'how' and the 'what' of learning. This throws a bit of a wrench in the classic 'process versus content' debate in education. If we take seriously Papert's idea of learning to learn, then we must be mindful of both how and what learners should learn, since they mutually inform and reinforce each other.

**Constructionist Perspective**

Papert's (1980) seminal work with LOGO, a programming software for young people, jumpstarted the constructionist movement. The inspiration for the project is rooted in Papert's yearning to engage students in his math classes the same way they were engaged in their art class down the hallway (Papert, 1991). Moving in this direction, Papert looked to computers as a context in which learners could make math in the same way that they make art. Technology, in this case computers, disrupt the nature of the learning process by shifting from "transfer of knowledge to students… [to]… the production of knowledge by students" (Papert, 1991, p. 10).

LOGO allows young people to input simple commands to guide the movement and actions of a turtle. Through implementation, constructionist theorists learned that the LOGO environments take abstract mathematical concepts and make them concrete, relevant, and accessible to learners. The turtle was first a virtual turtle shown on the computer display, then a physical turtle that moved around real-world space, and finally, with the LEGO/LOGO project, a learner-constructed ‘turtle’ (any object, really) that learners build themselves and control via LOGO programming (Harel & Papert, 1991). This progression mirrors the growing theoretical understanding that the more students constructed external artifacts, the more they seemed to learn. Constructionism was born from the LOGO experiment, which offered evidence that utilizing technology in innovative ways can subsequently change what “*kinds of knowledge are valued in education”* (Papert, 1991, p. 10, emphasis in original).

**Learning defined.**

Obviously, construction is the essence of constructionism, but what exactly *is* construction? Papert’s defining statement, “children don’t *get* ideas; they *make* ideas” (Kafai & Resnick, 1996, p. 1, emphasis in original), is the bedrock on which to build a deeper understanding of construction. The core idea here is *making* (versus getting). Papert’s contrast between getting and making reveals that knowledge is both active and created. In essence, learning happens when one “makes” rather than “gets” both knowledge and artifacts (Kafai & Resnick, 1996). Constructionists argue for a unique, interdependent relationship between knowledge-in-the-head and personally meaningful external artifacts; they interpret and reinterpret each other throughout the meaning-making process (Kafai & Resnick, 1996).

Papert’s get-make dichotomy pushes educators to think of students as active makers of ideas. Rather than passively receiving knowledge from an external source or randomly getting an idea out of nowhere, Papert suggests a more dynamic relationship between learners and knowledge exists through making — an iterative process of creating and revealing knowledge through constructing external artifacts. Papert doesn’t claim that cognition is either solely ‘in the head’ or ‘in the world’; instead, he asserts that knowledge exists in both places and construction bridges them together (Papert, 1993).

**Objects-to-think-with.**

Created artifacts—or "objects-to-think-with"—sit at the "intersection of cultural presence, embedded knowledge, and the possibility for personal identification" (Papert, 1980, p.11). In Papert's implementation of LOGO, he designates the turtle as an object-to-think-with. Papert does not suggest 'turtles for all' as a panacea for education, but he recognizes that physical and digital objects, like the turtle, serve a significant role in supporting learners' thinking (Papert, 1980; Kafai, 2006). As such, constructionism takes situatedness to a different level than most other learning theories, but it does not disregard abstractness altogether; instead, constructionism relies on concrete methods to make abstract thinking more manageable. For example, math principles are inherently abstract, but the turtle affords a more concrete space for learners to work out their understanding of abstract mathematical relationships (Papert, 1980). The use and making of external artifacts allows internal knowledge to be externally represented, worked on in a social context, and then (re)internalized as a process of constructing, examining, and revising connections between old and new knowledge (Kafai, 2006).

In addition to making the abstract more concrete, objects-to-think-with connect learners with emotional and social worlds. Objects-to-think-with afford *appropriation*, the process of taking ownership of and identifying with knowledge (Kafai, 2006). In constructionism, "forming new relationships with knowledge is *as important* as forming new representations of knowledge" (Kafai & Resnick, 1996, p. 2, emphasis added). Using a physical or digital object for meaning-making allows learners to build an intimate relationship with the knowledge itself.

**Bricolage.**

Since making is at the center of constructionism, the learner is better described as a maker. Learners actively tinker around in *microworlds*, interactive, incubator-like learning environments in which learners can work out real-world problems by exploring, constructing, and testing hypotheses. A microworld is not a virtual simulation, but it usually depends on technology to stretch learners' thinking much like the LOGO turtle helped children work out real math in a physical environment (Papert, 1980; Kafai & Resnick, 1996; Kafai 2006). Within microworlds the learner becomes a "builder" (Papert, 1980, p. 7) or *bricoleur*. Just as a builder needs materials, finds them in the surrounding culture, and creates with them, a bricoleur needs tools, uses the resources available in the surrounding environment, and constructs with them (Papert, 1980, 1991). In this bricolage style of working, creating becomes a conversation between the bricoleur and the environment in which constructing is happening; bricoleurs play with a range of tools that happen to be accessible around them and, as a result, create new tools that go back into the environment joining the repository of future resources of making.

Constructionists situate a planning style vis-a-vis a bricolage style of working, yet Papert (1991) insists that the affordance of constructionism is that it supports *both* styles, perhaps, among a variety of others. Formal learning has traditionally supported a structured, pre-planned work style where learners follow a step-by-step process. Alternatively, constructionist learning environments strengthen learners' ability to choose between cognitive work styles and, more importantly, to select a style that suits the problem (Papert, 1980). Kafai & Harel's instructional software design projects, in which older students design instructional software to teach fractions to younger students, illustrate many of the different trajectories learners can take within a constructionist learning environment (Harel & Papert, 1991). Different styles of thinking are useful for solving different types of problems, and constructionist learning environments — while favoring bricolage-style — support all styles of thinking.

**Constructionism and Learning**

Papert (1991) unapologetically pits constructionism against instructionism; he asserts that educators should be in the business of guiding learners through the production of knowledge rather than transferring knowledge to learners. Constructionist theorists wholeheartedly declare that learners transform implicit knowledge to explicit knowledge through construction of external artifacts, and this knowledge-building process *is* learning (Kafai & Resnick, 1996). Explicating learning as construction directly opposes the fact that schooling is exclusively “based on verbally-expressed formal knowledge” (Papert, 1991, p.11).

Constructionism’s pragmatic nature lends itself well for theorists to design learning environments, as demonstrated through the creation of the Computer Clubhouse. The Computer Clubhouse, an international afterschool program, is an effort using a theory-driven design to bridge the digital divide and encourage young people to create and innovate with technologies (Kafai, Peppler, & Chapman, 2009). Inspired directly from constructionism, Computer Clubhouses are driven by four guiding principles:

1. Support learning through design experiences;
2. Help members build on their own interest;
3. Cultivate an emergent community of learners; and
4. Create an environment of respect and trust (p. 5)

These four principles, particularly the first three, exemplify a constructionist learning model. In the following section, I elaborate on each of the first three principles and how they shape and define constructionist learning environments.

**Learning by making.**

Constructionism is sometimes referred to as learning through doing or learning through design or, as Papert describes, "learning-by-making" (Papert, 1991, p. 6). Constructionism is inherently about *making*. More specifically, it's about the making of both knowledge and personally meaningful external artifacts. Making is a constant conversation between interpretation and representation; learners build artifacts as representations of knowledge and (re)interpret the artifact as a representative object promoting understanding. The making process is not this clean cut, yet it is some form of cycling and spiraling between, around, and within these poles that ultimately develops learners' internal knowledge. Constructionists argue that engaging with this process *is* learning. Particularly, Papert describes this iterative process of constructing and reconstructing as "debugging," which functions as the "essence of intellectual activity" in making (Papert, 1980, p. xiii). Learning is not as neat and smooth of a process as traditional educational practices might want us to believe; instead, it is a messy, complex process.

Pragmatically, the practice of providing learners opportunities to make is especially fruitful. For instance, Blikstein and Wilensky (2007) introduce a "bifocal" (p. 4) approach to making by mixing virtual and real world environments with their NetLogo software. In this bifocal setting, learners were able to quickly test hypotheses and debug their models of scientific principles in ways that learners in a non-bifocal setting were unable to achieve. Following constructionist principles, Blikstein and Wilensky (2010) introduce another element — MaterialSim — into their NetLogo learning environment. MaterialSim allows learners to code their own virtual models in addition to building their own physical models, which immerses them deeper and more intensely in the scientific phenomena than learners without this option

(Blikstein & Wilensky, 2010). Therefore, while learning trajectories are not always clean and linear, educators can use making to guide the sensemaking process and encourage the conversation between the artifact and learner.

**Learning builds interest.**

Meaningful learning requires interest, and building interest takes time. One does not simply become a maker, instead, one develops an interest in making and this interest breeds a maker-mindset. It is helpful to think of this progression like a volcano beginning with bubbles and eventually exploding. In the beginning, learners' interest might be small bursts, but with persistence learners' interest-levels reach a point of critical mass and "learning explodes" (Papert, 1996, p. 23). Much like a volcano, experiencing learning with this intensity typically requires time for interest to simmer and swell.

Kafai and Harel (1991) suggest that learning happens in different phases. The first phase — the *incubation phase* — is when learners "mess around" (p. 90) and establish interest. Learners find themselves in an ill-defined problem space faced with a need to answer a lot of hard questions, but as they work through this phase they are not just defining a problem space, but investing in and taking ownership of the problem itself. As the making process advances, learners spiral deeper into their interests in a way that is unique to *making* rather than just *using* new media and technologies (Harel, 1988; Peppler & Kafai, 2007).

From a constructionist perspective, making is self-directed and interest-driven. Extracting these benefits and making them available in other learning environments requires deliberate design decisions. One option is to structure making within the constraints of project-based learning, which encourages learners to pursue "long-term investigations of significant questions and produce artifacts" (Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991, p. 392). Learners are able to invest themselves in projects according to their own interests, thereby increasing their motivation to learn more, and consequently improve their overall knowledge of specific content (Blumenfeld et al., 1991). In constructionist learning environments, learners require time and freedom to identify and follow their personal interests, which function as the beginning phases of the knowledge-building process.

**Learning is relational.**

Establishing and maintaining interest throughout the making process is much like cultivating a relationship. Hence, learning-by-making depends on learners' ability to build cognitive and social relationships.

***Cognitive relationships.***

Thinking of knowledge building in terms of relationship building brings forth an anthropomorphic perspective toward learning. Cognitivists often talk about connecting knowledge relationally in network form, but constructionists present something much deeper: building a relationship *with* knowledge (Kafai & Resnick, 1996). In the same way that one would develop a relationship with another person, constructionists encourage learners to cultivate a functional, healthy, rich, two-way relationship with knowledge. We can interact it with knowledge and it with us; suitably, building a relationship with knowledge is just as messy and complex as it often is with people.

Taking up relational perspective toward knowledge means that it actively lives and breathes in our everyday through our interaction with artifacts, as knowledge-bearing entities. Constructing external artifacts allows us to know objects inside and out (Harel & Papert, 1991) — what better way to know something than to create it yourself? Eisenberg and Buechley (2007) suggest that merging the ubiquity of new media with fabrication tools and devices can enhance learners' connection with and knowledge about a given artifact. They argue that ubiquitous fabrication in education will afford learners the ability to physically interact with their computational thinking. With fabrication, learners can literally translate their knowledge into a computational platform and then make that knowledge tangible (Eisenberg & Buechley, 2007). Building relationships with knowledge through fabrication is also particularly satisfying and valuable in teaching systems thinking, which has traditionally been a challenging endeavor for educators (Anderson, 2012; Hmelo, Holton, & Kolodner, 2000). Actively designing and making routinizes the use of knowledge through dynamic social and technical networks, so that it won't decay or fade away.

***Social relationships.***

Part of the bricolage-like, interest-driven nature of constructionism is shaped socially and culturally through "collaboration through the air" (Kafai & Harel, 1991, p. 88). Students in Harel's instructional software design projects were able to watch how other students approached a task through conversation, screen looking, and a variety of other direct and indirect interactions. Socially interacting "through the air" suggests that when learners are working in the same physical space together, knowledge floats around waiting to be "picked up" (Kafai & Harel, 1991, p. 88). In this type of learning environment, learners need space and time to pick up ideas when they're ready and to drop ideas when/if they need to.

Kafai and Harel (1991) offer practical guidance for how educators can design social learning environments to encourage learners to build an internal relationship with knowledge and interact with other learners, all while pursuing personal interests. Specifically, they suggest cultivating a collaborative production style where learners construct their own individual products, yet are working together under the same "umbrella goal" permitting learners to move between individual and collaborative styles as they desire/need (Kafai & Harel, 1991).

In sum, constructionism sheds light on how learners build relationships with artifacts through making and design processes. Relationships are sparked by interest and grow deeper as learners progress in their making trajectories. The focal point of learning in constructionism is on one's knowledge-building process through making tangible artifacts. As a theoretical tool, constructionism primarily explicates the learner-artifact relationship while recognizing the significance of social aspects of learning environments.

## Multiliteracies

Multiliteracies scholars take a different stance on learning by focusing on how learners communicate meaning to others through the artifacts they create. With this learning theory, we gain insights on how learners negotiate the artifact-community relationship. The New London Group (1996) coined the term "multiliteracies" to recognize a wave of new media and the new literacy skills necessary to interact with them. Multiliteracies materialized from the understanding that, as "makers of meaning" (New London Group, 2000), we are constantly "negotiating a multiplicity of discourse" (New London Group, 1996, p. 61) in our lives. The New London Group identifies two separate but complementary features of multiplicity: 1) the modes of meaning-making literacies available to individuals on a local level, and 2) new forms of communication that more tightly connect local and global worlds, resulting in a drastic increase of cultural and linguistic diversity in our daily lives. Accordingly, the purpose of learning is to engage learners as active participants in designing (their) *social futures* (New London Group, 1996; Cope & Kalantzis, 2000). A pedagogy of multiliteracies is built on the belief that knowledge is inextricably "embedded in social, cultural, and material contexts" (New

London Group, 1996, p. 82), and that learning happens through immersive and contextualized hands-on experience (Cope & Kalantzis, 2000).

Many literacies scholars have pushed for a movement to redefine literacy as we know and understand it in formal learning environments, particularly in schools (Barton, Hamilton, & Ivanic, 2000; Gee, 1991; New London Group, 1996; Lankshear & Knobel, 2003; Masny & Cole, 2009; Michaels, 1984; Street, 1984, 2005; Thomas, 2005). With the rising ubiquity of many new media, these scholars have argued for a fundamental shift in our understanding of literacy. In this section, I explore the *multiliteracies* strand of this discussion as it relates to makerspaces.

**Multimodal**

Multimodal literacy scholars challenge more traditional written and oral concepts of literacy by ascribing to the idea that new media and technologies are "increasing complexity and inter-relationship of different modes of meaning" (New London Group, 1996, p. 79). The New London Group (1996) identifies six modes as resources for construction of meaning-making processes: Linguistic, Visual, Audio, Gestural, Spatial, and Multimodal Design; Multimodal Design unites all other modes as complex and fluid meaning-making networks. Each mode consists of "Design Elements," or features of a mode, that learners can manipulate and negotiate as resources for representation. At some level, all meaning-making is intrinsically multimodal.

The proliferation of sensemaking resources is fundamentally altering the way we make meaning, and the types of meaning we are capable of making. For instance, on a more general level, a pencil, an iPod, a laptop, and a facial expression are all different modes with which learners can produce and interpret meaning. Yet, on a more specific level, even on a laptop a learner could use a video editing program, a word processing program, and an Internet browser as meaning-making resources for a class project. Opening up our understanding of meaning-making to more complex modes of representation allows us to construct and express ideas and values in new ways (Jewitt & Kress, 2003).

One of the interesting things about multimodal literacy is how single projects move across and between modes throughout their development. Using different modes (e.g., 2D drawing, writing, 3D figures, spoken dialogues, or a play performance) in stages helps structure the "process of making" in meaningful and useful ways (Jewitt & Kress, 2003). Learners arrive at a point of "'fixing' in the chain of semiosis" (p. 123) each time they transform content or material to a new mode. Not only does the explosion of multiple modes change the sorts of meaning learners can convey, but it also opens the door to new forms of learning (Jewitt & Kress, 2003).

**Global & Local**

Technological advancements (e.g., the Internet, Wi-Fi, or mobile devices) have augmented and strengthened the relationship between our local and global worlds. The New London Group (1996) describes three areas of our lives that are particularly affected by this change: work, citizenship, and lifeworlds. Educators need to consider all three in order to create "the learning conditions for full social participation" (New London Group, 1996, p. 61). In the domain of work, society is transitioning from hierarchical structures of mass production to more horizontal, informal collaborations of negotiating meaning. This movement offers an opportunity for "productive diversity"(p. 67) and comes with a need to negotiate new discourses that shape "locally sensitive and globally extensive networks" (p. 68). The domain of citizenship is experiencing a similar transformation, from monocultural and monolingual societal standards to more pluralistic guidelines of mediating cultural and linguistic differences. As the public realm welcomes more diversity, it invades into our lifeworlds (or personal spaces for local meaning-making) causing them to become so public they're almost nonexistent. Lifeworlds must continue to grow divergently in a fashion that permits autonomy, while still preserving valuable community memberships (New London Group, 1996). The changes in each of these domains points to an overarching need to utilize differences as a resource for, rather than a roadblock to, meaning-making. Most importantly, the move from homogenizing to diversifying society has huge implications for how we understanding learning and the design of learning environments.

**Bridging Contexts**

Just as the explosion of new media has connected our global and local worlds, it has begun to bridge our social and individual worlds, which has fundamentally redefined our understanding of literacy. As several new literacies reach ubiquity, researchers (e.g., Lankshear & Knobel, 2003; Street, 1984) strive to understand how literacy itself affects the sociocultural contexts within which it exists. Brian Street (1984, 2003) illustrates this by contrasting "autonomous" with "ideological" models of literacy. The autonomous model is heavily influenced by a written-only view of literacy, and declares that literacy acquisition itself has worthwhile social and cognitive effects (e.g., greater equality or higher cognitive functioning). From this viewpoint, if poor and illiterate people simply become literate void of any particular sociocultural context, then their economic conditions will also improve accordingly (Street, 1984). In contrast to the autonomous, unidirectional understanding of literacy, Street suggests that becoming literate is about learning a social practice and not just acquiring skills. Literacy is an ideological process "in which particular socially constructed technologies are used within particular institutional frameworks for specific social purposes" (Street, 1984, p. 97). From the ideological view of literacy, learning is more about negotiating a textual (in a broad sense of the word) conversation to create meaning within a social, cultural, and political context.

**Discourse**

A key shift in the multiliteracies and new literacies movements is a reconceptualization of the notion of literacy itself. Rather than ascribing to the traditional understanding of literacy as written and (sometimes) oral language, scholars (New London Group, 1996; Cope & Kalantzis, 2000; Gee, 2012; Street, 1984) broaden literacy to include semiotic activity across myriad meaning-making systems. Semiotic activity is the sensemaking process with which individuals engage when creating meaning(s) using new media. For instance, the visuals of applications on the iPhone interface are designed to communicate meaning in efficient ways. Some applications use icons of the object itself (e.g., the clock application has a picture of a clock); others use representations connected to the object (e.g., the mail application has a picture of a letter); and, still others use more symbolic icons (e.g., the Spotify has a picture of their logo), which often have no concrete connection to the object itself — Spotify doesn't use a screenshot of their interface or any representation that indicates it is a music application. Multiliteracies scholars require that producers and consumers of symbols and representations complete a complex meaning-making and interpretive process to learn with new literacies. The New London Group (1996) expands this approach even further by introducing "*orders of discourse"* as a "socially produced array of discourses, intermeshing and dynamically interacting" (p. 74). With orders of discourse, multiliteracies scholars situate semiotic activities on both the discourse-level and Discourse-level. In other words, the attraction to semiotics is the meaning-making process inherently involved with it; individuals participate in similar processes when doing literacy on its most basic level and on its meta-discourse level.

On a micro-level, "discourse" (lowercase 'd') describes our "language-in-use-in-society" (Gee, 2012, p. 2), and "is a configuration of knowledge and its habitual forms of expression, which represents a particular set of interests" (New London Group, 1996, p. 74). On a macro-level, "Discourses" (uppercase 'D') are "always and everywhere social products of social histories" (Gee, 2012, p. 3). The construct of Discourse exists on a meta-level of discourse recognizing that discourses and literacies themselves are negotiated and mediated according to sociocultural variables. For example, punk rock has its own Discourse (or way of being) part of which is discourse, along with more complex characteristics of "*who* I am" and "*what* I am doing" (Gee, 2012, p. 152) related to culture, identity, and power. A punk rocker may use language in a particular way (discourse) *and* listen to certain music (e.g., punk rock, obviously), participate in certain practices (e.g., skateboard and attend shows), and adopt a certain style (e.g., spiked belts and colorful hair) to embody a distinctive way of life (Discourse). Yet, if this punk rocker goes to a ballet or an opera, s/he is not only introduced to a different set of vocabulary and use of language (discourse), but is also forced to negotiate new ways of being in the world — this is Discourse.

(D/d)iscourse provides a more holistic approach to literacy by designating participation in various practices as the crux of language, literacy, and our meaning-making abilities. Thus, in addition to the global-local tension across literacy as a whole, there is a tension of Discourses between uses of language. These tensions are not simply resolved through regurgitating the proper nouns and verbs, but through negotiating participation in distinct practices. Redefining literacy to align with a multiliteracies perspective presents radical implications for the design of learning environments, which I outline in the next section.

**Multiliteracies and Learning**

From a multiliteracies perspective, the purpose of learning is to engage learners as active participants in designing (their) *social futures* (New London Group 1996; Cope & Kalantzis, 2000). As meaning-makers, learners socially construct their own realities — particularly through literacy — and are inherently always designing their own — and others' — social futures (i.e. work, citizenship, and lifeworld futures). In schools, "*curriculum is a design for social futures"* (New London Group, 1996, p. 73, emphasis original) functioning as a "designed artifact" (Halverson, 2003) that equips learners with practices and experiences necessary to "achieve success and fulfill employment" (New London Group, 1996, p. 1). Although multiliteracies scholars originally applied the theory to formal education contexts, it provides valuable insights for designers of out-of-school learning environments as well.

Teaching language, and literacy in general, poses a particular problem for designers of learning environments, because it is both the object of knowledge (content of learning) and the medium through which knowledge is acquired (learning environment) (Cazden, 1973). Multiliteracies scholars put forth a pedagogical theory as an effort to resolve this tension. A pedagogy of multiliteracies is built on an embodied and situated epistemological foundation, which means knowledge is inextricably "embedded in social, cultural, and material contexts" (New London Group, 1996, p. 82), and learning happens through immersive and contextualized hands-on experience (Cope & Kalantzis, 2000). More specifically, a pedagogy of multiliteracies consists of four aspects: Situated Practice, Overt Instruction, Critical Framing, and Transformed Practice. Each of these aspects represents a different piece of the knowledge-building process: in Situated Practice knowledge is made through hands-on experiences; and, with Overt Instruction implicit concepts and processes are made explicit; then, Critical Framing works to critically situate the knowledge constructed in its social contexts; finally, Transformed Practice serves to transfer this knowledge to new contexts. While knowledge-building and learning fundamentally happen in situated contexts, Overt Instruction and Critical Framing require that learners step back and abstract knowledge to engage in theory-making and interrogation processes (Cope & Kalantzis, 2000). With this epistemological and pedagogical understanding of learning in mind, I next highlight four defining attributes of this meaning-making process.

**Learning in "Design."**

Multiliteracies theorists ground learning in design; both in terms of design as a meta-language of literacy practices and as an iterative process. For these scholars, social construction of meaning is made up of three design elements: Available Designs, Designing, and The Redesign (New London Group, 1996; Cope & Kalantzis, 2000). First, Available Designs are the resources for meaning-making that learners have available to them when Designing. Not surprisingly, these resources include the multiple modes and forms of representation that define the multiliteracies perspective, each offering unique expressions of meaning. Second, Designing is the transformative process of redefining and (re)making Available Designs. This connects back to the process of semiotics that multiliteracies scholars pull from to elaborate sensemaking of new literacies. Put differently, Designing is where innovation happens — finding new uses for or repurposing 'old things'. Third, the product of Designing is The Redesign, which in turn becomes part of the Available Designs. This presents a constant, but valuable tension: the resources of design determine the designs that are possible, but the process of designing yields more resources to be used in future designs. Much like the notorious 'chicken or the egg' question, 'which came first?' is a pretty impossible question to answer. Thankfully, the value of this tension lies rather in its reinforcing, cyclical nature.

A multiliteracies perspective of learning supports learners' participation in a more iterative, flexible process rather than a linear, rigid process. One successful example of a learning environment centered on design is YOUmedia at the Chicago Public Library (Austin, Ehrlich, Puckett, & Singleton, 2011). Heavily informed by the "hanging out, messing around, geeking out" framework (Ito et al., 2008; 2010), the design of the space allows youth to freely transition between different genres of participation with the goal of making and producing with new media. Another example from more formal school environments is Jim Mathews' Neighbourhood Game Design Project (2010) in which students designed mobile media texts based on original research. As part of this learner-centered studio design process, Mathews (2010) embedded components like "design journals" and "critique sessions" to support a more fluid and malleable learning environment. In both cases, the goal of the learning environment is to build learners' literacy of new media through design.

The New London Group (1996) uses this design perspective to understand literacy itself *and* to support an iterative learning process; the 'thing' learners design could be as small as a sentence and as large as a mobile media project. Hence, the core ideas here are that we are continually designing literacy practices in socially constructed environments and, depending on their goals, designers of learning environments have the power to afford and constrain different practices.

**Learning builds representations.**

Building from the foundation of learning in Design, it is important to recognize that, in the spirit of Vygotskian constructivism, sociocultural theories of learning tend to put an emphasis on the representational factor of products of design. Multiliteracies scholars emphasize the significance of negotiating meaning through design as a representational tool braiding together both individuals' identity and cultural values.

Roger Schank (1995) offers a valuable epistemological perspective on representation that complements the multiliteracies perspective of learning. Schank claims, "we are the stories we tell*"* suggesting that the way new media are changing literacy is more substantial than a first glance may let on. The representations we make of ourselves (the stories we tell) are not just representations of our own knowledge or cultural artifacts, but they also become markers of our intelligence and pieces of our identity (Schank, 1995). Likewise, Gee (1991, 2012) encourages us to think of Discourse as a type of "identity kit" that instructs us how to act, look, and talk. Through a multiliteracies lens, then, the representations we design, produce, and take up are windows into the very core of who we are. So, as new technologies and media offer additional resources for design and provide new forms of meaning-making, individuals are able to negotiate and express their work, civic, and lifeworld identities in new ways.

As such, designers of learning environments are increasingly taking interest in understanding and utilizing multimodal literacy — multiple modes of meaning working together to convey a common representation. Following a design-focused learning process, a logical next step is to ask what Available Designs will be/are available in the learning environment. Designers of learning environments can constrain and tailor these resources to fit learning objectives and design goals. For example, one might restrict learners to using a specified primary mode or form of meaning-making (e.g., radio production) or one could limit the content of meaning (e.g., require learners to create a message about politics or biology). The social context itself might inherently limit valuable resources and thus restrict learners to bias repositories of meaning-making; for instance, most commonly discussed (e.g., Hull & Schultz, 2002; Michaels 1981) is the constrictive environment of traditional schooling, which is often criticized for only validating dominant culture. Sarah Michaels' (1981) research shows that sharing time in Kindergarten classrooms legitimizes certain narrative strategies and neglects others, which hinders minority students' performance. Michaels explains that the discrepancy is due to a difference in the resources of "home-based oral discourse" (p. 424). That is to say, the discourse style that African American youth use at home is further from the literate standards in schools, which makes it more difficult to transition from oral to written literacy (Michaels, 1981). In addition to strategically constraining Available Designs, educators must also carefully consider the meaning-making resources available to learners as determined by the social context.

**Learning is social.**

Literacy is inherently a social practice (Street, 1984, 2004; Barton, Hamilton, & Ivanic, 2000). We can say that literacy is a social activity defined by a practice and/or that literacy is a practice constructed through social means. Either way, we arrive at the same place: building literacy requires a social element. New media are not just technologically innovative, but are also culturally innovative. Thus, the vehicle through which one becomes literate is dependent upon social contexts. As a sociocultural perspective, the intersection of social context and literacy practices remains a focal point for learning environments inspired by multiliteracies.

On a practical level, I use the Digital Youth Project (Ito et al., 2008, 2010) to illustrate how the intrinsically social properties of literacy emerge in learning environments. Ito and her colleagues (2010) completed a three-year ethnographic study yielding a valuable ecological model of "hanging out, messing around, and geeking out" that describes how young people engage with new media. With the ecological framework, scholars identified two primary genres of participation: friendship-driven and interest-driven. Friendship-driven participation with new media describes how shared practices with friends act as an entry point for youth — friends are the reason they "hang out." As individuals become more interest-driven (move from "messing around" to "hanging out"), they build new relationships around a specific topic or passion (Ito et al., 2010). This study reveals how deeply situated new media are in social contexts, and that individual learners balance this social component of literacy with their interest in particular practices.

The Digital Youth Project offers a concrete example of how literacy practices, particularly with new media, are intrinsically social. But what does this really mean for learning? How does this inform our design of learning environments? I turn to two more pragmatic sociocultural frameworks to further support our understanding of social learning environments.

***Communities of practice.***

Aligning with multiliteracies scholars, Lave and Wenger (1991) argue that knowledge is situated in specific contexts, and meaning-making occurs through interactions with others in these contexts. In a *community of practice* learning is, either explicitly or implicitly, continuously happening (Lave & Wenger, 1991; Wenger 1998). Learners become members of groups and build relationships with other members by participating in distinct practices, often through an apprenticeship-like process.

Wenger (1998, 2002) describes three main characteristics of a community of practice: domain, community, and practice. All communities of practice are embedded in some sort of a domain of interest, which acts as a joint enterprise of shared competence uniting (and, thus, defining) the group. The community encompasses the mutual engagement of interactions and relationships that are built around the domain. Members of a community of practice are more than just members, they're practitioners; through this practice, members create a shared repertoire of resources to support the community.

The community of practice framework is reminiscent of the Design framework introduced by the New London Group (1996). Similar to the elements of the Design process, the domain, community, and practice facets of a community of practice are dynamic and evolving, making it difficult to pinpoint which characteristic is most predominant. Just as educators can afford or constrain certain experiences within Design, each of these ‘community of practice’ constructs can be intentionally designed for according to the social and relational goals of a given learning environment.

***Participatory cultures.***

A second framework that lends a few tools to understanding sociocultural learning environments is *participatory culture* (Jenkins, Purushotma, Clinton, & Robinson, 2006). As sociotechnical systems, participatory cultures fundamentally shift “the focus of literacy from one of individual expression to community involvement” (p. 4). The focus is on “the emergence of a cultural context that supports widespread participation in the production and distribution of media” (p. 6). Expanding the concept of learning to building cultures is important in the context of the local-global tension that exists in literacy studies; a culture is large enough to connect the local and global, if designed to do so. So, to design a participatory culture (or “affinity space” as Gee (2004) calls them) one must orchestrate a context that fosters participation (community of practice) in some production (Design) process (Jenkins et al., 2006).

Notice what just happened? On a more individual level, Design (New London Group, 1996) is a tool to facilitate learning with new media. At the community level, community of practice (Lave & Wenger, 1991; Wenger, 1998, 2002) becomes a useful design tool to form communities around a specific practice, perhaps developing some new literacy. Broadening to the cultural level, participatory culture (Jenkins et al., 2006) emerges as a promising tool to shape a system in which multiple communities can practice and produce with different technologies and media. While this is likely better understood as an ecological model, taking up these three frameworks simultaneously (as complex as it may be) yields an extensive sociocultural understanding of learning that happens in makerspaces.

## Convergences: Connecting Making and Learning

Despite the fact that constructionism and multiliteracies emerge from different paradigms, they are both versions of constructivism and appropriately arrive at many of the same principles for learning (Honebein, 1996). In this section, I elucidate how makerspaces offer a platform on which we can meld these learning theories, just as *design* bridged the cognitive and situative theories of the cognitive debates of the 90s (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Derry & Steinkuehler, 2003; Hannafin, Hannafin, Land, & Oliver, 1997). My intent is to align the theories in a way that affords "grounded design" (Hannafin et al., 1997, p. 102) without sacrificing the integrity of the theories themselves.

On the one hand, constructionism introduces learning *by* making and explains that the process of creating something allows learners to relate with knowledge in new ways. From a constructionist perspective, the social context shapes the learning trajectory and is viewed as a repository from which learners can draw resources to work out their thinking with more concrete methods. Ultimately, the goal is for learners to build relationships and connections with knowledge both cognitively and socially. On the other hand, multiliteracies presents learning *in* design and positions the context of constructing as the thing *in* which learning happens. Multiliteracies scholars suggest that we live inside a world made up of a variety of design practices, from crafting sentences and gestures to ordering our morning coffee to producing a 3D representation of ourselves with a 3D printer. In essence, as modes of design continue to grow, learners weave them together to participate in meaning-making by creating representations of themselves as socially constructed beings. Both constructionism and multiliteracies are concerned with building learners' *design literacies*, if you will, putting engagement and conversation with design at the forefront of learning.

Makerspaces are so intrinsically rich with learning that they have attracted educators and researchers from all different disciplines and backgrounds. I propose that the natural collision of constructionism and multiliteracies in these spaces is precisely what is drawing the masses. The process and practice of making *and* the participation in community equally define makerspaces. Of parallel significance, is that makerspaces innately offer fresh insights into learning — they were not initially built as places for people to learn, but rather as places for people to make. Makerspaces ascertain that making *is* learning.

In the rest of this chapter, I discuss how constructionism and multiliteracies coalesce into a viable theoretical structure with which we gain a deeper sense of makerspaces as learning environments. I highlight three key convergences of these theoretical perspectives: 1) learning is about building relationship with tools and people; 2) making is a way to learn; 3) producing external artifacts is evidence for learning. While there is scant empirical research connecting making and learning, scholars have conducted ample research examining and/or informing each of these three concepts.

**Learning as Building Relationships**

When designing learning environments, whether they realize it or not, designers are instantiating their beliefs and values about knowledge and learning (Bruer, 1994; Bransford, Brown, & Cocking, 2000). Interestingly, despite some epistemological differences, constructionism and multiliteracies converge at situated learning theory. While the former arrived there via situated and distributed cognition (Brown, Collins, & Duguid, 1989) and the latter through situated and distributed practice (New London Group, 1996; Wenger, 1998), both agree that knowledge and learning is situated (Lave & Wenger, 1991). This movement toward situatedness is inspired by Dewey's observation that:

> The great waste in the school comes from [the learner's] inability to utilize the experiences he gets outside of the school in any complete and free way within the school iteself; while, on the other hand, he is unable to apply in daily life what he is learning at school. (Dewey, 1899, p. 89)

Situated learning connects person, activity, knowledge, and the social world with practice (Lave & Wenger, 1991). Through this, it connects personal lifeworlds (New London Group, 1996) with global worlds and emphasizes the need for personally meaningful problem tasks. Situated learning environments allow space and time for learners to build intimate relationships with knowledge through tools, community, and space.

Learning as relationship building is not a novel concept. Papert (1980) explains that, as learners build relationships with tools, they are also building relationships with knowledge. Making and hacking define not only the actions and activities people complete in makerspaces, but also the relationships members build with tools, projects, and each other. For instance, as objects-to-think-with, tools — especially ones that learners themselves hack or build — become something with which learners can cultivate a relationship. With a constructionist framework, this relationship between tool and learner is something that can be studied, designed for, and cultivated.

Furthermore, a multiliteracies lens elucidates the relationship between a community and a learner. In makerspaces, depth and breadth of participation often explicitly define membership. From a communities of practice (Wenger, 1998) perspective, both participation in the space itself and participation with other members are landscapes on which learning is built. Learning in makerspaces often happens through a collaborative apprenticeship-style process, which is intuitively scaffolded to suit learners' abilities. This takes shape formally through the practice of community projects and informally through the participatory, distributed nature of making, and such collaboration often blurs the lines of ownership (i.e. knowing 'who' produced what). On a cultural level, makerspaces are as unique as the cities they're in and they draw people with a diverse set of skills and expertise; they are a reflection of their own communities.

Constructionism and multiliteracies agree that the intersection of community and spatial design is a key feature of learning environments; learning cultures (Kafai, Peppler, & Chapman, 2009; Sawyer, 2006), communities of practice (Wenger, 1998), and participatory cultures (Jenkins, 2006) and affinity spaces (Gee, 2004) collectively indicate that learning happens in designed social worlds. Interestingly, theorists from both paradigms (constructionism and multiliteracies) suggest a natural progression from "messing around" to more deeply engaging with knowledge as interest grows (Kafai & Harel, 1991; Ito, 2010). Makerspaces inherently allow members to freely oscillate from playing around to intensely hacking and back. For instance, the space at Sector 67 follows a hub-and-spoke model where there is a center table (hub) and members can spoke off to different areas (e.g., welding, CNC machining, etc.) to geek out according to their interest. Such spatial designs distribute knowledge throughout the space itself, always available to be "picked up" and used when a maker is ready for it. Knowledge is also picked up from fellow members by "collaboration through the air" (Kafai & Harel, 1991, p. 88). Direct and indirect collaboration through space and people is the 'air' of makerspaces; it is what keeps them alive and well. The design of makerspaces is fueled by a desire to make things *with* people, whether explicitly or implicitly. Sometimes makers work on projects together, other times they work on similar projects next to each other, and still other times they work on different projects individually, but in the same space. Learners want knowledge and resources on *their* terms (Gee, 2003; Kafai & Harel, 1991), and the physical space of the social world itself can be designed to support such accessibility and interactions (Walls, Schopieray, & DeVoss, 2009). The gem of makerspaces is that there are electrical, artistic, technical, mechanical, and myriad other types of knowledge and expertise floating around the space in the form of people, tools, and other materials/resources.

Distributing knowledge and practices across tools and people, as is the case with makerspaces, has fundamentally changed what it means to produce (Ito et al., 2008). Curiously, makerspaces breed the types of relationship-building practices that education scholars have imposed upon formal learning environments for decades. Since each makerspace is so closely tied to the community in which it resides, it may be particularly challenging to effectively scale these spaces; however, some variables are easier to capture and imitate. For example, any given makerspace is likely to have a wide range of members, who come with a diverse set of expertise, yet unite around the "umbrella goal" of making. Surveying makerspaces for practical understandings about features like distributed expertise will help inform how the space itself contributes to learning and will provide concrete guides to designing similar community spaces.

**Making as a Way to Learn**

Whether scholars believe learners conceive of ideas and relationships or learners act as conduits of social meanings and discourse practices, both constructionist and multiliteracies theorists assert that knowledge-building and meaning-making are iterative, cyclical design processes. Despite their divergent epistemologies, these theories converge at the design process. Constructionism lends researchers the tools to examine how one's knowledge is developed through the design process, and multiliteracies sheds light on how the community is shaped in the design process. One practical example of iterative processes in makerspaces is that members take things apart as fast as they put them together. The cyclical nature of design has shown to be effective at increasing content knowledge and transfer of knowledge (Fortus, Krajcik, Dershimer, Marx, & Mamlok-Naaman, 2005). Even more, Halverson (2013) argues that the production process itself provides ample evidence for learning.

Building knowledge in iterations through making echoes Papert's "debugging" (Papert, 1980, p. xiii) process, which he deems essential to intellectual activity. Even more, the Design framework of multiliteracies (New London Group, 1996) explicates how learners in makerspaces iteratively make meaning: makerspaces are full of a distinctive blend of "available resources" with which members "redesign" and hack to churn out new forms of media and, thus, fresh ways in which they can make meaning — expanding available resources. Makerspaces and new media have a reciprocal, self-sustaining relationship; new media shape makerspace communities just as much as makers mold and produce new media. For instance, 3D printers open the door to a whole new form of meaning-making and representation. While this medium isn't found only in makerspaces, one might find a maker building a larger 3D printer from scratch to craft representations of knowledge and meaning that were not possible with existing 3D printers. Makerspaces offer a unique opportunity for members explore new media through design and even conceive new literacy practices.

As new media, technologies, and tools continue to (re)shape the knowledge, practice, and participation of learners, they lend themselves well to distributed scaffolding and strategic inclusion/exclusion in learning environments. Both paradigms use technology, but neither is techno-centric. On the constructionist side, technologies act as a context within which learners can (re)make knowledge in more concrete ways (Papert, 1980). In contrast, on the multiliteracies side, technologies are literacy tools learners depend on to construct representational artifacts and practices (New London Group, 1996). These views are not incompatible. Scratch, a software design environment through which learners engage with "creative production" (Peppler & Kafai, 2007, p. 2), is one example of an attempt to practically integrate these two theories. The underlying goal of constructionist and multiliteracies scholars is to build learners' *design literacies*. By design literacies, I mean building learners' literacy in the process of design (or making) itself.

Technologies can be tools that support relational knowledge *and* literacy practices to enhance these design literacies. For instance, the Arduino and Raspberry Pi afford the knowledge-making process constructionism calls for and the participatory literacy practice multiliteracies requires. Makerspaces are littered with these microcontrollers and members use them across a wide range of projects. At Sector 67, members prototyped a large, LED sign that functions as an Arduino-controlled timer to limit members' speaking time during monthly meetings. Through the prototyping, members use the sign as an object-to-think-with to convey a specific message to an audience (other members). The resourcefulness demonstrated in these types of projects resonates with the converging idea that learners are bricoleurs (Cope & Kalantzis, 2000; Gee, 2012; Papert, 1993). Bricoleurs draw from available resources around them to design, make, and innovate. Distributed scaffolding (Puntambekar & Kolodner, 2005) is a practice that pushes bricoleurs' making process forward by fading resources out of the learning environment as design progresses. Making, like design, is a way to learn; scaffolding the tools, materials, and resources made available in a makerspace or learning environment is one method to support learning through making.

While available resources vary across makerspaces, makers are typically free to follow their individual interests. Whether they are creating artistic representations, trying out risky ideas, building new inventions, or launching entrepreneurial projects, members of makerspaces are still bonded together by their overarching interest in making. The interest-driven nature of making parallels the way in which constructionist and multiliteracies theorists imagine learning. Scholars of both traditions designate learners' freedom to explore interest as a crucial feature of the learning process. Moreover, seasoned makers also make for a purpose; for instance, as they encounter interesting problems in the world waiting to be solved, they find solutions. In more formal learning environments, learners typically learn how to solve a problem, but they have difficulty recognizing problems worth solving (Bruer, 1993; Sawyer, 2006). Makers do the opposite; they select a worthwhile problem and use tools, materials, and resources to investigate viable solutions, representations, and innovations. Situating learning in real-world contexts and problems is an intrinsic characteristic of makerspaces that aligns with situated learning theory (Lave & Wenger, 1991). As a learning process, making requires freedom to pursue interest and take ownership of ideas, problems, and innovations.

Both the natural synergy between constructionism and multiliteracies around design and the way this synergy exists in makerspaces testify that making is also a viable learning trajectory. Through participation in making processes and practices, learners build relationships with knowledge. Researchers have designed learning environments supporting this type of participation in and through a variety of contexts, for example, afterschool programs (Kafai, Peppler, & Chapman, 2009) and libraries (Ito et al., 2008, 2010). While these spaces are not identical to makerspaces, the socio-technological, situated learning processes and practices that happen within share many characteristics with the making processes and practices of makerspaces. Given the freedom and flexibility of makerspaces, learning does not necessarily look the same across spaces. Investigating how/whether learning is scaffolded in makerspaces will offer more concrete insights to making as a learning trajectory. With strategic design, we can draw on these insights to build learners' *making literacies,* particularly with new media and iterative design processes.

**External Artifacts are Evidence of Learning**

Constructing external artifacts allows a learner to more deeply explore an idea (Papert, 1993) and negotiate technology-mediated meaning (Gee, 2012; NLG, 1996). The ability to construct an external representation of a complex idea is the marker of intelligence across disciplines (Enydey, 2005). Researchers provide evidence for the connection between external artifacts and learning across myriad contexts including writing (Magnifico, 2010), digital art making (Halverson, 2013), creative media production (Peppler & Kafai, 2007), and e-textiles (Buechley et al., 2008; 2013).

If we play out constructionism and multiliteracies, we end up at the same point: external artifacts provide evidence of learning. On the one hand, constructionism says that the making of the artifact *is* the learning process, and that the artifact itself embodies the learning that happened. On the other hand, multiliteracies says that the artifact is a representation of self, so the learning happens in the (re)presentation of the artifact (e.g., a critiquing process). Basically, the former is concerned with building knowledge-based relationships and the latter with literacy-based representations.

Given the appropriate set of tools and resources, learners can make knowledge and make meaning in one process through *mixed multiple external representations* (De Vries, 2006). Making processes often entail creation of artifacts across several different media (e.g., written brainstorming, design drawings, talking through troubleshooting, etc.), and De Vries (2006) illustrates how these collectively make a "composite representational system" (p. 224) of learning. By blending constructionist and multiliteracies representational goals, educators can strategically interpret artifacts that learners produce in making experiences as evidence of learning. Educators can also scaffold the endless tools and resources available in makerspaces to guide learners toward specific goals.

New media change the way learners ‘make’ knowledge *and* the way they ‘tell’ knowledge, and this in turn changes the identities of learners (Barab & Duffy, 2000). Makers are persistently developing new media and literacies, which continually expands the methods and resources of expression of self. This practice has direct implications for the “representational trajectories” (Halverson, 2011) learners take in making. As new tools and resources become available, makers not only build corresponding expertise, but also explore their own identity through a new medium. The complex relationship between available resources and expression of self parallels the Design process of multiliteracies (New London Group, 1996).

One of the most notable ways that new media have changed identity-making paths is through entrepreneurship. The Internet has fundamentally changed the way in which one can become an entrepreneur (Anderson, 2012). Etsy and Kickstarter, which bypass the traditional pathway of mass factory production, are two entrepreneurial platforms that offer makers an opportunity to jumpstart their ideas and inventions. Made possible by new technologies, this shift has turned makers into entrepreneurs and drastically magnified makers’ target audiences. Recall that multiliteracies scholars have an overarching goal of designing social futures, particularly through fulfilling employment. This rise of entrepreneurship has fundamentally altered the social futures available to learners and the ways in which they achieve them.

Makerspaces are sites of rich experimentation and innovation where learners construct artifacts that provide evidence for learning content, process, and identity. Through making, learners build relationships with knowledge, communities, and even themselves; the relationships built are worked out through an iterative making process that results in the creation of external artifacts. In makerspaces, makers innovate new media, technologies, and literacies, which constantly expand the ways in which learning is represented and demonstrated. What does one learn from 3D printing? E-crafting? Launching a balloon into space? And how do the artifacts produced provide evidence of learning? As scholars examine making as a learning trajectory and consider makerspaces as learning environments, our understanding of learning and assessment of learning must adapt accordingly.

**Connecting Theory to Design: A Framework**

These three convergences of constructionism and multiliteracies not only establish that existing theory connects learning and making, but also reveal three underlying design threads shaping our understanding of learning in makerspaces: activity, identity, and community. Each thread cuts across the theoretical convergences discussed above. In this section, I outline how each thread connects theory and design, and use the maker movement as a working example to illustrate how the activity-identity-community framework can be applied.

Scholars agree that learning is an *activity*; constructionism and multiliteracies describe this activity as building relationships through design. These learning theorists support making as a way to learn and external artifacts as evidence of learning; thus, I define activity by both the processes and the products of learning. As such, *making* — using tools, materials, people, and other resources to engage in processes and make products — is the activity of the maker movement. As an activity, making is a learning process of building relationships with tools and people to construct external artifacts. Connecting back to theory, the making trajectory (process) and the artifact (product) define making.

Though the learner is situated differently in constructionism and multiliteracies, *identity* is an important thread weaving together their convergences. Identity scholars of both theoretical perspectives emphasize the significance of negotiating meaning through making as a representational tool braiding together an individual self with cultural values. A learner is defined both by herself *and* by the community in which she learns; even more, her identity is represented by the product that results from learning. In this sense, identity is exhibited through knowledge and representation; further, building relationships with knowledge, tools, and people becomes identity work, and the artifact functions as a representation of self. An active member of the maker movement takes up an identity of *maker*. Thus, the process by which one makes becomes the process by which one negotiates identity as maker, and the artifacts generated through this process are representations of the maker.

Across the theoretical convergences, constructionist and multiliteracies theorists take slightly different takes on community; the former focusing on the context in which individuals learn and the latter highlighting learning as a social act carried out within a community. Collectively, however, they offer a comprehensive perspective of the role of community as learners build relationships and make external artifacts; *community* consists both of the *context* in which and the *audience* for which one makes. Within the maker movement, the community context is the makerspace in which one makes, while the audience varies widely. An inherent characteristic of makerspaces is that makers are making *together* in some fashion — whether via "collaboration through the air" (Kafai & Harel, 1991, p. 88) or explicitly seeking help and collaboration from others. The community thread most appropriately translates to *makerspace* as the context in which makers make together to build relationships and artifacts.

Using the theoretical convergences of constructionism and multiliteracies as a platform, I map these three design threads onto the maker movement: making, maker, and makerspace. Given the complexity of the activity of making, I separate it into making trajectory (process) and artifact (product) for operational purposes. From the assumption that learning is building relationships, we are able to understand the maker-artifact relationship (drawing from constructionism) and the makerspace-artifact relationship (drawing from multiliteracies). These relationships align with the assumption that making is a way to learn by positioning the making trajectory as the construct negotiating this relationship, and external artifacts become clear evidence of learning. In other words, the connection between maker and makerspace is negotiated through the making trajectory and mediated by artifacts. Figure 1 visually represents the complexities of this relationship.

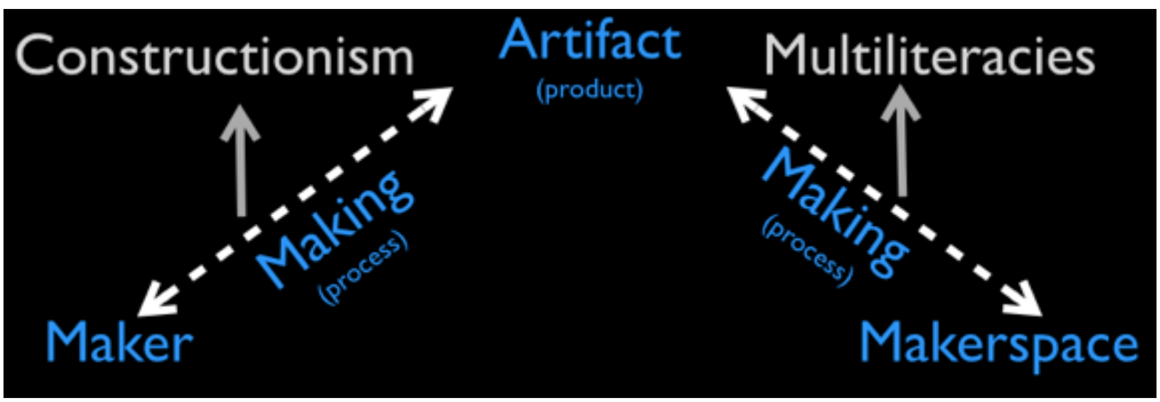



**Figure 1. Theoretical roots for the activity-identity-community framework.**

Weaving the theoretical convergences together with the activity-identity-community framework offers a rich design and analytic frame heavily rooted in learning theory. Applying this framework to the maker movement affords a deeper understanding of the movement by dissecting each thread one at a time. As scholars and practitioners continue to push the maker movement forward, it is imperative that we look more closely at each thread of the movement; there are: making trajectories and artifacts, makers, and makerspaces. Though collectively they make up what we've dubbed 'the maker movement', each thread can be designed and examined individually. For example, not every classroom can become a *makerspace*, since makerspaces require a community element that transcends the systemic limitations of a traditional classroom; instead, classrooms can offer fruitful *making* opportunities with comparable learning outcomes. Confounding making, maker, and makerspace threatens our ability to productively design or examine much of what is happening in the maker movement.

The activity-identity-community framework has utility beyond this application to the maker movement. I use the framework as my analytic frame for the comparative case study in this dissertation further illustrating its potential as a functional design and analytic tool. In future research, I plan to explore the affordances and constraints of the activity-identity-community framework to new contexts.

## Youth makerspaces as learning environments

The maker movement spotlights making as a viable way to learn, and scholars continue to explore and demonstrate what learning through making looks like across a range of contexts. So far, our current understanding of learning through making lacks a deep, cohesive understanding of maker communities. Constructionism and multiliteracies situate learning (and making) as happening in communities, not in isolation. Using the activity-identity-community framework above, I designate *community* as a main thread of the maker movement. Recall that designers of makerspaces identify community as the most defining feature of makerspaces (Baichtal, 2011; Britton, 2012a). Even so, there is a gap in our current understanding of how these spaces work, especially in regard to how they support learning.

As I demonstrate in the theoretical chapter, much of what we know about similar learning environments (e.g., YOUMedia and Computer Clubhouse) helps us understand how making communities function and the learning that happens within. Makerspaces, though, are unique in ways that we have not yet fully grasped. Researchers and practitioners are co-opting making as a learning activity without fully understanding the communities and cultures in which they are practiced. What features and characteristics of makerspaces make them different from other learning environments? Does making in a classroom mean that the classroom becomes a makerspace? Is it more than just the activity of making?

Our *Learning in the Making* research team has put forth the first effort to fill this gap. We conducted a comparative case study of three community makerspaces across the country and explored how these spaces may function as learning environments (Sheridan et al., 2014). We studied an adult hackerspace-type makerspace (Sector 67), a youth afterschool makerspace (Mt. Elliot), and a family museum makerspace (Makeshop). Through this investigation, we found that there is a uniquely diverse set of learning arrangements (e.g. individual projects, workshops/classes, and groups projects) present in makerspaces that distinguishes them from informal communities of practice or participatory cultures and formal studio-based learning environments. Through these learning arrangements, makers demonstrated a type of learning that transcends disciplinary boundaries. While the duration of making activity varied substantially according to sites, the three making communities emphasized learning as the process of making and regularly iterating and sharing their artifacts (Sheridan et al., 2014).

Each of these makerspaces also maintains some form of online community presence. Sector67 has the strongest online presence and hosts both public and member-only online forums. These forums function as a natural extension of the making community and the activities that happened in the physical space. In an in-depth discourse analysis of the public online forum, we found that most online exchanges were to encourage or solicit online participants to visit the physical makerspace (Litts, Bakker, Halverson, & Stoiber, 2014). Participants also used the online forum to distribute expertise and share resources to support making-at-distance for those working on projects outside of the makerspace. The makerspace community at Sector67 reaches beyond the walls of the physical space, which enables even more learning arrangements and forms of participation (Litts et al., 2014). The work of *Learning in the making* lays a foundation on which scholars can conduct additional research exploring the complexities of makerspaces as places rich with new forms of learning.

In this chapter, I seek to expand what we know about the communities and cultures within which making is practiced. Building on our findings about community makerspaces (Litts et al., 2014, Sheridan et al., 2014), I specifically examine *youth* makerspaces as learning environments. I present a comparative case study (Stake, 1995) of three youth makerspaces. Through this study, I seek to answer the questions:

RQ1: How do youth makerspaces vary as learning environments?

SQ1: What are the affordances and constraints of activities, identities, and communities exhibited across youth makerspaces?

I lean on the activity-identity-community design framework outlined in the previous section to shape my data collection and analysis. For this comparative case study, I operationalize each plane broadly with specific research questions:

*Activity*: What happens there? What processes and products are supported (through people, tools, & materials) in the space?

*Identity*: What identities are taken up and supported?

*Community*: Who is involved both directly and indirectly? What is the community context and structure?

In my analysis, I provide rich descriptions of each site according to each thread of this framework. Further, I complete a cross-case analysis in three chunks aligned with these planes: activity, identity, and community. From the analysis, I realize four key features that cut across the three cases in this study: activity structure, resources for making, equipping facilitators, and community ethos. Drawing on these features as typical of youth makerspaces, I discuss implications for design of makerspace-inspired learning environments.

## Method

I adopt a *case study* (Stake, 1995) research strategy to understand youth makerspaces as learning environments. Stake (1995) differentiates *intrinsic* from *instrumental* case study; in an *intrinsic* case study the goal is to understand the case itself, while in an *instrumental* case study the goal is to use the case to understand something else. I pursue both goals in this study. First, I conduct an intrinsic case study of each site by offering individual narrative accounts of each case. Second, I take an instrumental case study approach when comparing across cases; not only do I use this comparative study to inform the design experiment, but also to shed light on youth makerspaces more broadly. The evidence provided from each case is to serve the broader instrumental goal of capturing the practices and skills that exist across these youth makerspaces, and link these to the variances of structure and ethos of each space. Moreover, this is a *collective* (Stake, 1995) or *comparative* (Miles, Huberman, & Saldaña, 2013) case study in which I look at three different cases as illustrative examples of youth makerspaces — not to represent all youth makerspaces, but to provide insights to the affordances and constraints of the distinct models that exist.

The activities, identities, and communities of these youth makerspaces act as functional boundaries (Stake, 2008) defining each case. These sites are constantly iterating and evolving their structure and environment, thus, the data I present here provides an in-depth snapshot of the sites and is not meant to be all encompassing. Between site visits the makerspaces had subtle to major differences, which are melded together in this analysis. I am not investigating change of site over time, but rather comparing the affordances and constraints of the different site models according to their current state. Since my relationship with each site began at a different point, my familiarity with them varies; specifically, I know Makeshop extremely well from our collaboration through *Learning in the Making.* My main goal, though, is to gain a sense of how these three youth makerspaces function as learning environments.

**Site selection**

In this study, I focus on three sites: Makeshop at the Children's Museum of Pittsburgh, Assemble, and Millvale Community Library. I provide a thorough description of each site as part of this comparative case study, so here I give a brief overview of *why* these sites were selected for this study. First, I focus only on sites that engage experienced young makers in Pittsburgh. Second, we had an established relationship researching at Makeshop, so studying this space was convenient. Through our connection here, I cultivated relationships with Assemble and Millvale. Both Assemble and Millvale have a partnership with Makeshop, but neither have direct collaborations with the other. Third, each site offers summer programing for young makers, so they are active and lively during the time I planned to collect data.

Individually, each site brings forth a unique community structure of making and variation of project type and grain-size. Makeshop is a well-established museum makerspace primarily supporting drop-in making experiences. Assemble is a semi-established afterschool makerspace largely offering workshop-style programming. Millvale is a newly founded mobile makerspace within a small-town neighborhood library typically supporting drop-in making. During data collection, Millvale was in the process of transitioning from a mobile makerspace to a more permanent library makerspace. These three sites offer a diverse sample of the types (library, museum, afterschool, mobile/pop-up) of youth makerspaces emerging all over the country (e.g., Barniskis, 2014; Brahms & Werner, 2013; Petrich, Wilkinson, & Bevan, 2013). They do not represent the traditional hackerspace-type makerspaces that adults frequent, but rather they are examples of how informal spaces have embodied the maker movement to target young makers.

**Pittsburgh, Pennsylvania**

All three of the sites included in this study are located in Pittsburgh, PA. As the maker movement has gained traction in this country, Pittsburgh has actively and aggressively integrated making throughout its community. Maker programs across Pittsburgh are well-connected and often collaborate informally and formally through networks like Pittsburgh Kids+Creativity Network (remakinglearning.org), a collaborative working together to remake learning in Pittsburgh, and the recently established Hive Network (hivepgh.sproutfund.org), a network supporting Connected Learning opportunities at youth organizations across the city. Organizations like the Children's Museum of Pittsburgh act as hubs connecting maker programs, like those at Assemble and Millvale, across the city. Pittsburgh is rich with deeply connected maker communities and programs many of which are supported by the local Sprout Fund, a foundation that "supports innovative ideas that are catalyzing change in Pittsburgh" (www.sproutfund.org). Earlier this year, the Tribeca Disruptive Innovation Awards recognized the entire city of Pittsburgh for its "forward-thinking education initiatives" targeted at making (Tribeca Disruptive Innovation Awards, 2014; Zook, 2014). President Obama has even called on Pittsburgh for advice about developing and sustaining maker communities; in June, Pittsburgh Mayor Bill Peduto hosted a roundtable to compile resources and information to pass along to the President (Nath, 2014).

Within such a fruitful maker city, residents have many opportunities to engage with making across contexts. For instance, during my first visit to Millvale I met a family—mother, son (~5 years old), and daughter (~3 years old)—who spends many afternoons at the library *and* visits Makeshop at the Children's Museum of Pittsburgh at least one day a week. While this example may not be representative of the city, it is an illustration of the cross-site engagement that is possible, which ultimately is what attracted me to the city.

**Data Collection and Analysis**

I used the qualitative techniques outlined by Miles, Huberman, & Saldaña (2013) to shape and guide my data organization, collection, and analysis. I collected a range of data for this comparative case study, which resulted in over 60 hours of field observations and interviews. Additional data includes photo, video, and audio documentation of makers' artifacts, making activities, and makerspace interactions, and supplemental information accessible via the sites' online presence. I used the following data in this comparative case study:

| Data type | Makeshop | Assemble | Millvale |
|---|---|---|---|
| Observation | 15+hours | 15+ hours | 15+ hours |
| Photos | 67 | 105 | 107 |
| Interviews | 2 | 2 | 3 |
| Field notes | 5+ days | 4 days | 3 days |
| Website | Yes + blog | Yes + blog | Yes + blog |

Since I had a different level of familiarity with each site, I aimed to have a minimum of 15 hours of observation (which included photo documentation) across each space focusing primarily between January 2014 and July 2014. The goal of the observations was to understand: the layout of the space, who comes, what activities happen, and the general flow of the space — essentially, how patrons engage there. I interviewed the site director and at least one program coordinator at each site (see Appendices A and B for respective interview protocols). At Millvale, I interviewed both program coordinators, since they worked as a team throughout the summer. The goal for the site director interviews was to gather the foundational story of each space and the general ethos embedded and maintained within the space. On the program coordinator level, the goal was to capture how this is practically enacted within the space.

Observations and documentation are meant to capture how young makers in the space take this up (or not). All three sites have a strong online presence hosting their own websites. From June 2014 to August 2014, I thoroughly investigated each makerspace's website, blog, and other available documentation (calendar, mission statements, values, floor plans, etc.) to get a sense of how the space presents itself publicly.

I followed Emerson, Fretz, and Shaw's (1995) ethnographic jottings, fieldnotes, and memoing practices. I took jottings, photos, and (where appropriate) audio recordings for real-time observations, wrote fieldnotes as soon as possible after the field visit, and tracked themes with memos; I also recorded my remote interactions (via email and phone) with each site. I primarily maintained an observational stance throughout data collection, though I did participate in some of the drop-in activities across sites. For example, I completed a soldering kit at Makeshop.

I lean on the activity-identity-community design framework to shape my data collection and analysis. I rely heavily on data describing the activities observed and declared to happen in the space, the identities demonstrated and articulated in the space, and the features and characteristics of the makerspace as a community. For my analytic framework, I interpret data from this comparative case study by operationalizing each plane as follows:

*Activity*: What activities happen? What processes and products are supported (through people, tools, & materials) in the space?

*Identity*: What identities are taken up and supported?

*Community*: Who is involved both directly and indirectly? What is the community context and structure?

Using the activity-identity-community framework broadly allows me to build a cohesive understanding of how each site functions.

I used the Text Analysis Markup System Analyzer (TAMS Analyzer) tool for analysis. TAMS Analyzer is an open-source qualitative research tool designed for ethnographic and discourse research, and it affords basic coding of text and multimedia data. It is well suited for my analysis, because it allows quick and easy cross-data views using comparative tables or "matrices" (Miles, Huberman, & Saldaña, 2013) linking directly back to data in-context. Also, TAMS Analyzer simplifies conducting several rounds of analytic coding through building 'code sets'.

Using this tool and following Saldaña's (2009) coding methods, I completed numerous rounds of coding. In "first cycle coding," I conducted line-by-line initial coding using elemental methods, primarily a combination of in vivo and descriptive coding (Saldaña, 2009). With this, I moved to "second cycle coding" employing provisional coding exploratory methods using the activity-identity-community as the guiding "chunks" (referred to in TAMS as "code sets"). I then completed more focused code-driven methods to further develop existing codes; take the following data chunk as an example:

> Well, I mean the Make Shop [at Millvale Community Library] is pretty much geared toward kids. It's rare that we have adults want to take part and when we do the adults are parents of the kids. So, we focus a lot of our activities here on kids. I mean we do appreciate our adult patrons and we try to provide programming for them, but the kids are really our primary mission in all respects here. (Luke, Interview, 07/31/2014)

In the first cycle I coded this chunk "mission" (among other codes like "kids" and "demographics"), and in the second cycle I added it to the "community" analytic frame code set.

I then used the “mission” code to guide a round of line-by-line coding through all the data to ensure that all instances of “mission” were captured with the code. Later, I separated the “community” code set into “internal” (e.g., space and demographic) and “external” (e.g., partnerships and neighborhood) code sets. In this process, the “mission” code was folded in with other codes (e.g., goals) to become “ethos.” The “internal” and “external” code sets then became sub-code-sets of an overarching “Community” analytic frame code set.

When codes did not directly or easily connect with the activity-identity-community framework, I continually compared them across data sources and sites. For example, the code “funding” came out of a first cycle In Vivo coding, but did not smoothly connect to the analytic frame — at that point, it would have been a stretch to add it to the “community” code set. When I conducted a round of focused coding for “funding,” it was evident across data sources and sites; thus, I developed it as a theme separate from the analytic frame. Other themes include: Accessibility, Digital vs. Analog, Freedom (of facilitation), Open Structured (making activities), Ownership, and Time. Many of these themes are discussed in the findings alongside the analytic frame, yet some are backgrounded or dropped completely; for instance, the code “Time” was eventually dropped, because it only occurred once across all data sources and sites, and the context in which it occurred was brief and non-descriptive.

Throughout analysis, I oscillated between bottom-up (e.g., In Vivo) coding and top-down (e.g., analytic frame) coding working to build a bridge between the two. Using TAMS Analyzer, I easily and iteratively compared codes and code sets by data source for within site descriptive analysis and by site for between site comparative analyses throughout the coding process.

# Findings

In the following chapter, I first offer a composite narrative description of each space primarily based on ethnographic fieldnotes and website documentation. These composite narratives serve a functional purpose of providing an overview of the space including: geographical location, spatial layout, materials and tools, people, projects, and interactions, as well as capturing the 'feel' of the space. Next, I provide more historical context and general ethos of each space primarily based on interviews. With this, I describe the sites by using the activity-identity-community framework. Finally, I leverage this framework to compare across sites, and draw conclusions and discuss implications for makerspaces as learning environments.

## Makeshop

On Pittsburgh's North Side, driving around the Allegheny Center square I turn onto Children's Way and into a parking lot: $4/day for members and $6/day for non-members. The sign explains that I must pay at the front desk to get my ticket; at first I found this odd, but I suppose it's how they control the use of the parking lot. Other than a parking garage for the business offices on the opposite side of the square, I didn't see any other parking options, so I park in the lot under a giant fish sculpture. Though I'm still in Pittsburgh, I feel an eerie distance from the hustle of downtown and vibrancy of other neighborhoods. Aside from the elementary school across the street and some apartments down the way, unmarked business buildings dominate the square. I begin walking back through the parking lot, past a fenced-in outdoor garden and playground attached to beautiful historical building, and continue around the corner back up Children's Way. I stop at the beginning of a well-manicured courtyard with tall thin pillars off to the right spewing mist in a different direction every few seconds. Curiosity tempts me to take a closer look, but my gaze is quickly broken by a group of kids cheering for a "Green

Roof Roller Coaster" above our heads to the left; the I look up and notice the cars are full of plants. The sign below the roller coaster reads "Children's Museum": Welcome to the Children's Museum of Pittsburgh.

I walk up the ramp along a wall of windows and through silver automatic doors. Inside a large group of kids are being shuffled past big blue bins where they drop off their coats in one and lunches in another. I go to the front desk and explain that I am visiting a friend, and they provide me with a visitor nametag; otherwise I would have had to pay. Down a ramp to my left is an art room where kids are painting and building with clay and up a ramp to my right is a large cafeteria. I walk up a ramp in front of me past a multi-floor padded play area offering little people an alternative ascending and descending route between Museum floors. There is a large wooded wall with "MAKESHOP" five times in graph paper print. Past the wall is a large 1,800 square foot room sectioned off into three public spaces. In this first carpeted room, a few young kids sitting next to a "Build-It" sign are attaching precut and holed panels of repurposed material with screws and bolts. Down the room from them a mom and her young girl are playing with puzzle pieces on a tabletop that appears to be changing the scene projected on the wall in front of them. I overhear a Teaching Artist[3] ask the couple, "I see you're interested in this, do you have any questions?" Over in the corner of this room, two small children — no older than three — are on top of a wooden box

[3] Name of the Makeshop staff

connecting clear PVC pipes colored by lights shining through the holes in the wood. On the wall above their heads, I see a sign: "What do you want to make today?"

Hardwood floors and steel framing with a plywood wall between two posts allow free movement from this "introductory area" to the "flexible shop." On the wall hangs a framed sign titled "Welcome to Makeshop" with a description of the space highlighting phrases like "materials and tools," "make things together," and "you are a maker."

Walking onto the hardwood floor, I notice a sink on the left wall below shelves exhibiting various projects. The far left corner is made of windows allowing much needed natural light into the space; an art installation of colorful zip ties attached to steel pieces in the shape of a star hangs in the corner. Below that is a large wooden floor loom where a Teaching Artist is teaching (as-needed) a kid how to weave with different materials. Along the back wall are shelves of yarn and thread perched above a table of more materials, and in the far corner is a RotaBin of recycled materials.

Two tables sit in the center of the room. The first table in front of me is full of circuit blocks with a family busily connecting alligator clips to nails making and breaking circuits with motors, lights, and switches to see what happens. The mom instructions her son to connect "red to red" and helps her daughter, who is sitting on her lap, connect "black to black." A "Circuit Blocks" sign with a brief description of circuitry sits unnoticed on the table. A Teaching Artist challenges another girl at the table, who just completed her first circuit with a light, to "add a switch" to her circuit. The table toward the back of the room is a bit bigger and is filled with sewing materials: thread, yarn, fabric, scissors, etc. Two signs sit on this table: one titled "How to thread a needle" with step-by-step instructions and the other titled "Soft circuits" with more descriptive information. Despite the excitement echoing throughout the Museum, the kids here are intently focused on their projects, even as kids flow in and out of this space around them. In addition to the large sign hanging overhead, the message "What do you want to make today?" is duplicated several times on signs throughout the space.

The final room, the "workshop," is sectioned off by large wooden-window walls, one of which slides as a door. This allows the whole room to be closed off to the public, yet permits them to still see what is going on inside. Inside this room are two large tables bordered with several stools. To the right are a sewing machine station and a shadow box puppet show station. Along the back wall are a laser cutter and a 3D printer along with several wood working tools and materials. Along the wall to the left is a second RotaBin full of recycled materials, a stand full of all types of tape, and a large workbench with soldering irons, glue guns, and other tools. Perched above the workbench are more jars of materials from plastic battery packs to LED lights to recycled bottle caps to paper clips. On the wall are magnetic tin cans with nails, screws, and other smaller materials.

Several items sit on the table, including scissors and a couple of metal trays filled with various recyclable and cheap materials. Two teen girls are making a robot and a unicorn out of plastic jars, fabric, pom pom puffs, construction paper, and other crafty materials. Across from them a teen boy, who wanted to learn to solder, is practicing by soldering together a wire dog.

Behind this room is a fourth, smaller room blocked off by a waist-height accordion gate. This room was full of even more materials: woodworking, batteries, etc. Around the corner is a small desk with a computer buried under… lots of stuff. As I left this area, some of the Teaching Artists were setting out woodworking tools and materials on the tables for the afternoon woodworking drop-in workshop. One of the Teaching Artists mentioned that she was excited to use the laser cutter as part of the workshop.

As a Museum makerspace, Makeshop invites visitors daily from 10am-4:30pm to make something in an "open-ended and casual" environment. Welcoming people of all ages, Makeshop is specifically designed for families with children up to age 12 to "play with real stuff." A team of Teaching Artists helps visitors "translate their visions into tangible objects" by engaging in the same tinkering and prototyping processes through which Makeshop itself was designed. The physical space was constructed from wood and other repurposed materials; attachments and fasteners were left exposed "to tell the story of how things are made." While Makeshop is bound within the Children's Museum of Pittsburgh, it reaches beyond restraints of traditional museum exhibits through after hours and outreach programs.

**Activities.**

The range of activities that happen in and around Makeshop is overwhelming for an 'exhibit space' situated within a Children's Museum; the boundaries between making-related and non-making-related activities are relatively clear. Thus, I focus specifically on what happens in Makeshop. A majority of the programming offered at Makeshop is relatively open-to-the-public, drop-in style; however, there is a range of programming beyond this:

| Program | Description | Age | Cost | Frequency | Duration |
|---|---|---|---|---|---|
| Open-access, drop-in | Day-to-day programming set up available on the floor in Makeshop | No target age — all Museum patrons welcome | Museum admission or membership | Rotates either for a limited number of days (e.g., shadow puppets) or nearly-all-the-time (e.g., circuit blocks) | Minutes to hours |
| Limited-access, drop- | More in-depth making activities | No target age — all | Museum admission or | Varies widely and rotates frequently, but | Typically an hour or more |

| | | | | | |
|---|---|---|---|---|---|
| in | (e.g., woodshop) often in the workshop space that are inherently limited by space and safety | Museum patrons welcome | membership | also open according to interest (e.g., soldering) | |
| Schedule, open-access | Workshop-style format without space or safety restrictions (e.g., Maker Story Time) | No target age — all Museum patrons welcome | Museum admission or membership | Set timeframe, but duration and frequency varies according to Museum schedule and staff expertise | Minutes to hours |
| Scheduled, limited-access | Workshop-style format where participants are expected to sign-up and engage the whole time (e.g., laser cut stamp design) | No target age — all Museum patrons welcome | Museum admission or membership | Set timeframe, but duration and frequency varies according to Museum schedule and staff expertise | Typically an hour or more |
| Field trips | Class visits, scheduled groups, and professional development | Usually school-aged, but also adults | Varies | Varies/Custom according to needs | Typically an hour or more |
| Youth Maker Nights | After hours casual, open programming | 10-15 | $10/($8 for members) | Monthly | Two hours |
| Youth Alive/Club Make | Afterschool, semi-structured, regular participation expected | Grades 6-8 | Free for kids attending neighborhood partner school | Three days per week during the school year | ~45 minute chunks |
| MAKEnight | After hours casual, open programming | 21+ | $15 pre-sale/($12 for members; $17 at the door) | Quarterly | 3 hours |
| Special Events | Usually after hours events, often contracted, that include Makeshop in some way (e.g., Birthday parties, Father/Daughter Dance) | Varies widely | Varies | Varies/Custom according to needs | Typically an hour or more |
| Outreach | School, library, and other community organization partnerships often in the form of “mobile makerspace” | Varies widely | Varies | Varies, usually consistent throughout school year | Minutes to hours |

While all tools and materials are usually available to suit visitors' interests and project ideas, Makeshop has developed a portfolio of program offerings. Aside from after-hours events and field trips that are often crafted by request, much of what is offered depends on the Teaching Artists' individual interests and expertise. For example, Derek, a Makeshop Teaching Artist, is known as the joinery and woodworking guy, and he is given time to explore this interest, develop his expertise, and even prototype joinery activities as part of the rotating schedule of Makeshop activities. Through staff sharing and professional development, Teaching Artists enjoy freedom of ownership over Makeshop activities, as Hillarie, the Makeshop Manager, details:

> I want people thinking of new activities or like how can you do that as a workshop or how can we do that as an outreach. So from that perspective just being able to support that [pursuing their own interests] grows everything from there, and then there's a sense of ownership from the team whoever's instigating it, and then if they're sharing it then everybody feels onboard and everybody buys-in and is like I want to do outreach with this, because I developed this program, and I want to test it in schools or I want to do this workshop. (Hillarie, 07/30/2014)

Investing in Teaching Artists in this way keeps Makeshop programming fresh and exciting, though it comes at a cost. Hillarie recalls the trade-off when a former Teaching Artist left,

> He was like the 3D printer guy, so one of his passions was 3D printing. And so he sourced us like this Solidoodle printer — we have I think it's on like permanent loan from the ETC — and a Makerbot Replicator Dual, but he was really the one who loved like tinkering with it and tweaking it…We actually just had him come in two weekends ago? The 18th and 19th? Because he had all that knowledge in his head, he wrote up some stuff, but I asked him 'would you do a staff professional development in the morning so

> that we all can learn?' So that was something that we actually asked him to come back to train us on that, because it did go with him. So maybe now — also the printer had to be fixed — but maybe now that we're all a little more aware, maybe that will be something that comes back into the offering. (Hillarie, Interview, 07/30/2014)

Hence, many of the activities, tools, and materials readily available and visible for visitors are dependent on the interest and expertise of the Teaching Artists. That said, Makeshop displays to visitors nearly all materials and tools; their visibility is largely scaffolded based on sustainability and/or safety. For instance, the batteries and saws are some of the few materials kept in the small back room of Makeshop, and even as access is restricted, they are still somewhat visible.

Moreover, the range of tools and materials available at Makeshop is wide and deep enough to support all types of making activities. What's most interesting is the way the availability of tools and materials are scaffolded according to practices and skills: circuit blocks teaching basic circuitry and hand weaving introducing sewing are freely available as part of Makeshop's open, drop-in flexible shop. As visitors' interests deepen, they can move deeper into the workshop where a different set of tools and materials is available; here, they can solder their own circuit or sew their own creation.

Hillarie elaborates on the process by which Teaching Artists guide visitors through the space:

> It's not like there's a one-to-one ratio or something with the visitors, but ideally there's somebody there who can kind of assess where you are and then guide you through it. So if you have an idea, it's determining what your needs are in terms of tools and materials. If you don't have an idea, guiding you through the thinking process and then through the

> tools and materials, but just figuring out where you're at and where you want to be. Or where you need to be to make the next step. So I think that is the process and the facilitation side is all process. (Hillarie, Interview, 07/30/2014)

Thus, the intentionality behind the design of Makeshop from the training and support of Teaching Artists to the visibility and availability of the tools and materials coalesces around engaging visitors with a process. Since the focus is on learning the process, when a product is made it is most often taken home and, with few exceptions, rarely left in the space. Consequently, while much of the making process is often collaborative in some capacity, the products are more often individual.

**Identity.**

Like the Teaching Artists, visitors are also supported to explore and develop their own interests and expertise. As such, Makeshop supports individual identities through the making process, yet more broadly inspires visitors to think of themselves as "makers." For instance, at the entrance of Makeshop, visitors are greeted by a sign declaring:

> Welcome to MAKESHOP this is a place to mess around with tools and materials, play with ideas, and make things together. We inspire makers of all ages to explore MAKESHOP. For your safety some experiences will be limited in capacity and age level. No matter your age, we believe YOU ARE A MAKER.


Even more, "what do you want to make today?" signs sprinkled throughout the space push visitors, of all ages, to think of themselves as someone who can make. Within Makeshop, makers are defined simply as those who make — anything. No matter what one's interest is, the space is designed to encourage visitors to "play with real stuff" from introductory to advanced levels and make something.

Makeshop Teaching Artists come alongside visitors and support them on an as-needed or as-requested basis. Otherwise, they're busy making and working on their own projects. They're all trained to engage visitors in the same process, though there is variation in approaches and content-areas between Teaching Artists, so not all offer the same experience. For instance, a Teaching Artist, who is more drawn to thinking about joinery and attachment, can provide deeper support for woodworking processes than can his peer, who is obsessed with the laser cutter and more suitably supports multimedia design processes. Collectively, they all work to expand conceptions of what it means to be a maker and empower visitors to do the same.

**Community.**

Makeshop, as part of a Museum, is a community space in a broad sense, in that, it attracts visitors across the city, state, country, and even internationally. For those who come regularly, the Museum functions as a "social hub" connecting people from across the city, and at times yielding relationships that exist outside Museum walls. Many regular visitors with young children (under age 5) maintain memberships at the Museum. Residents in the surrounding neighborhood are not typical patrons to the Museum; Hillarie expands on this issue:

> It's actually not a lot of people from the neighborhood, which is a struggle that we have, and it's something that there's interest and work to kind of figure that out. But because this is a lower-income and lower-economic area, and we are a Museum that has fairly high admission, it's prohibitive. (Hillarie, 07/30/2014)

One initiative Makeshop has contributed to this effort is afterschool programming for the school across the street. Other programs, like Mobile MAKESHOP, support local partnerships with schools and out-of-school learning environments like with Millvale Community Library.

Makeshop exists to build a community of makers on the micro-level with each visitor experience and on the macro-level with other making-focused organizations. Many key partnerships are funded through national grants; Makeshop itself was born out of a partnership between the Children's Museum, Carnegie Mellon's ETC program, and the University of Pittsburgh Center for Learning in Out-of-School Environments. The Children's Museum of Pittsburgh, and Makeshop in particular, is recognized across the country for its excellence. They act as a local and national hub for making practitioners and researchers and host Pittsburgh's Mini Maker Faire and the National Research Meeting on Making and Learning.

**Assemble**

Driving down Penn Ave into the Garfield neighborhood, I'm welcomed by a Family Dollar Store and blocks of construction orange occupying your typical parking space. The block is lined with temporary "No Parking" signs forcing me to park on a side street, though I notice quite a few cars whose drivers seemingly ignored the posted signage. The 'safe' side of the block is temporally managed by one-hour parking signs pressuring me to park on the 'dangerous' side of the block around the corner. Sure, it's frustrating, but the location kindles a sense of fear when I look down the block at a park where a teenager was shot and killed just weeks prior. With heightened awareness, I catch myself locking my car twice as I walk up the block toward my destination. Passing tattered and worn storefronts, I arrive at one with a fresh coat of orange paint and floor to ceiling (unbarred) windows: Welcome to Assemble. In addition to the posters decorating the outer windows, the center window displays a decal: "assemble a community space for arts + technology."

I open the door and step into a large (over 30 feet long and 15 feet wide) open room complete with wood floors and various art-installations on the walls. At the far end of the room, kids are sitting around two large rectangular tables wrapped in paper. I wonder: 'What *is* this space?' Listening in, I hear the kids' plans to construct an alien version of the game *Operation* and see them mapping out their ideas on the table. A facilitator sitting at the table with them is pushing their brainstorming: “you need to think about the shape of it.” The front of the room from which I entered is completely empty and open, except for an art installation of animal, charts, graphs, and map combination overlays painted on rice paper on the wall to the right. The chalkboard wall to the left is playfully covered in messages and ideas of various types. It feels very different from when I was here about two months ago and there were kids’ projects exhibited *everywhere* (even hanging from the ceiling). The local artists’ projects on display feel disconnected from what the kids in the space are building and making, whereas when the kids’ projects were displayed it gave a glimpse into the youth making that happens and what is possible in the space.

Moving to the back of the room and toward the kids is a bit awkward. Along the way, I pass a table exhibiting the projects they’ve made throughout the day: cyanotypes, ‘bugs’ made out of recycled materials, and painted paper cars. All the projects look similar and resemble grasshopper-like critters, though each has unique twist of creativity and varies, for example, in size, color, or bug features. To the left, there’s a staircase going down… somewhere? It’s blocked off with string and a ‘Do Not Enter’ sign. For a fleeting moment, I wonder what’s down there, but notice on the wall next to the stairs hangs a second art installation of glass tiles with navy blue silhouettes painted on them.

Opposite this installation across the room is a table full of flyers of all types: programming information and community information, making and non-making related. Next to the table there are two large papers taped to the brick wall: one labeled “Rules” and the other labeled “Punishments.” The list of rules was long and written in different colors hinting that, perhaps, it is a living document to which additions are continually made. Some rules that catch my eye: #2 All eyes and ears on the teacher, #5 Stay in your seat, and #10 Raise your hand and wait to be called on. “Have fun! :)” ranked #8 on this list, and more peculiar rules like “don’t die!” were sprinkled throughout. There are few punishments, but varying in severity from sitting out on the next activity to your grown-up getting a phone call with ‘sit in chair of shame with hat of shame’ falling in the middle. I wonder again: ‘What *is* this space?’

Strolling around the table that the kids are working at, I see their hand-drawn outline of an alien, who will of course be green, and the facilitator explains what materials they will be using. Behind the kids, at the very back of the room, is a steel-grey sliding door with a sign detailing that access is only permitted with an Assemble staff member. The door is slightly open, so I peek in; the room is fairly small, but full of an array of equipment: an iMac, laser cutter, 3D printer, LED lights, wires, Makey Makeys, hand tools hanging on the walls, and boxes of supplies on metal storage racks on either side. I see hanging on the wall I see a large poster demanding “Students & teachers, Do Not Forget To Clean! Take 15-30 minutes to help. [heart] Assemble.” On the wall outside this room is a third art installation of bottles of all types with messages inside complete with paper and pencils to write one’s own message and contribute to the art.

This installation ends at a doorway. I push the curtain to the side and walk back entering a small space labeled “Volunteer Central,” which continues into the next room. Along the wall to the left there are inboxes and outboxes, several manila envelopes (labeled: evaluations, learning party, etc.) pinned to cork boards, clipboards, a first aid kit, portable filing cabinets, a whiteboard displaying another “Don’t Leave Without Cleaning!!” sign, and many other odds and ends. To the right are aprons hanging and two floor-to-ceiling metal storage racks full of supplies in meticulously labeled storage containers of all sizes: permanent markers, adult scissors and hole punches, rubber bands, clay and tools, stencils and decorative punches, balloons and pumps, electrical batteries & misc., e-textiles, Alka-Seltzer + food dye, special paper, etc.

Entering into the next room I see about four more metal racks with supplies and more storage containers, though these are labeled a bit differently: ice cream, spectroscopy & assemble, terrarium, etc. Also, attached to this room is a full bathroom — though the colorful, paint-stained shower is hardly suitable for washing — and a storage closet full of cleaning equipment. In the middle of the room is a kit-made cardboard rocket ship dripping blue paint onto layers of newspaper. One of the walls has a hand-drawn map of the Garfield neighborhood labeled “A Place of Hope.” There is larger equipment scattered about: large tables, fans, a crockpot (because… why not?), a dolly, and a large robotic input-output machine of some sort with a ‘temporarily out of order’ sign stuck to it. Taped on the doorway to the back room are two pieces of paper cluttered with additional post-it notes outlining ‘to-dos’ for the teen interns and stipulating “no ‘YouTube’ or Chromebook usage until ALL of this is done!” for the teen interns.

The last room in the space resembles an office. To the left, there are three computers on a large corner desk, several chairs, a bookshelf scattered with office supplies, and a wall full of colorfully painted clipboards each labeled for a different purpose. Appropriately, on the chalkboard next to the bookshelf there’s a sign: ‘Don’t Forget To CLEAN!” A handful of teens are hanging out at the computers and in chairs, chatting with each other, and evidently ignoring their assigned ‘to-dos’. Next to the desk is a stack of 18-pack Miller beer — they must have a lot of trust in these teens, I think. To the right, there is a sink just as paint-stained as the bathroom with two signs above: “DO NOT LEAVE PAINT BRUSHES IN THE SINK! Or Leslie will eat you!" on lime green duct tape on the wall and "these dishes are not for food" on the chalkboard cabinets. There's also a door in the back right corner that leads to a steel balcony and overlooks an alley between the shared backyards of the neighborhood. Down the way to the left in the distance I can see the street where I parked my car, and I'm reminded where I am. Inside Assemble my heightened awareness had subsided — nearly forgotten — almost as though I'd escaped to a refuge of sorts.

As a neighborhood out-of-school learning space, Assemble embodies an ethos of *community*. The founder, Leslie, speaks about Assemble as a "platform for artists, technologists, and makers," and the website expands "a platform for experiential learning, opening creative processes, and building confidence through making." The physical space itself can transform from a makerspace, to art gallery, to party venue all in a single day. Thus, there are many stakeholders to please: artists who display their art monthly for a fee, kids who participate in programs, and community members who rent the space. On a first walk through, it very much feels like a "platform" prompting the 'what *is* this space?' question. It's not just a youth afterschool program and it's not just a makerspace… it's a platform on which a community of artists, technologists, and makers share and build with each other.

**Activities.**

Leslie describes Assemble has having three main "bubbles" or activities:  showcase, educate, and incubate. Thus, the lines between making- and non-making-related activities are fused together by these verbs.

The main room at Assemble showcases a different set of two or three art installations for three weeks every month as part of the Unblurred Gallery Crawl happening the first Friday of every month. Leslie describes how the cycle involves more than just wall space:

> Every show in our space has to be interactive and engaging in someway where people are *doing* things. And then there's like an artist talk or workshop at some point in time throughout the month, so there's a way of opening the how, the why, the how can I do that to. (Leslie, 07/24/2014)

Artists, makers, and technologists showcasing in the space are expected, as "experts," to educate the community in someway about their pieces, styles, or methods. Exhibitors are also encouraged to incubate their ideas by trying them out with the youth in order to improve or iterate. Leslie offers a tangible example of how this takes shape, "So, we've had like Create Lab, who is a robotics group at CMU [Carnegie Mellon University], come and have the space for the month, and like they have their robots everywhere — you can play with things." Thus, the main room of Assemble is used simultaneously as a showcasing space and as the central making space for youth programming.

Candice, a contract-based employee, explains that when she started at Assemble, "it wasn't set up where I had trainings or anything like that, so I had to teach myself to use the tools, which is fine. There was a learning curve and I'm okay with that." Facilitators at Assemble do not receive any structured pedagogical or technical training, but Candice explains that the trade off is she has "a lot of freedom" to do what she wants with the programming she develops. This freedom of facilitation results in a range of programming offered for different purposes and demographics and at varied costs and time:

| Program | Description | Age | Cost | Frequency | Duration |
|---|---|---|---|---|---|
| M3 (Materials, Media, & Me) | An artist or technologist uses a STEAM educational approach to explore a new material with which kids will make a take-home creation. | "Children" (age unspecified) | State and federal funding sponsor | Sporadic | Hours |
| Make It! | A making series for youth to gain experience with soft, hard, and smart materials. | "Tween" $6^{th}$-$9^{th}$ grade | Shared grant with Children's | Once weekly, with optional | Hours to weeks |

| | | | | | |
|---|---|---|---|---|---|
| | | | Museum | drop-in | |
| Youth Maker Night | A making series for youth to hang out and create something in a community | "Tween" $6^{th}$- $9^{th}$ grade | Shared grant with Children's Museum | Monthly | Two hours |
| Saturday Crafternoons! | DIY workshops with local makers that promote project-based learning, hands-on making, experimentation, and community engagement for youth. | Ages 5-10 | Grant sponsored | Weekly | Minutes to hours |
| Teens as Teachers | A class through which teens learn how to implement STEAM programming in their schools and communities. | Teens | Grant sponsored (stipend offered) | 6 sessions | N/A |
| stART | A sensory color adventure inspired through song, books, light, and water tables. | Ages 2-3 (+adult companion) | $15/class or $60 for 5 classes | Weekly | Minutes to hours |
| Learning Parties | Station-based activities facilitated by local experts for local kids to look, learn, and make. | Neighborhood kids (Ages 3-14) | Free | Monthly | Minutes to hours |
| Classes/ Workshops/ Birthday parties | Choose from a range of options all offering $21^{st}$ Century skills and STEAM. | Custom | Varies | Private scheduling | Varies |
| Make and Take | Make and take activities Assemble brings to an external location/event. | Custom | Varies | Private scheduling | Varies |

Many of these programs are modeled after traditional school classes, and the facilitators use matching language (e.g., "teacher," "student," "lesson plans") and practices to suit. For instance, in establishing rules and punishments at the beginning of a STEAM camp, one of the facilitators prompts "what are some of the rules you have in your classroom?" to encourage the kids' brainstorming. Many of the maker-related activities manifest as make-and-take projects planned, organized, and implemented by the facilitator. From experimenting with milk-painting, to collecting leaves in the park for a placemat project, to building bugs out of recyclable materials — rarely do projects span longer than a couple of hours. With some exceptions, most youth programming takes on this structure.

The Make It! program, for example, takes a more scaffolded approach in three roughly one-month phases introducing soft, hard, and smart materials and culminates in a project that combines elements from each phase. Another instance of a more in-depth project structure was when the Saturday Crafternoons! kids partnered with an expert carpenter to build a Little Free Library for the neighborhood. Additionally, outside of the programming, volunteers and facilitators work on smaller-scale projects typically contributing back to the space. For instance, in addition to cleaning and organizing, teen interns were tasked with making photo booth props, including assembling and painting kit-based rocket ship, for the upcoming Maker Party hosted by Assemble.

All tools and materials are stored in the “maker room” and in the back room, essentially, making them invisible to the newcomer. While the tools and materials are not publicly visible, they are well-organized; reserve materials and even kits of ready-to-go supplies for specific activities, like building terrariums, are stored in clearly labeled plastic containers in the back room. The maker room houses most of the tools Assemble has to offer, for example: laser cutter, 3D printer, sewing machines, woodworking tools, Makey Makeys and other micro controllers, and an iMac. Assemble has such a wide range of tools and materials available to support a range of activities from crafting to woodworking to electronics to sewing. One of the facilitators explains that, even with these seemingly well-organized materials, it gets frustrating sometimes because it’s difficult to find what you need, and the artists who exhibit can sometime be demanding about how the space looks, so tools and materials cannot be stored in the main room.

**Identity.**

At the broadest level, Assemble fosters identities of artists, makers, and technologists as experts of the space. The focus on arts, making, and technology is rooted in Leslie’s understanding of STEAM learning: “art is how we communicate things” and “technology is the stuff that we create,” and Assemble lives in the “in between space” where the two worlds begin to touch each other (Leslie, 07/24/2014). By focusing on art and technology through making, Leslie believes that science, math, and engineering inherently become part of the interactions that happen in the space.

Furthermore, Assemble is fueled by a desire to connect “experts” of all types, but specifically artists, makers, and technologists, to learners of all ages. Leslie pinpoints the purpose for inviting experts into the space: “I don’t feel like it’s for me — trying to break that whole nuance.” She elaborates how this process works:

> I feel when you’re transferring knowledge you need to have a personal relationship with people or like that’s the experience. So you’ve experienced a lot and that’s what makes you an expert, and you’re talking to me or you’re sharing things with me or showing me how, you’re also maybe giving me images or other things, and that’s how you’re actually transferring your expertise is through those action. (Leslie, 07/24/2014)

At present, experts are primarily adults and learners are most often kids — though while I was there Assemble was initiating the process of offering adult programming. Within the programming, there is a traditional student-teacher-like hierarchy between the facilitators and youth. Hence, an interesting tension exists between Leslie’s mission for Assemble to function as a leveling platform by making knowledge more accessible and the hierarchies embedded in the space.

**Community.**

As a non-profit, Assemble has a Board of Directors that approves all major decisions. Leslie is the founder and Board member, and she manages much of the outreach and administrative work. A few contract-based volunteer employees manage the day-to-day needs, organize programs, and teach classes with help from several different volunteers strands, for example, Maker Corps, Maker VISTA, and Pittsburgh's Youth Employment Program.

Assemble is a community space that inspires "the whole community by inviting experts to become educators and everyone to become learners," as proclaimed on their website. When Leslie first opened the space, she hung out from 6-9pm every day and invited people to simply "come inside and make things!" As the space grew, this informal, drop-in model was replaced with a more sustainable program-based model, yet still with the goal of reaching neighborhood kids. Drawing from her background in architecture, Leslie explains that "changing physical space" (the neighborhood) by building a place like this can really make an impact and be a "mind shifter"; her goal: "we're just building trust, building community, and not just building buildings" (Leslie, 07/24/2014). She explains that often the kids not from the neighborhood aren't typically allowed to visit the area, but Assemble is a parent-approved entry into the neighborhood. The space functions as a platform of cross-community interaction of the youth; they get to meet kids from other neighborhoods with which they normally wouldn't come in contact and build relationships with them.

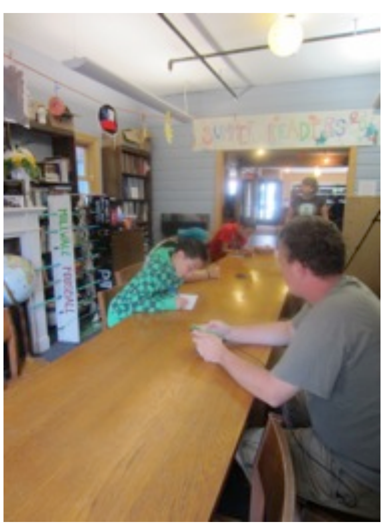
Further, Assemble maintains strong community partnerships with myriad organizations throughout Pittsburgh. Many of Assemble's programs and public events are sponsored by local and national organizations (from the Sprout Fund, to the National Endowment for the Arts, to Yelp!). Some of these sponsorships fund additional partnerships; for example, Cognizant funds the Make It! Program, which partners with the Makeshop's Youth Alive program. Additionally, many of the youth programs partner with community experts who either visit or are visited by the kids to help or advise them in a specific project. Through this range of partnerships and working closely with the Garfield Community Action Team, Assemble aims to serve and remain accessible to kids in the surrounding neighborhoods. Even more, scholarships distributed on a sliding scale are available primarily for kids from the neighborhood, since program costs are often prohibitive.

**Millvale**

Driving across 40$^{th}$ Street Bridge, I exit the highway and pass through a junction welcomed by an instant change of scenery. Away from the scamper of the city and highways, I drive down Grant Avenue and enter what appears to be a quaint, peppy suburb. Vintage, coin-operated parking meters line the street, so I turn down one of the cobblestone side streets, which have no parking restrictions. The old-city style street lamps, cobblestone, and wooden welcome sign are reminiscent of many small, European-style towns I've visited. A semi-truck bursts down the street in front of me and compels me to look closer. A Family Dollar Store sits down the road, a Subway hidden at the entrance of the town, and a gas station anchoring the opposite end of the block with several paint-chipped storefronts in between; the blue-collar poverty of the town can be initially mistaken for rich suburb. I walk down the block and am greeted by a statue — nearly as tall as me — of a dog with several books in his mouth and a freshly, yellow painted building with a series of announcements, including "Maker Thursdays," posted in the window. Welcome to Millvale Library: the community's first-ever library, it is less than a year old.

I reach for the handle, which is a Harry Potter-sized book, and enter through the first set of doors. The entry way is lined with brochures and pamphlets of various types. I open the second door and walk into a space roughly 2,400 square feet. To either side there are a few tall, wooden bookshelves one would expect in a traditional library, and two sets of tables and chairs perched along the large front windows. A door connecting the library with the neighboring building sits between two of the bookshelves on the left. The half carpeted, half linoleum interior includes colorfully painted walls with wooden trimming detailed with steel, welded art pieces.

To the left past the bookshelves a few teenagers and adults sit at the computers and a large printer/scanner sitting next to them along the far left wall. Behind them, in the center of the building, is where Luke, the librarian, sits. Equipped with a computer, desk space, and even a jar of candy from which the teens periodically come up and ask permission to take. Several steps farther is the main area of library where a few kids sit at a large child-height table eating free boxed-lunches. Along the left wall behind them are more bookshelves, extending from Luke's desk all the way through into the next room to the back wall. In the center of the room is a half-circle of tables with four more computers — all occupied — and art projects hanging on strings from the ceiling. To the far right are three wooden doors: a women's bathroom, a men's bathroom, and an office/storage room, which looks relatively inhabitable. In the corner is a RotaBin of crafting supplies and recyclable materials from which two young girls grab some markers and string.



Continuing straight through a large doorway, I enter a modest, book-lined room with a large table where the girls, ages 4 and 6, return to make paper-plate looms with yarn. The 6-year-old, whose mom is sitting across from them, just completed her first paper-plate loom minutes before, and she is boasting in her ability to now teach the 4-year-old how to make her own. One of the facilitators appears to be supervising their process while simultaneously searching online resources on her MacBook in order to assist a 9-year-old girl to sew an LED light onto her purse. On the far end of the table is a homemade foosball table which a few kids and another facilitator are playing and testing out. One of the 10-year-old boys, Jackson, insists that his team needs another player and he grabs an action figure from a bucket he'd brought from home and takes it outside.

More art projects hang above my head and a large "Summer Readers" banner above the doorway behind me. Along the right wall, there were a mess of tools and materials in cabinets, on cabinets, and scattered around the white molded fireplace in the center. It was impossible to know what was even there, though I could see remnants of a soldering iron, a Makey Makey, a manual hand drill, paint of various types, circuit blocks, puzzles, and games. The two facilitators repeatedly asked each other where a material or tool was. Posted on the back wall is a paper sign detailing in marker the weekly schedule of "Make Shop": Monday – closed, Tuesday – Bike Tuesday, Wednesday – Junior Gardeners & Craft Day, Thursday – Maker Thursday, Friday – Fiber Friday. French doors line the back wall of the library, as I exit out these doors I notice an older lady grab one of the wooden CSA crates of food, which are all piled up in the corner.

Outside there is a large deck surrounded by a large grassy yard. On the deck, a 10-year-old boy is using the saw and C-clamp to saw off the arms of his action figure. Aside from the woodworking table he's at, there is a set of patio table and chairs to the right. Out in the yard a group of 8-10 boys and girls are playing football. To the right of them on the ground is an elegant wooden sandbox awaiting sand that the teens recently built for the library through an apprenticeship program. To the left is a large community garden in full bloom. To the back of the yard is a large shed and a steel-wire fence and gate, which is currently open, leading out to a gravel-covered alley between several neighborhood houses.

Millvale Community Library looks much like a typical small-town library on the outside, but inside it offers more than just books. Suitably, the “Make Shop” is one of the “big things” the library offers and sustaining it is a “primary priority.” Originally a pop-up or mobile makerspace funded by a partnership with the Children’s Museum of Pittsburgh, Millvale’s Maker Program has a unique history and uncertain future as they work to build a more stable library-style makerspace. Through this partnership, the drop-in-style Maker Program initially manifested as “Maker Thursday’s.” Often this entailed a Makeshop Teaching Artist coming to facilitate the day from 10am – 6pm. Although, Luke explains, on days when someone is not available to facilitate the space, “we have to put out the basics, which is the circuit blocks and the iPads. I hate those days. I like to see the kids getting involved in new and creative things.” The grant ended with the school year, but Luke shares that “Jamie and Nicole came to us through the national Maker Corps to fund it through the summer. Now we’re kinda looking at where we’re going to go at the end of the summer.”

During the time of data collection, Millvale was in the midst of a shaky transition from a mobile extension of the Children’s Museum to a consistent library makerspace. In Millvale’s case, “mobile” is in the temporal sense (existing only on Thursdays) versus the locative sense. Luke serves as the librarian for Millvale Community Library, and does not run the Maker Program, so if there is not funding for facilitation, then the kids are on their own to make with the materials Luke decides to make available. Millvale’s Maker Program reveals a clear tension with necessary maintenance funding in makerspaces, especially, as they work toward growing it into a more permanent library makerspace.

**Activities.**

At Millvale, the line between making-related and non-making-related activities is fluid; thus, I make only a minor distinction between the library as a whole and the Maker Program houses within. In regard to programming, they offer "Maker Thursdays" in their Maker Program space, during which their activities are most overtly making-related. Jamie and Nicole, Maker Corps volunteers, reiterated several times that they were attracted to the space by the "freedom" it offered to "be more influential in the programming" compared to Assemble and the Children's Museum, since Maker Thursdays was still in its infancy as a "pilot program." Thus, over the summer, Jamie and Nicole expanded the existing programming of Maker Thursdays to include three more thematic maker-based programs: Bike Tuesdays, Junior Gardeners & Craft Day, and Fiber Fridays. Though collectively they all tie into making, Jamie expresses her view that each day is a separate program:

> A: The programs or would you call it an entire program?
>
> I: However you prefer… Do you see them all as separate?
>
> A: I do. Different people come to each one. But it's starting to fuse, like Drew usually only comes on Tuesday, but now he's been here all week. (Jamie, Interview, 07/31/2014)

Their intent in crafting programming together was to offer throughout the week variation of skills and practices appealing to different audiences each day. Though, even in this conversation, Jamie admits that the individual programs are beginning to "fuse" into a more cohesive program as kids' interest peaks.

Much of the programming was put together in response to or in collaboration with the kids:

> So we just kind of responded to what the kids wanted and kind of did it that way. I mean Wednesdays are so vague that we're able to do kind of anything the kids want like make ice cream that's what we did yesterday. (Jamie, Interview, 07/31/2014)

> Then Friday is Fiber Fridays and the kids decided to do that. Yeah, the little girls, Shayla and Kayla, came up to us and asked if they could start a sewing club on Fridays, and I was like totally. So we kind of use that as an excuse to pull out the sewing machines every week, and that's chaos. They just do whatever they want. It's been hard to make structure. (Nicole, Interview, 07/31/2014)

Maker-related activities vary widely according to youths' interest. With the flexibility and vagueness of the programming, some projects span across days or weeks and easily override the scheduled activities for the day. For example, the kids began building a foosball table, which originally began as a Maker Thursday activity, yet quickly bled into other days; Jamie expounds, "But really they were excited about it. They would come here and be like 'when are we working on the foosball table?' 'Eh okay right now.' Which is cool" (Jamie, Interview, 07/31/2014).

Their approach supported a variety of collaborative practices and projects. The foosball table is an illustrative example of how making activities are most typically conceived and carried out:

> But the foosball table, one guy said it, the other kids really responded, they drilled the holes. I had no idea what we were gonna do for the majority of that project. All the kids kinda pitched in and had the ideas. Like the action figures are a huge one, I mean we had bags and bags of action figures. Some of them too small you know we got rid of those, some of them really big, so you know cut them in half. The kids' enthusiasm with that,

> especially Jackson and Darren, was kind of awesome. It's really awesome to see like… I would not have completed it without them there. Other was it's just like eh… I don't know how to do this and no kids are interested, so I'll do something else. (Jamie, Interview, 07/31/2014)

The themed days and the matching bag of activities do yield fruitful processes and small-scale products, yet ideas are often conceived, envisioned, and carried out by the kids themselves resulting in grassroots processes and group products. As Jamie describes with the foosball table, one kid's idea was supported by his peers, a couple kids drilled holes, a group of kids painted, a few others contributed materials (e.g., action figures) to the cause, and everyone helped playtest and fine-tune accordingly. Gradually, a subset of kids, in this case Jackson and Darren, spearheaded and owned the project sustaining it to completion, but the foosball table is a product of the community as a whole. This style of youth-driven programming comes at the cost of the facilitator's own goals and often requires them to teach themselves on the fly in order to support the project. Nicole elaborates,

> My goal at the beginning of the summer was trying to get the kids to think about art…Then, I got here, and that's not what they're interested in at all, which is cool. So, then the whole making movement is like more than just crafts and art things, it's like woodworking and circuitry and tinkering of all kinds. That was stuff that I had no experience with, so since then our goal has been like learning stuff ourselves that we can teach the kids. (Nicole, Interview, 07/31/2014)

The accessible, drop-in style of the Maker Program makes it challenging for the inexperienced facilitators to structure making activities on the fly for specific learning objectives. If the kids aren't interested in what's planned for the day, they pitch and pursue their own ideas together. Even so, Jamie and Nicole are able to support and model prototyping, trial-and-error, and iterative making practices. For example, they built a prototype of the foosball table out of cardboard and clothes pins, because they weren't totally sure how to make it, so they started with something small to test it out first; both functioning as a small-scale model and a project for the younger kids.

The daily programming structure, though flexible, seemed primarily driven by the need to make certain tools and materials visible for the day. For example, Nicole describes Fiber Fridays as "an excuse to pull out the sewing machines each week"; otherwise, they're not visible — I never saw them. In terms of space, the Maker Program is limited to a single, albeit large, table in the back room of the library, which links to the back porch. There are two cabinets and a RotaBin ("craft kart") overflowing with tools and materials for the Maker Program, but participants, even facilitators, regularly struggle to find what they need. Thus, each day the facilitators make new tools and materials visible in accordance with the daily theme, yet at Millvale one won't find tools, like 3D printers or laser cutters, often associated with makerspaces. Typical tools used include: soldering irons, paintbrushes, circuit blocks, crafting tools, and manual woodworking tools. Moreover, materials like electrical supplies, crafting and sewing supplies, and recyclables were provided by the Children's Museum, while other materials, like wood, are bought as needed. Also, it's not unusual for kids to bring in materials from home for projects or for facilitators to make a quick trip to Family Dollar Store for just-in-time materials.

Interestingly, while computers are part of the library's core set of tools, they — like the iPads or Makey Makeys — are rarely used for the for making-related activities; though, Jamie and Nicole use their personal MacBook to access online resources as needed. A lot of activities were "a little less techy and a little more hands-on" (Nicole, 07/31/2014), because the "kids aren't really interested in being on the computers, they're more interested in being outside and working with wood, and doing things like that…they're taking apart things and looking at stuff. Outside, though, like not with the laptops, not with the iPads" (Jamie, 07/31/2014). At times, hands-on, outdoor activities crossed over into more "techy" activities, for instance, building new circuit blocks requires some woodworking, but also taking apart old electronic equipment, soldering, and circuitry. Curiously, this is a shift from when Marcus, Makeshop Teaching Artist, ran Maker Thursdays during which circuitry, Minecraft, and programming were commonplace activities.

**Identity.**

Millvale Community Library is a space built by and for the community of Millvale, especially, the youth. Luke shares that helping build the library gave the youth "a real sense of ownership of the place." He expands on how it fueled their excitement for the space: "They want to see it succeed. They want to see it thrive and they just love coming here" (Luke, 07/31/2014). Even the treasured foosball table is labeled "Millvale Foosball." In this sense, it is a community space that fosters a community identity.

Mirroring this community ownership, the interest-driven nature of the space suggests that the kids are given exceptional ownership over their individual practices and projects. Nicole shares how such agency has begun to transform one kid's stigmatized identity:

> Jackson's our really tough one, because he has the reputation of being bad, like everyone tells him he's really bad. So he feels that he has to live up to that like 90% of the time…He is super smart though, he's like — I don't want to say best — but he's the one that's usually the most engaged in everything that we're doing. But we realized that to get

> him to be like that we have to give him some sort of ownership, so that he feels like he has to be there, because his name is going to be on this. So basically we've just let him literally write his name on everything that he's doing or to the Millvale Day's thing we're doing this festival." (Nicole, Interview, 07/31/2014)

Further, in an interview with the local newspaper, Jackson boasts:

> I: Cool. Now the foosball table is going to be at Millvale Days?
>
> J: Yes
>
> I: So that means other people are going to get to play…
>
> J: Mhmm
>
> I: Cool… Are you excited to see other people play with it?
>
> J: Yeah
>
> I: Yeah? How come?
>
> J: Because they'll be like 'this is awesome! Who made this?' And then I'll be like 'me!' (Millvale, Fieldnotes, 07/24/2014)

Shortly after this exchange, Nicole encouraged Jackson to wood burn his name on the table somewhere, because he had led the project well. The library's missional slogan is "more than a library — an agent for positive change," and this rings true not just on the community-level, but also on the individual-level.

Aligning with the goal of changing the community for the better, facilitators all express their heartfelt desire to empower kids to explore their creativity and learn new skills. Jamie believes "kids can do this stuff without us. They can fix their bike without us, they can sew without us, and they can solder without us" (Interview, 07/31/2014), and she wants to empower them to take up identities as people who can do these skills themselves. Nicole adds "whether it's here or not… even if it's just like one thing out of the five that we're teaching them, if they can keep doing something after we leave, that would be awesome" (Nicole, Interview, 07/31/2014). Accordingly, they work together to equip youth in the community with the confidence to creatively make and do.

**Community.**

Serving 65 – 100 visitors a day, Millvale Community Library is a place where Millvale residents can come together, hang out, and do life together. The library's backyard is nestled between the homes of these kids — "the regulars" — acting as a functional meeting place for them to hang out and learn. Oftentimes, youth in the neighborhood walk over, but Millvale is a small enough borough that the library is accessible by bike for kids who live a bit farther. During the school year, these same kids hop off the school bus and come straight to the library after school. At times, this informal drop-in nature of the library is misinterpreted as drop-off, daycare-like structure about which facilitators express frustration and concern. In some cases, though, "notable" parents or grandparents, especially those visiting from neighboring townships, accompany their kids.

Millvale's website boasts "love of community" as one of its core values, and Nicole elaborates:

> Since Millvale is actually separate from Pittsburgh, it has like a totally different ecosystem here that really the library is trying to live within, but also like affect in a positive way. That's like a lot of what Brian does is just like the free lunches, and he's trying to create like a community within the library where like the kids can come and hang out and have like positive influences, role models, and a place where they can read and change the literacy count here. (Interview, 07/31/2014)

The entire ethos of the library is community; Brian, the founder of the library and many of the kids' schoolteacher, has established the library as an epicenter of Millvale. With this mission, the library targets and attracts youth, in particular, giving them a safe space to hang out and carry out "positive change," even offering them free lunch. Under this umbrella, Luke shares his goal, "if I can get them off of computers, if I can get them off the streets and give them a safe place where they can be kids, but explore a different side of their creativity, then that's a great thing" (Luke, Interview, 07/31/2014). The Maker Program is designed to align with this goal; recall, however, that one of their biggest struggles is finding consistent facilitation for the program. As the sole librarian, Luke is unable to facilitate the Maker Program beyond setting out tools and materials when a scheduled facilitator is absent.

The underlying ethos supports collaborative, community-focused activities in the Maker Program to the extent that much of the making is often done *for* the community. Several of the products (e.g., the sandbox and the foosball table) were left at the library and kept available to the community. Even more, every time the kids finished a project, whether it is a newspaper palm tree or a giant Jenga game, they were encouraged to contribute it to Millvale Days, the borough's annual celebration.

As a neighborhood hub, Millvale primarily maintains local partnerships within the neighborhood and towns nearby. For example, the town's CSA is delivered to the library and the garden beds in the backyard are rented out to the community. Free lunches offered during the summer to help bridge the gap for kids who get free or discounted lunch during the school year were established through a joint effort with Touching Families of Pittsburgh and Pittsburgh Community Kitchen. Additionally, Millvale's extremely successful summer reading program is a product of partnerships with Shaler North Hills Library in a neighboring township and the Boys and Girls Club in Millvale. Jamie and Nicole, Pittsburgh natives, also brought their networks with them to help build the Maker Program. For instance, Jamie's previous work with Positive Spin, a program to empower youth to cycle, made Bike Tuesdays possible through partnerships with Free Ride.

**Cross-site: Activities**

Drawing from the activity-identity-community framework, activities are defined as processes and products; thus, in this section I look broadly at how and what processes and products are supported by site features, specifically, considering the affordances and constraints of each. The *Learning in the Making* comparative case study (Sheridan et al., 2014) highlighted several features of makerspaces, two of which I carry into this analysis: learning arrangement and activity duration. Sheridan et al.'s broad focus on community makerspaces contrasts my narrow focus here on *activities* that happen in youth makerspaces. Therefore, I identified other site features based on themes I noted in my analysis, primarily those that were repeated by facilitators as points of triumph or tension. The table below compares these features across:

| Feature | Makeshop (museum) | Assemble (afterschool) | Millvale (mobile/library) |
|---|---|---|---|
| **Learning arrangement (most common)** | Drop-in: Individual with regular collaboration | Class: Individual with minimal collaboration | Drop-in: Collaboration with minimal individual |
| **Facilitation style** | Youth-driven, Trained | Facilitator-driven, Untrained | Youth-driven, Untrained |
| **Design structure** | Structured closed-to-open | Structured closed | Unstructured open |
| **Learning goal** | Process-based | Product-based | Skill-based |
| **Product (when applicable)** | Individual | Individual | Community |
| **Activity duration** | Minutes to hours | Minutes to weeks | Hours to months |
| **Tools & materials** | High visibility, Surplus availability | Low visibility, Surplus availability | Medium visibility, Limited availability |

**Learning arrangement and facilitation style.**

The primary learning arrangements and facilitation styles across sites are linked in an interesting way. In this comparison, I consider the most common learning arrangement — realizing that sites often supported more than one — and define the facilitation style as either youth-driven or facilitator-driven and trained or untrained. Youth-driven facilitation style means that the facilitation is scaffolded in a way that allows youth to freely explore their own interests, and facilitator-driven style means that the facilitator guides youth participants along a path allowing for limited exploration of interest. Across all sites, facilitators encouraged youth to help and teach their peers, but there was a clear youth- or facilitator-driven distinction of how this was taken up. Trained and untrained distinguishes between how facilitators are on-ramped into their position; trained means that there is a system in place to on-ramp facilitators and untrained means that facilitators must on-ramp themselves.

Makeshop and Millvale, while primarily drop-in learning environments, adapt this learning arrangement in different ways. On the one hand, youth in Makeshop usually navigate the space freely and collaborate with others regularly based on interest. For example, a child interested in sewing may approach the hand-sewing table and begin working alone yet collaborate and interact with others also working at the table to support his individual process. On the other hand, youth in Millvale collaborate from the idea-pitching stage, which most often results in a community product. For instance, the foosball table gained traction only because there was buy-in from the community from the start. Even when making individual products (e.g., paper-plate looms) the process is inherently collaborative; however, Jackson was sawing his own giant-sized Jenga game primarily alone, which revealed some evidence of individual processes, though the product was still for the community. Both sites encourage youth-driven exploration, but yield contrasting collaborative styles, due perhaps to the disparity of training facilitators. While Makeshop doesn’t necessarily situate Teaching Artists as ‘experts’, they are equipped pedagogically to support making processes in a way that Millvale volunteers usually are not. The intensely collaborative nature at Millvale is likely also a result of the fact that youth in the space are well acquainted with others attending the same school and living down the street from one another in a way that Makeshop patrons rarely, if ever, are.

Assemble is more straightforward, in that, the most common learning arrangement is through classroom-style, facilitator-drive workshops that most often yield individual products. Even in cases where youth collaborate, the purpose is usually to manage shared tools or materials. Facilitators at Assemble are largely untrained pedagogically and left to on-ramp themselves in necessarily content areas — many beginning from scratch with ‘making’ and ‘makerspaces’. The vision and education philosophy outlined on the website and by the director are not fully realized in practice, and lack of funding for training facilitators could play a huge role in this.

**Design structures, learning goals, and products.**

There is a difference between *who* prompts the activities at each site, which influences both the process and product; hence, learning arrangements and facilitation styles are heavily influenced by the design structure and the overarching learning goal. I define design structure as structured/unstructured and open/closed. I draw from computer science and cognitive psychology’s contrast of well-defined and ill-defined problem space (Simon, 1973; Voss, 1988) to define the two dimensions of space design. I do not suggest that any of the makerspaces in my study offer purely well-defined activities in the way cognitive psychologists conceive, but rather I use this dichotomy as a tool to define these constructs. Structured/unstructured describe the degree to which the space is intentionally designed as a learning environment; structured is a space designed to be a learning environment and unstructured is a space where learning happens — both fall toward the ill-defined end of the spectrum. Open/closed define how prescribed activities are and the number of corresponding trajectories (or outcomes) possible — open resembling ill-defined and close resembling well-defined.

At Makeshop the design structure is embedded with constructivist learning theory, as the exhibit is designed by educational researchers; thus, it is *structured* in such a way that prompts particular learning experiences. For instance, the space itself is scaffolded; in the front room, the tools are limited and afford a *closed* making experience, as the programming blocks only allow for one activity: programming with blocks. In the workshop space, however, the making space is *open* and the possibilities are seemingly endless. There is little in the space prescribing activity or engagement offering kids infinite trajectories they can choose to deeply and freely explore. Hence, Makeshop offers a structured closed-to-open — the activities become more open-ended as youth (literally) move deeper into the space — design structure, which suits its process-based learning goals. Makeshop boasts a desire to engage young makers in *processes*. Teaching Artists are trained on how to support youth through an "ideation, prototype, iteration, and reflection" process. Different pieces of Makeshop support different parts of this process, so many activities in Makeshop do not necessarily yield products in the personal artifact way we often envision. This type of artifact creation is not fully supported until makers enter the workshop space — the most ill-defined area of Makeshop.

As I describe above, Assemble adopts a class-like *structure* for most of the activities and programs they offer. Each experience is for a narrow purpose, thereby *closing* the ways in which youth can engage in the space. Unlike Makeshop, materials are organized in a back room, so the making space is like a blank slate. Materials are labeled and compiled in a way that best supports closed, kit-based making experiences. For example, there is a "Terrarium" storage container that holds all the necessary materials for kids to make terrariums. This tight design structure matches Assemble's product-based learning goals. There were a few cases of youth making for the community, yet the large majority of products followed an individual make-and-take approach.

In interviews, facilitators expressed a need to appeal to parent's demands by having products as evidence of the kids' learning, and with limited knowledge of education research they felt ill equipped to communicate otherwise. Assemble is an example of the impact of training facilitators (or lack thereof) has on the design structure and learning goals, a challenge Millvale also faces.

Aside from the thematic-daily schedule, Millvale largely maintains an *unstructured* design structure, in that there is little, if any, structure given around making experiences. The daily schedule manifests as setting out corresponding tools and materials, which passively suggest a possible genre of activities for the day. Other than that, the space remains *open* and permits unlimited trajectories through which youth can move through the space. At times, there are attempts to provide structure, for instance, one day the facilitators put out a bunch of old electronic equipment and encouraged kids to take them apart and salvage parts for circuit blocks, though this is fairly uncommon. In this more freeform design structure, youth do not synchronously partake in the same activity, but are supported by facilitator's skill-based goals. Rather than taking a process- or product-driven approach, Millvale works to equip youth with skills like circuitry and woodworking that they can use in their everyday life. When youth want to learn a skill outside of the facilitator's skill set, they collaborate and draw on outside resources (e.g., local experts or various websites) to compensate. As such, most activities at Millvale are precariously ill-defined (or unstructured and open) making it difficult to cultivate learning beyond basic skill building in some of the deeper, long-term projects. With limited training, facilitators struggle to provide a structure that pushes youth toward any formal learning goals, and instead encourage young makers to pursue their own interests — whatever that may be for the moment.

**Activity duration.**

Across sites, activity duration is generally as short as minutes to as long as weeks. The range varies slightly by space: Makeshop offers short activities introducing a skill or material that can span as short as minutes whereas Millvale often has longer-term activities spanning as long as months. Each site has examples of shorter and longer projects, yet each has a tendency in one direction; for example, it is more common for activities in Makeshop to span minutes and more rare for activities to span hours. Assemble is particularly interesting, because it offers week- and semester-long programs, yet it is unusual for activities to span longer than a few hours of raw making time. Pragmatically speaking, activity duration inherently affects the depth of process and sophistication of product in a given context.

The variance in activity duration is linked to the purpose and audience of the space. Makeshop and Millvale are both drop-in spaces, yet the former drop-in measure is minutes and the latter is weeks or months. On the one hand, Makeshop appeals to an international audience and is bounded by admission costs and specific ‘open’ hours of the Museum. With a steady flow of new people day-to-day, the space is designed to support shorter spans of engagement and does not lend itself well to people leaving projects to return to later. On the other hand, Millvale functions as a neighborhood hub and young makers typically drop in and hang out for days, especially during the summer. Youth around the neighborhood — a much smaller audience — flow freely in and out of the space, and projects are safely put down and picked up over weeks and months.

At present, Assemble most often attracts smaller groups and typically maintains a 10:1 ratio with classes and workshops. These programs are highly structured by timeframes; for example, many classes are two hours long, so the activities they offer are structured to fit within such constraints. Activities are rarely carried across days even in programs with more regular participation over longer periods of time. Instead, Assemble specializes in bite-sized making activities that yield relatively uniform products.

**Tools and Materials.**

Availability and visibility of tools and materials shape the processes and practically constrain the products. All three sites fairly consistently offer cheaply replenishable tools and materials (e.g., scissors, tape, pipe cleaners, paper, fabric, and recycled materials) available for youth to freely use. More expensive or technical tools and materials, however, are in surplus at Makeshop and Assemble compared to Millvale. For instance, Millvale had a single soldering iron and hot glue gun to share across the spaces, whereas both Makeshop and Assemble have enough to support workshop-style engagement. Also, unlike the other two sites, Millvale does not have a 3D printer or laser cutter. Though the tools and materials available at Millvale are relatively basic, comparatively speaking, their youth-led projects are rarely limited by such.

Visibility of tools and materials is especially varied across the three sites. At Makeshop, tools and materials are almost always visible, but not always reachable. Generally speaking, tools are all within reach and often times ready-to-use, and they follow rule-of-thumb to keep the most replenishable materials within reach and the more expensive materials within eyesight. A Teaching Artist is typically nearby to support tool operation or help gather materials. At Assemble, tools and materials are well organized and often labeled, but not in the making area. Instead, most tools are stored in the 'maker room' and materials sit in plastic containers on metal shelving units in the back room. Millvale has the most limited quantity of tools and materials, yet they sit considerably unorganized, piled on top of cabinets. The lower visibility of tools and materials at Assemble and Millvale makes it challenging for makers to find what they need when they need it. Even though Makeshop does not experience the same challenge, facilitators still express a need to better organize the resources they have available.

Sites also vary what tools and materials they make visible. Millvale is described as an “analog community” and, even though they have many of the digital tools (e.g., iPads and circuitry), facilitators and kids gravitate toward the analog tools (e.g., woodworking and crafting). With many of the digital tools buried, most of the visible tools and materials support analog making. Neither Makeshop nor Assemble had a similar leaning, but rather made tools and materials more or less visible based on specific process or product goals.

**Cross-site: Identity**

**Owning making.**

These youth makerspaces subtly and overtly support identities of “maker” by encouraging young makers to take ownership of making as a process, practice, and/or product. Makeshop’s signage and rhetoric situate youth as makers, no matter their age or experience. The design of the space and the facilitation style of the Teaching Artists support young makers in the process of making; facilitators want youth to embody the process as something that is ‘theirs’. Both Assemble and Millvale aim to position making as an accessible practice youth can own. In particular, through connecting experts with young makers, Assemble resolves to break the “I don’t feel like it’s for me” barrier preventing youth from identifying with a given making practice. For instance, by contributing to their knowledge about and experience with woodworking, young makers can begin to see themselves as persons who can make with wood. Millvale adopts a similar approach by focusing on pragmatic skills (e.g., repairing bikes or sewing) that youth can smoothly utilize in their everyday lives. Even more, Millvale encourages youth to own their products by etching their individual or community (Millvale) name in final artifacts.

There exists a consistent desire across sites to present making as an accessible process or practice that yields useful skills or products. Not all sites work toward overtly building kids' identity as "maker," yet they do empower youth to *own* making. This trend contrasts with what we found in Sector67's online forum through which making was often made inaccessible to beginners as experts described complex processes as "easy" (Litts et al., 2014). In this adult makerspace, there is an inherent assumption that participants "buy-in" to the idea that making is meaningful to their daily lives (Sheridan et al., 2014). Youth makerspaces in this study, however, put forth an explicit effort to remain accessible even to those who do not yet feel ownership over making.

**Disciplinary-based facilitation.**

Across sites, identities of facilitators were heavily rooted in their disciplinary backgrounds, and this affected their facilitation styles and methods. At Millvale facilitators' hesitancy to push youth to expand their own interests appears rooted in their own expertise and comfort. Both makers at heart — Jamie's interest stemming from architecture and Nicole's from art — they admit that, like Millvale, they lean more toward analog than digital in their own making. Recalling one of her visits to Millvale to shadow Marcus run Maker Thursdays, Jamie reflects:

> It helped me understand how making is supposed to be playful, because making to me is very problem, and solution, and site-specific, and those other stuff like that…Yeah I mean you can see on the top of the bookshelf, there's a lot of little things that are like little fighting robots that Marcus made. I was there that day and I just like couldn't even

> think about what to glue to another thing. I didn't really understand why were making these things vibrate across the table, shouldn't it crawl or something? You know? And then it's like, just because I don't know… I don't think that way… think like, I mean architecture taught me to think that there's a problem, or a site — very specific — and you make something responding to it or solving to it, maybe not solving it, but responding to it. So, if I want something… when they were trying to make a fighting robot thing I was like well the problem here is that you can't control the direction it goes, so if I can make it crawl a certain direction and control that, then that would solve the problem…But you can't make like a little motor crawl in like 30 minutes. I don't know. Maybe you can, I haven't figured it out. (Jamie, 07/31/2014)

Jamie grapples with her own problem-focused approach compared to Marcus's playful approach to making fighting robots. She elaborates further about her proficiency, "I want to learn how to make things that are more artistic and not so… I don't know, *pragmatic*, is that the word? Because right now I feel very pragmatic." She affirms that her preferred approach to making is rooted in the pragmatism of architecture, which affects and limits her "comfortability" in facilitating certain activities. The transition in facilitation from Marcus to Jamie and Nicole resulted in a similar transition in tools, materials, and practices.

While not as explicit, Makeshop and Assemble acknowledge and address the weight of facilitators' background and expertise on making activities they support. At Makeshop, facilitators are encouraged to explore and build their preferred disciplinary expertise, but are also equipped with "pedagogical content knowledge" (Mishra & Koehler, 2006) related to facilitating making experiences. Sharing knowledge and expertise (e.g., bringing in a former Teaching Artist to host a 3D printing training) is a practice they adopt to ensure breadth beyond individuals' disciplinary preferences. With several facilitators, they support a wide range of complementary content areas, skills, and practices — largely neutralizing the limiting effects evident at Millvale. Assemble strives to function as a platform on which facilitators and experts merge to expose young makers to a holistic reservoir of disciplines and content areas. Both Makeshop and Assemble sites leverage the distributed expertise to offset the clear impact individual facilitators' disciplinary perspective has on the types of making experiences they offer.

**Site orientation toward identity.**

Youth makerspaces encourage youth to think of themselves as makers across myriad disciplines, yet the three sites in this study took that up in different ways. Similarly, Halverson, Lowenhaupt, Gibbons, & Bass' (2009) argue different orientations toward identity exist across Youth Media Arts Organization (YMAO). These scholars draw from developmental psychology's individualistic and collectivistic orientations toward identity (e.g., Triandis, 1995) and Coté and Levine's (2002) viable social identity, to demonstrate that digital art-making supports both individualistic and collectivistic orientations toward identity. An individualistic orientation manifests as youth engaging in individual process within a community context and encourages an individual's viable social identity. A collectivistic orientation is demonstrated by a community of individuals engaging in a collective process together and encourages a "community viable social identity" (Halverson et al., 2009).

I borrow this analytic approach to expound the different orientations Makeshop, Assemble, and Millvale take toward identity. Makeshop supports individualistic identities, by pushing individuals to think of themselves as makers and primarily engaging youth in an individual making process. Assemble follows a similar individualistic orientation toward identity. In both cases, as I mentioned in the activities section above, products are most often created and owned by individuals. Millvale advocates a collectivistic identity most often supporting community-making processes where several individuals contribute and products are shared with and used by all.

I do not mean to suggest that Makeshop and Assemble are not community-oriented. On the contrary, they both advocate collaboration and community building. Makeshop provides opportunities for youth to contribute to a collective identity by contributing to the most recent floor loom project — an ongoing community project where patrons can weave as many rows as they like and the product is displayed in Makeshop. Likewise, Assemble situates itself as community platform working hard to connect various stakeholders. This tension of individualistic identity vis-a-vis community space echoes the complexities of identity development Halverson et al. (2009) highlighted in YMAO's. At their core, all three youth makerspaces work to engage youth in collaborative making processes and practices.

**Cross-site: Community**

| | **Makeshop** | **Assemble** | **Millvale** |
|---|---|---|---|
| **Ethos** | Family | Community | Neighborhood |
| **Scope** | National with some international | City | Townships |
| **Audience** | Personal | Personal | Local |

**Ethos.**

Though all community spaces, each site espouses a slightly different ethos. Makeshop embraces the family-oriented ethos of the Children Museum and works to build community through family collaborations. Many of Makeshop's efforts and programs reach beyond families, but it is the only site in this study that focuses heavily on encouraging and equipping families to make. A big part of the conversation at this youth makerspace is exploring best practices of supporting parent/guardian-child interactions through the making process.

Assemble and Millvale embrace an ethos thick with community and neighborhood focuses. Assemble first serves as a community platform connecting experts and young makers throughout the Pittsburgh area. With this ethos, Assemble seeks to change the surrounding neighborhood more locally by equipping youth to see themselves as having productive futures. Millvale, as the borough's first library, implores the neighborhood to use the space as more than just a place for books, but also as a community built, community run neighborhood hangout, especially for the kids. As youth makerspaces, all these sites are oriented toward youngsters; however, Millvale sits on the extreme end of this spectrum and solely serves neighborhood kids through their maker programming. Both Assemble and Millvale rest on a bedrock of community and neighborhood revitalization by offering a safe space for kids to explore creativity and discover viable life pathways, but offer slightly different takes on how youth makerspaces can change the communities within which they're situated.

There is a complex relationship between the maker-level identities a site supports and the site-level ethos it embodies. Interestingly, a site's orientation toward identity does not necessarily mirror its community ethos. Makeshop and Assemble lean toward supporting individualistic identities, though they both embody a community-driven ethos. In contrast, Millvale heavily supports a collectivistic identity aligning with its neighborhood ethos that advocates community making. Halverson et al. (2009) grappled with this relationship in the context of YMAO's suggesting that this tension spans across contexts.

**Scope.**

The variation in scope of community participation at each site provides some insight to how community context shapes the making within. Makeshop attracts patrons nationally, even internationally; Assemble targets participation across Pittsburgh reaching into the neighboring suburbs; and Millvale sees visitors from the Millvale borough mixed with a couple more rural townships nearby. Makeshop's international reach and influence is not surprising, as Children's Museums are often tourist destinations. The constant flow of new faces has obvious implications for the type of community they can cultivate and offers some insight to their individualistic orientation toward identity. Assemble and Millvale have a narrower scope of participation enabling stronger, tighter sense of local community. Assemble's scope is broader than Millvale's; the former draws in more experts throughout the city and connects them with a wider range of young makers. Millvale's smaller scope affords a family-like community that simply could not exist at a place like Makeshop. Considering the scope of participation across sites sheds light on the affordances and constraints of certain models of youth makerspaces.

**Audience.**

Recall that learning theorists describe learning as a representational process through which learners communicate meaning to specific audiences. (De Vries, 2006; Halverson, 2013; Michaels, 1981; New London Group, 1996). Audience, therefore, is a feature of the making community, and these three youth makerspaces support different avenues of making *for.* With their individualistic nature, the majority of making that happens at Makeshop and Assemble is for personal use. Most often, makers adopt a make-and-take process and bring their products home with them. Millvale skews toward a more practical approach of making for local use. At times this is playful as in the case with their ongoing foosball table project, and at others it's more utilitarian like building new circuit blocks for the makerspace.

Though each site tends toward a particular audience, they all offer at least some opportunities to more formally or publicly display artifacts. Whether makers leave behind scarves to be hung in Makeshop or informally share woodworking projects with their parents at Assemble or publically exhibit e-textile projects at a community festival at Millvale, all three spaces integrate some form of showcasing into their community. At Makeshop and Assemble the opportunities to showcase are heavily dependent on programming, whereas at Millvale facilitators are constantly encouraging youth to think about sharing their projects with the community.

**Partnerships.**

These makerspaces are heavily sustained through community partnerships; from establishing shared expertise, to connecting youth with peers and making, to securing funding, to growing the maker movement. All three spaces adopt and maintain partnerships to expand expertise and knowledge beyond the limitations of their regular facilitators; Assemble and Makeshop are also forming artist-in-residence style partnerships. Likewise, all sites work to connect youth with peers across the neighborhood, the city, or even the nation. Assemble and Makeshop, in particular, maintain strong outreach programming to keep making accessible to youth across the city.

Moreover, funding sources and structures vary across sites. As non-profit organizations, each site has complex funding structures, but the way this impacts their maker-based offerings varies. As a mobile makerspace, Millvale's funding is the most precarious; from season to season they strain to secure funding to keep their Maker Program running. As a stand-alone, afterschool space, Assemble is detached from any stable funding and, at present, only supports contract-based employees and volunteers. Available programming is heavily tied to community engagement; for example, support from the Maker Corps members prevented some summer camps from being canceled, as attendance was too low to support a facilitator. As a museum exhibit, Makeshop has the most stable in maintenance funding, so partnerships often secure funding for special resources and to carry out research agendas.

At different levels, each site works to grow the maker movement. Millvale primarily maintains local neighborhood partnerships, but with respect to the Maker Program, sees itself as "an example to libraries all over the country." Assemble's "platform" approach yields substantially more varied partnerships than any of the other sites; nearly everything they do is a product of a partnership — and not all are making-related. Partnerships are formed, in part, to fund programming, but even more to fuse the community together. Makeshop acts as a networking hub of the maker movement not just in Pittsburgh, but also across the country. While Millvale and Assemble don't have any direct partnerships, they are both partnered with Makeshop through programming, shared funding, and indirectly through third-party partnerships, like Maker Corps.

## Four features of youth makerspaces

In this comparative case study, I examined activities, identities, and communities across three youth makerspaces. From the analysis, I realize four crosscutting features of the three cases: activity structure, resources for making, equipping facilitators, and community ethos. The four features I discuss are characteristic of the museum, afterschool, and mobile/library youth makerspaces I examined in this study. I also highlight how these features inform the design of youth makerspaces more broadly.

### Making Structure: Activity Scale

Youth makerspaces offer activities of varying scale and this study provides insight to the affordances and constraints of three scale-units of making activities: micro-introductory, limited kit-like, and open-ended (see Figure 2). With such a wide range of programming at each site, I observed these three units at each makerspace. Thus, I do not want to essentialize the makerspaces to fit categorically along the continuum. The scale-units, however, are chiefly defined by activity duration, which varied more explicitly by site as I outlined above. In that sense, Makeshop tended toward micro-introductory activities, Assemble toward limited kit-like activities, and Millvale toward open-ended.

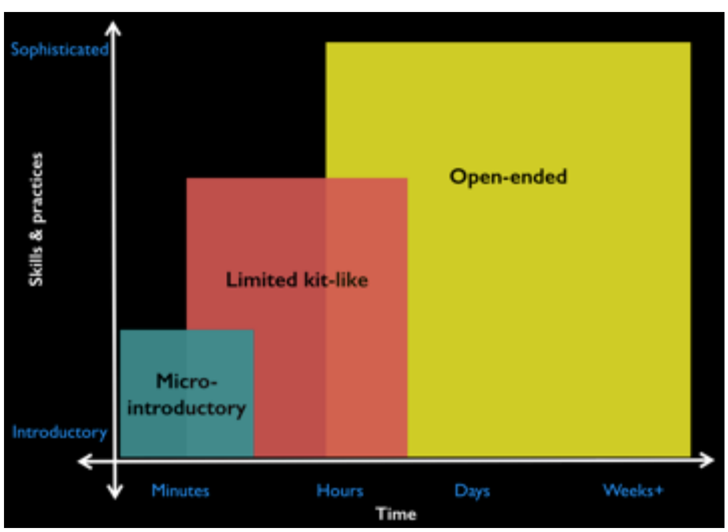



**Figure 2. Making structures across youth makerspaces.**

Micro-introductory activities, for instance playing with circuit blocks at Makeshop, usually lasted less than an hour and introduced simple tools and materials, basic skills, and small-scale practices. These activities were typically freeform and supported asynchronous exploration, but were constrained by the tools or materials included. Using circuit blocks, kids experimented with wires and conductive materials to build preparatory circuitry skills and tinkering practices. Micro-introductory activities were used to on-ramp youth to making with specific tools or materials.

Limited kit-like activities spanned up to a few hours and afforded exploration of tools and materials, intermediate skill-building, and essential practices. Activities of this scale were most often structured and followed a somewhat linear process usually with the goal of completing an individualized product. Making ice cream, building terrariums, and soldering badges (from kits) are all examples of activities of this scale. Each required combining more involved tools and materials, learning unique skills like measuring or soldering, and employing experimentation practices. In these cases, the process was usually fixed, but allowed for some creative flexibility depending on the tools and materials used. In other cases, for instance woodworking or laser cutting workshops, the tools and/or materials were fixed to suit the skill-focused goals. Limited kit-like activities offered breadth and allowed youth to explore a particular interest or content area.

Open-ended activities ranged from hours to months and supported deep investigation of complex tools and materials, expert-level skills, and sophisticated practices. Due to their extended duration, activities of this scale yielded projects of multiple iterations and more polished final products. The foosball table project at Millvale is a successful example of this activity scale. This project fostered collaborative design practices, like prototyping, and required researching and remixing several tools and materials, for instance, sawing action figures to make the appropriate size ‘players’. The iterative nature of open-ended projects helped refine skills, like woodworking. Activities of this scale afforded depth and were utilized for deepening interest and/or community projects.

I observed examples of each activity scale-unit in all three types of youth makerspaces (i.e. museum, afterschool, mobile/library) offering evidence that activities of all scale-units are possible in any makerspace model. Instead, as I depict in Figure 2 above, the activities are most defined by timespan; micro-introductory activities require less time than open-ended activities. Youth makerspaces offering activities with heavily constrained durations should opt for micro-introductory or limited kit-like activities. Each activity type affords a unique set of skills and practices. Thus, makerspaces looking to achieve specific learning goals through a certain activity should consider factors like the current skill-level of participants in addition to available time. This study highlights three scale-units of activities that exist in youth makerspaces and encourages designers to consider the affordances and constraints of each scale-unit. I expect that further research will uncover more scale-units of activities and/or deepen our understanding of the ones I present here.

**Making Resources: Tools & Materials**

Balancing availability and visibility is a key component of managing tools and materials in youth makerspaces. Practically speaking, the availability of tools and materials is unavoidably diverse across youth makerspaces, yet this does not appear to meaningfully limit the breadth or depth of making activities. Instead, the visibility of tools and materials seems to greatly impact the possible making experiences in a given moment. Keeping tools and materials within eyesight seems to support ideation and envisioning processes. Further, scaffolding what tools and materials are reachable helps scope the making activity. As such, one common practice I observed in all three makerspaces was to set out tools and materials on the working table. Even when the activity was not restricted to specific tools and materials, facilitators consistently arranged a subset of tools and materials directly in the workspace, as if prepping it to be ready-to-make.

Learning theorists (Ito et al., 2008; New London Group, 1996; Papert, 1980) have established the relationship between tools/materials and ideas in other learning environments, so it's not surprising how the visibility of tools and materials affect possible making trajectories. Scholars (e.g., Puntambekar & Kolodner, 2005) have already explored ways in which tools and materials shape learning activities and trajectories, and this study suggests that this is a worthwhile line of inquiry for youth makerspaces. The most interesting piece this study contributes to the conversation is how greatly making is impeded by the sheer bareness of a making space. Assemble was the most extreme example in which the tools and materials were stored in a separate room from where the making happens. One of the benefits of makerspaces is the range of tools and materials present there, but this benefit seems to be lost in cases where tools and materials are separate from the making space.

Much of the current rhetoric in the maker movement (e.g., Lipson & Kurman, 2013; Ratto & Ree, 2012; Tanenbaum, Williams, Desjardins, & Tanenbaum, 2013) designates the available technologies as the hallmark of makerspaces. While access to and making with 3D printers, laser cutters, and e-textiles builds new types of literacies and representation, these technologies should not be prerequisites for makerspaces. Instead, the youth makerspaces in this study provide evidence that rich making processes are viable regardless of the available technology. Even lacking a 3D printer and laser cutter, Millvale exhibited a similar range of projects to Makeshop and Assemble. I do not mean to argue that the technology is irrelevant, but rather spotlight the value of making activities that do not include 3D printing or laser cutting. Young makers learn more than just technological skills in makerspaces. The real gem of youth makerspaces is the way in which they foster a "maker mindset" (Dougherty, 2013) that can be applied and refined with any combination of tools and materials.

**Maker Identity: Equipping Facilitators**

Youth makerspaces work to build youths' identities as young makers, and this study highlights the facilitators' identities, especially in terms of background, as equally important. The disciplinary preferences and corresponding expertise facilitators bring to a youth makerspace notably shape the making experiences. The shift in facilitation at Millvale from Marcus to Jamie and Nicole most clearly illustrates the impact of facilitators' disciplinary background. Jamie's Architecture-based pragmatic approach influenced the way she interacted with kids, the design processes she supported, and the problem-based projects she initiated. For instance, she implemented Bike Tuesdays in response to Millvale's need for bike safety. Technical expertise varies with individual facilitators and primarily indicates a digital or analog inclination. At Makeshop, for example, they describe having the laser cutter Teaching Artist or the woodworking Teaching Artist. Some facilitators across sites are more comfortable working with physical materials whereas others are more comfortable working with digital materials.

Assemble faced a similar challenge, but the lack of pedagogical content knowledge (Mishra & Koehler, 2006), or pedagogical *making* knowledge, severely limited facilitators' own ability to expand their disciplinary knowledge or expertise. Instead, Assemble maintains a practice of partnering with local experts to ensure that making experiences are supported properly. Makeshop strategically leverages the disciplinary differences and expertise variance across facilitators, and compensates for gaps through equipping them about making and learning. Ideally, youth makerspaces need more than one facilitator, but even when that's unfeasible, they should regularly collaborate with local experts to fill in gaps. To balance the variance in disciplinary approaches and expertise among facilitators, it is important to maintain practices of shared facilitation and distributed expertise and to develop facilitators' pedagogical making knowledge.

**Ethos: Community Partnerships**

As shown in Sheridan et al. (2014), community partnerships are also the bread-and-butter of youth makerspaces. Consequently, there is a range of partnerships that exist: financial, mutual, outreach, and public. Financial partnerships are one-way and straightforwardly exist to secure funding for the site; these relationships are particularly important for mobile makerspaces and young makerspaces that do not have a sustainable business model in place. Mutual partnerships are more specialized, bidirectional relationships. One example of this is a research-based mutual partnership, where all parties participating in the partnership benefit from the research in some way beyond just financial gain. Another instance is a goal-based mutual partnership, where partners work together and share resources toward a common goal (e.g., revitalizing the neighborhood). Outreach partnerships, like financial partnerships, are one-way, but exist to serve in some way, either voluntarily or for compensation. Most often these relationships require the makerspace to be relatively stable in order to support mobility of facilitation and resources to other locations. Finally, public partnerships are those that exist for the benefit of the public, but don't necessarily directly benefit either party. Acting as a site for a citywide free lunch program is an illustration of such; this type of relationship benefits the youth, but is not tied directly to the makerspace itself.

## Conclusion

Youth makerspaces are more than just making spaces, they're community spaces. As the maker movement proliferates, we are more commonly referring to them as learning environments and co-opting making for more formal educational purposes. Interestingly, in some youth makerspaces learning is not necessarily a focal point for making, but rather a byproduct. Even so, it is apparent that learning happens in these spaces (a point I investigate in the next chapter). Sheridan et al. (2014) contributes one of the first attempts of framework for understanding makerspaces. I add to this effort by shedding light on the tensions specific to youth makerspaces; this comparative case study has implications for both designers and researchers of youth makerspaces.

Makerspaces are popping up all over the country and even the world — perhaps, on track to reach some level of ubiquity. In a sense, the movement is a grassroots version of the Computer Clubhouse movement (Kafai, Peppler, & Chapman, 2009); however, the maker movement bleeds into existing organizations like museums, libraries, and even Computer Clubhouses. Designs for new youth makerspaces will inevitably vary according to the constraints of the context in which they are situated; however, the findings of this comparative case study offer design principles that hold consistent across varied contexts.

I illuminated the affordances and constraints of three scale-units of making activities that I observed across sites. With this, designers should craft making activities according to time and scope of participation. To an extent, these variables are tied to particular makerspace models. Museum makerspaces, for example, often offer different scale-units of activities than smaller, neighborhood-focused mobile or library makerspaces. The youth makerspaces in this study demonstrated how targeted programming widens the range of making activities they offer. For instance, museum makerspaces can offer regular afterschool programming through which young makers pursue more open-ended making activities.

As learning environments, makerspaces have direct implications for the role of the teacher/mentor/facilitator. Across all contexts in this study, making activities required some level of facilitation whether facilitators simply hung out with youth or strategically scaffolded youths' process. The way facilitators participated, though, had an immense impact on how young makers engaged with the making processes. Though making intersects with existing disciplines and practices, there appears to be something unique about facilitating making activities that require what I call pedagogical making knowledge. In the youth makerspaces I examined, pedagogical making knowledge was assumed in two of the three cases and resulted in facilitators spontaneously and inconsistently supporting learning. These makerspaces, however, maintained practices of shared facilitation and distributed expertise to mitigate these challenges. Sharing design work with education researchers and those with pedagogical making knowledge can also expand, deepen, and focus the learning that happens in youth makerspaces.

Partnerships, especially on the local level, are like the legs of youth makerspaces. The youth makerspaces I observed depended heavily on partnerships to provide expertise and/or funding. All three cases sought out local partnerships to legitimize and sustain themselves as community hubs. This solidifies what others (Baichtal, 2011; Britton, 2012a; Library as an incubator, 2012; Sheridan et al., 2014) have found and offers particular insights into specific financial, mutual, outreach, and public partnerships that are taken up in youth makerspaces.

Drawing from the findings of this study, I highlight three core lines of inquiry for researchers and scholars in the maker movement. First, as we continue to build our understanding of learning through making, it is important to consider process-focused alongside the present techno-focused questions. Learning can happen in all types of making activities regardless of what technology is used. At present, scholars have essentialized the value of learning through making according to the new technologies with which young makers engage. Further research should focus on what young makers learn through the process of making and how facilitators can support this trajectory through developing their own pedagogical making knowledge.

Additionally, the field has yet to firmly agree what defines a “maker.” As we move toward a definition, we must consider how makers are situated within a community environment. I build on Halverson et al.’s (2009) work looking at identity in YMOA’s and illustrate that similar individualistic and collectivistic tensions around identity development exist in youth makerspaces. These studies provide evidence that individual identities are nested within community ethos. In further research we can examine what this insight means for how we develop maker identities and how we develop identity more broadly across youth learning organizations.

What’s more, sites in this study all embody some version of a community-based ethos of which we have limited understanding in education research. Sheridan et al. (2014) have begun to lay groundwork in this area, but most current research around making focuses on the activity itself. Community is woven into the core of these youth makerspaces; as scholars leverage the making activities within them, it’s imperative that we understand the role community has in learning through making, especially if it’s something that we plan to strip out or artificially create.

**Making learning in youth makerspaces**

Current research on making illustrates what making looks like across contexts and investigates how to make with certain technologies. Books like *Design Make Play* (Honey & Kanter, 2013) and *Invent to Learn* (Sousa & Pilecki, 2013) share narrative accounts of making in classrooms, museums, libraries, and afterschool programs. Within these contexts, more empirical research examines fabricating with 3D printers, crafting wearable circuits with electronic textiles, and programming with tangible interfaces. The existing works on learning through making focus on the benefits of making with these types of technology in fostering STEM learning (e.g., Eisenberg, Eisenberg, & Haung, 2013; Fields & King, 2014; Kafai & Burke, 2014; Peppler & Glosson, 2013). A handful of these scholars have begun to consider assessment of making activities.

Two early approaches of assessing learning through making are “debuggems” (Fields, Searle, Kafai, & Min, 2012) and circuit diagram assessment (Peppler & Glosson, 2013). Debuggems, or pre-designed challenge problems, adopt a debugging approach to assess learners’ engineering and programming knowledge after a four-week e-textiles workshop. Fields and colleagues challenged learners to debug coding and circuitry and found that these ‘debuggem’ deconstruction kits are promising tools for evaluating e-textile making activities. In another study, Peppler and Glosson (2013) measured circuitry learning in a two-week-long (20 hours total) e-textiles workshop with a pre- and post-circuit diagram drawing task assessment. Rather than debugging, researchers asked learners to draw a working circuit before and after crafting their e-textile projects and found that the circuit diagram assessment effectively measures change of circuitry knowledge. Drawing on these studies, Lee and Fields (2013) are currently developing an “Interactive Toy Interview,” a clinical interview with a sequence of three tasks targeted to measure conceptual change in an e-textiles-based university course. At present, our understanding of assessment of learning in making activities is limited in richness and scope. Namely, these studies are all focused on e-textiles and do not take place in makerspaces. Nonetheless, these scholars lay the groundwork for this design experiment.

Drawing from this work on evaluating learning through making, I focus my own assessment efforts on how learning is demonstrated in maker*spaces*. In particular, I do not presuppose gains in particular domain areas (e.g., circuitry), but rather take a broad stroke look at how learning is exhibited through making. I draw from pilot work I completed as part of *Learning in the Making* to shape the design experiment and subsequent data collection. In this chapter, I contribute to the growing body of making research by connect the making that naturally happens in makerspaces with learning. I present a collection of three design experiments. Through this study, I seek to answer the questions:

> RQ2: How do experienced young makers' processes and products vary according to design stances exhibited?
>
> > SQ1: What disciplinary practices and technical skills do experienced young makers exhibit while making?
> >
> > SQ2: How do features of youth makerspaces relate to the learning demonstrated there?

I present findings in three slices: design stances, practices and skills, and features of youth makerspaces. Design stances, the approaches makers take toward their making, function as the analytic frame for all findings discussed. Further, I expound design stances and their defining features (e.g., goal and product) as demonstrations of learning in youth makerspaces. Next, I discuss the disciplinary-based learning exhibited through the design experiments focusing on disciplinary-based practices and technical skills (e.g., circuitry or crafting). Disciplinary-based practices are a synthesis of design practices valued by specific disciplines (art, engineering, and architecture). Finally, I tease out features of the youth makerspace environment and ethos that afford and constrain learning. Specifically, I outline the role of availability and visibility of resources and how collaborations were initiated and sustained in young makers' making trajectories.

## Pilot study: Design stances

With *Learning in the Making's* exploration of learning through making, we have identified the existence of *design stances* people take toward making. A design stance is the approach a maker takes toward making. We identified a set of three design stances (aesthetic, functional, and pragmatic), each defined by unique goals and product features and inspired by disciplinary practices. In short, with an aesthetic design stance — inspired by Arts — one makes something that looks cool, with a function design stance — inspired by Engineering — one makes something that works, and with a pragmatic design stance — inspired by Architecture — one makes something that solves a problem. In the next section, I introduce the pilot data and resulting design stance framework that shapes and informs my own data collection and analysis of. I first use a making activity — building a 3D printer — commonplace at Sector67, a community makerspace in *Learning in the Making's* study, to illustratively define and distinguish each of the three stances.

### Aesthetic

The driving goal for an aesthetic design stance is to make something that represents and/or communicates meaning through its form. At Sector67, a group of members explored how to build a 3D printer that prints in sugar. In conversation with Frank, a member, he explained that the goal of building such a printer is simple: it's cool to print in sugar and make edible objects that look better than ever before. One night members brought in a Justin Bieber birthday cake for one of the members, and Frank remarked that they could have made better decorations if they had a 3D printer that prints sugar (Sector67, Fieldnotes, 11/30/2012). Printing sugar decorations to dress up a birthday cake serves aesthetic purposes. To do so, they do not need to build the sturdiest, most efficient, or largest 3D printer. Even if the 3D printer is slow and buggy, it functions well enough to suit their aesthetically driven goals of creating 3D-printed sugar objects. Like many of the artistic endeavors at Sector67, though, this sugar 3D printer idea never reached fruition. Theoretically, with a sugar 3D printer, they would be able to express themselves through a new medium that has never before been accessible and experiment with aesthetic features like color. The aesthetic design stance is inspired by artistic disciplines that value discovering meaning through forms of representation, communication, and expression.

**Functional**

The chief goal for a functional stance is to make something that works well. A member of Sector67, Jacob, continues to build and rebuild a 3D printer for over a year; persistently prototyping and testing to build the most highly functional machine possible. When something is not working properly or if he discovers a better material or method, he is not afraid to completely disassemble his printer and start from scratch. For example, during one visit to Sector67, Jacob had much of his 3D printer dismantled to troubleshoot a heat issue he was having with the extruder nozzle (Sector67, Fieldnotes, 10/16/2012). A functional stance adopts a highly technical approach debugging and experimenting with materials, and products typically espouse functional features like efficiency. At Sector67, members most often exhibited a functional design stance toward their making, particularly working to accomplish a given task in the ‘best’ way possible. The functional design stance is inspired by engineering disciplines, which value products that work effectively.

**Pragmatic**

The driving goal for a pragmatic design stance is to solve a particular problem or fill a need. One member of Sector67, Gerald, took up this design stance to build an extra large 3D printer, since he needed to print something larger than what the current 3D printers produced.

His exploration and experimentation were purely in service of his end goal of printing a large object. In his blog post, Gerald exclaims, “I’ve finally finished (more or less) building a very large 3D printer!” (Sector67 blog, 12/12/12). As his disclaimer “(more or less)” alludes, his 3D printer and the objects it produced were not aesthetically beautiful nor did they “work” for much other than what he intended. They did, however, successfully print the larger objects he needed, which marked the completion of his project. The pragmatic design stance is inspired by architecture disciplines — the practical branch of arts and engineering.

**Entrepreneurship and design stances**

Entrepreneurship — financially profiting from the products of making — is a motivator that cuts across all three design stances. Monetizing products, regardless of design stance, has direct implications for audience and provides evidence for the existence of a secondary design stance. In our pilot data, audience was not obviously tied to design stance. Whether the product is for personal, local, or global use, the motivating factor was entrepreneurial in nature. One of the highest-profile cases of entrepreneurship at Sector67 is Alisa’s state-shaped cast iron skillet project. Alisa’s craft has been exhibited on various media outlets including receiving Martha Stewart’s American Made Award (MSAM, 2012). With an artistic design stance, she began crafting a map titled “Made in America” made out of state-shaped cast iron skillets. In her original piece, many of the skillets were too large to be functional or pragmatic. Interest grew and Alisa began creating functional state-shaped skillets for the general public, but treads carefully to avoid sacrificing her artistic roots. She elaborates in a Q&A with the Martha Stewart Show:

> Going from art to industry has been an unusually defining process for me, as I've come face to face with questioning why I'm making certain choices and essentially, focusing on

> a chapter of my life where my creativity has shifted into the project of "entrepreneurship," alongside maintaining a studio practice and still following my passions. (MSAM, 2012)

A secondary functional design stance became apparent to serve Alisa's new entrepreneurial goals of selling her state-shaped cast iron skillets. For instance, many of the original skillets needed to be scaled down to be functional for everyday use. Reflecting on the aesthetic and functional tensions of her work, she explicitly claims her primary aesthetic design stance by explaining, "the production line [of skillets] could easily be a full-time gig, but I'm an artist" (MSAM, 2012). As such, the skillets primarily serve an aesthetic purpose, as they aren't the "best" cast iron skillets one can buy nor do they solve a cooking problem, they simply look cool and work well for making things like state-shaped pancakes.

Further analysis and research is needed to really understand the relationship between entrepreneurship and design stances, but this example highlights two characteristics of design stances: 1) design stances are tied to project or purpose not individual, and 2) one might exhibit secondary design stances depending on the project or purpose. These two characteristics shape my present study by situating the project as the unit of analysis to determine design stances and assuming a young maker can take up different design stances depending on the project or purpose. Design stances can also manifest as primary or secondary. Alisa exhibited a secondary functional design stance to make skillets that she could sell while keeping her primary aesthetic design stance intact.

**Using stances for assessment**

In this study, I track learning according to young makers' chosen design stance toward the task — leaving the door open to identifying additional stances. Tracing learning along representational trajectories is not a new concept. Metarepresentational competence (MRC; diSessa, 2004) describes the process of selecting optimal representations for a given task, utilizing novel representations effectively, and crafting new representational tools as necessary. DiSessa (2004) argues that understanding the affordances and constraints of representations, especially in science disciplines, is a key marker of learning. Halverson (2013) illustrates the value of MRC in artistic production through "representational trajectories" through which youth choose optimal tools and media to tell a story.

To date, much of the work around MRC has been in disciplinary-specific tasks, but in this study I explore MRC in making tasks by tracing design stance — inspired and guided by disciplines, but not necessarily tied to such. I take a learner-centered approach to MRC and assume, for example, the learner rather than a given discipline can define an optimal representation. In other words, where traditional MRC approaches lean on existing values of scientific fact or artistic genre, I lean on the values learners articulate in their making process. Consider an example from pilot data:

In a spring break maker program at Sector67, young makers were told to *make flow,* whatever that means to them. Alice,[4] a second-grader, brought the concept of flow into her already existing project, thus demonstrating an aesthetic design stance. She made a charming-but-frail sugar mill from a glass jar, cardboard rolls, sugar, tape and scissors to accompany her construction-paper city (Figure 3). Darren, another participant, had used these tools earlier to create a modified hourglass — his interpretation of flow (Figure 3).

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[4] Names changed to maintain anonymity

**Figure 3. Darren's hourglass (left) and Alice's sugar mill (right).**

Alice transformed Darren’s initial tool/material use into an artifact that fit into her already existing design and translated the concept of flow from a functional design stance (sugar flows through an hour glass) to an aesthetic design stance (Alice explained her sugar mill was art and did not need to work). Tracing her development of MRC over time reveals her (self-described) aesthetic stance in contrast to Darren's functional stance.

In this example, the young makers take up different design stances toward the same tools and materials. This indicates that multiple design stances are possible with the same prompt and set of resources. Likewise, as with the above example of building 3D printers, design stances are not tied to a specific product or purpose. In contrast to Alice’s sugar mill, another maker might adopt a functional design stance and instead build one that works reliably. Or a maker with a pragmatic design stance might build a sugar mill in response to a problem — perhaps a city that cannot transport sugar. In the current study, I work to build a more cohesive understanding of design stances and how they function as demonstrations of learning.

With the design experiments, I seek to solidify and further develop design stances in order to expand the goals and features that define them. Building on existing work around MRC, I experiment with a cooperative approach to understanding design stances much like Halverson's (2013) representational trajectories. I follow experienced young makers' goals and artifacts through a design cycle. I cooperatively assess process and product according to the design stance articulated and exhibited. For instance, in Alice's case I would assess her sugar mill from an aesthetic design stance (e.g., does she believe its form conveys satisfactory meaning?). In Darren's case, I would assess his hourglass from a functional stance (e.g., does he believe it works properly?). Cooperatively assessing learning in this way ensures that the measurement aligns with the intended goals of the learner, and supports a key characteristic — pursuit of personal interest — of makerspaces. This method of assessing learning is experimental, so I plan to discuss whether and how this approach works as a measure for learning, and explore alternative approaches if necessary

**Scope of research questions**

Design stances are project-centered not learner-centered; thus, I do not assume that one brings one design stance to all projects, but rather that one can adapt and change one's stance according to the project. I am investigating the range of design stances experienced young makers bring to a single project (make flow). This study is the first stepping-stone in understanding how design stances exhibit learning demonstrated through making and what connections might exist between design stances and learning environments. I specifically explore how experienced young makers *demonstrate* learning. This means that I am not measuring learning according to specific outcomes, but rather follow young makers' trajectories and artifacts according to MRC as a marker of learning. I also map practices and skills exhibited while making to well-established practices and skills of experts across specific disciplines. As I explore the construct of design stances, I focus on participants' own articulation of their design stances and evaluation of their artifacts. Once design stances are established as a viable approach to understand and assess learning through making, we can employ more comprehensive methods around evaluation.

## Method

Taking a design experiment approach (Brown, 1992; Collins, 1992), I investigate the learning demonstrated in makerspaces and explore the construct of design stances across participants. A design experiment methodology encourages "extended (iterative), interventionist (innovative and design-based), and theory-oriented enterprises whose 'theories' do real work in practical education contexts" (Cobb et al., 2003). Through design experiments, researchers design *conceptual corridors* (or designed learning experiences) through which learners navigate along *conceptual trajectories* (pathways of learning conceptual content), which are thoroughly documented (Confrey, 2006). Likewise, I designed a making activity (or corridor) and strategically documented the making trajectories by which participants travel.

Given that our understanding of learning in makerspaces is in its infancy in educational research, we're still very much in an *exploratory* phase. Drawing from *Learning in the Making's* ethnographic findings and folding ethnographic methods into my design experiment methodology suit the *how*-based exploration underlying my research questions. Put simply, there's a lot we do not know about learning through making, so conducting design experiments that are rooted in theory and shaped by pilot data offers a deeper understanding of this phenomenon.

Cobb et al. (2003) emphasize five crosscutting features of design experiments, each of which support my use of design experiment as a methodology. First, design experiment is one of the most functional methodologies to understand simultaneously the learning process and the design structures that support learning (Cobb et al., 2003). My overarching goal with this study is twofold: to understand the process by which young makers learn through making and to realize implications for design and assessment of makerspace-learning environments. The essence of my study mirrors the spirit of design experiments.

Second, design experiments are highly interventionist in nature and are “test-beds for innovation” (Cobb et al., 2003, p. 10). Since making is such a naturalistic activity, in order to best understand how to *design for* it, we must test theory- and data-driven ideas and suspicions. As stated, one of my overarching goals is to discuss design principles for making activities and assessment of them, and the best way to identify design principles is to conduct more formal interventions.

The third and fourth features of design experiments are that they are equally prospective and reflective and this results in their iterative temperament. Leveraging these characteristics of design experiments legitimizes my use of *Learning in the Making’s* pilot data and permits me to use findings as they emerge to continuously inform my inquiry. As I explore the relationship between design stance, making trajectories, and external artifacts, I am aware that I may not have all the necessary information up front to design the making activities. This methodology allows me to empirically study the phenomenon of making, while remaining open to new conjectures as they may arise.

Finally, the most defining feature of design experiments is that they generate theories that “do real work” (Cobb et al., 2003, p. 10). The goal is bigger than just providing sufficient evidence of learning or implications for design; design experiments offer an intermediate theory functionally demonstrated in specific circumstances while yielding universally applicable design principles. The pragmatic nature of design experiments not only suits my own goals in this study, but also the goals of educational researchers more broadly.

**'Make flow' Activity Protocol**

The *Learning in the Making* lab piloted the prompt *make flow* in several spaces with a range of populations, for example: a makerspace with adults, a spring break program with youth, a mentorship program with young adults, and a museum with the general public. In these contexts, participants represented the prompt using water, gravity, electricity, words, and heat through a variety of interpretations from getting a ball or sugar to flow to creating a water wheel to developing a rhyming machine. As mentioned above, piloting the prompt in a spring break maker program revealed how it supports more than one stance, even when using the same tools and materials. The prompt also afforded, but did not force, collaboration across demographics and contexts. In a community makerspace, adult participants deliberated ideas and ended up working together to construct a collective representation of flow. At the museum, the prompt sparked an ongoing, asynchronous project — a rare occurrence for this museum — to which children, families, and other museum visitors contributed.

Through piloting the make flow prompt we learned: 1) it is stance-ambiguous, 2) it affords myriad interpretations beyond a specific set of disciplines, and 3) it allows for collaboration. I use the make flow activity in this study as a broad foundation on which experienced young makers have the freedom to make anything. The goal with this activity is to examine how participants demonstrate learning in youth makerspaces *through* their exhibited design stance. I use an expansive, stance-ambiguous prompt that is as non-prescriptive as possible to allow participants to naturally engage in their youth makerspace.

**Participants**

The participants I target for this study are *experienced young makers*.

**Experienced makers.**

I define experienced as either self-identifying as a maker *or* has actively participated in their youth makerspace for at least six months. I take the either/or approach, because scholars have yet to agree upon what makes a maker, so I leave it open in this study, allowing a participant to self-identify or assign identification via participation.

**Young makers.**

I originally intended to focus on 9 to 12 year olds. Though adolescence is often dubbed the prime period of identity development, this preadolescent stage is what lays the foundation for which identity trajectories are possible in adolescence. In developmental psychology, Freud outlines this stage as the *latency* period during which youth become less reliant on their parents and begin to explore peer-based relationships through participation in a range of social activities. Erikson describes this phase as *industry versus inferiority* during which the basic virtue of *competence* is developed through exploring a range of activities; the defining question of this stage is 'how can I be good?' (Erikson, 1959). Young makers' participation in the making activity itself is an exploration and/or expression of their identity.

I made the pragmatic shift to include adolescence (9 to 17 years old), because many of the programs at the sites participating in the study organize their programs around various school ages (e.g., middle school) or are not organized by age at all. Given the much stronger connection between adolescence and identity development, the shift does not jeopardize the study.

**Participant selection.**

I worked with each site individually to figure out the most suitable way to conduct the design experiment at their sites. At all three sites, we completed the making challenge as an activity separate from any existing program. We arranged for a facilitator to be present to support the young makers as needed; this allowed me to solely focus on data collection. I advised the facilitators to interact with the youth just as they normally do. I shared my criteria (age range and maker identification) with the program coordinators and they invited the experienced young makers who they thought fit the criteria. I aimed for three to five experienced young makers at each site. Eight experienced young makers participated in the design experiments:

| Name | Age | Site |
|---|---|---|
| Sarah | 14 | Makeshop |
| Charlie | 14 | Makeshop |
| Mack | 15 | Makeshop |
| Sasha | 12 | Assemble |
| Cody | 12 | Assemble |
| Jackson | 10 | Millvale |
| Shawn | 10 | Millvale |
| Britney | 14 | Millvale |

***Makeshop.***

At Makeshop, the youth program coordinator, Cheryl, invited participants who were working in the VolunTEEN program for the summer. This program is an employment program for high school aged youth during the summer with the option to work year-round. In the VolunTEEN program youth are assigned an area in the museum (e.g., Makeshop, exhibits, or front desk) where they serve for the summer.

Sarah and Charlie, both 14-year-old Caucasian girls, attended the middle school across the street and participated in the YouthALIVE program for three years. They graduated from the middle school this spring and continue to participate in the Children's Museum through the VolunTEEN program. Neither Sarah nor Charlie was assigned to work in Makeshop this summer, but they have extensive experience in Makeshop through YouthALIVE. Mack, a 15-

year-old Caucasian boy, is working his second summer in the VolunTEEN program. Both summers he has been assigned to work in Makeshop alongside the Teaching Artists[5].

I worked with Hillarie, Makeshop director, and Cheryl to coordinate a time for the design experiment during one of the regular VolunTEEN shifts. The other youth participating in the VolunTEEN program were not able to make it this day due to sickness and last minute issues.

***Assemble.***

At Assemble, Candice, the program coordinator, invited participants through the Make It! program she runs during the school year. Make It! is an afterschool program for middle schoolers with some summer events; for example, they took a trip together to the Detroit Maker Faire the weekend before this design experiment.

Sasha, a 12-year-old Black girl, participated in the Make It! program since last December. She lives in a nearby suburb of Pittsburgh, but actively participates in the program. Cody, a 12-year-old Caucasian boy, recently joined the Make It! program a couple of months before following a recommendation from a Teaching Artist at Makeshop.

I worked with Candice to organize a time to conduct the design experiment. Candice's attempt to solicit participation, though, was haphazard compared to the other sites. The young makers at Assemble also had to make a special trip to participate in the design experiment whereas other sites folded it into times when youth would already be there.

***Millvale.***

At Millvale, the librarian, Luke, invited participants who are active in the maker programming. With the unique culture at Millvale, participation varied between participants.

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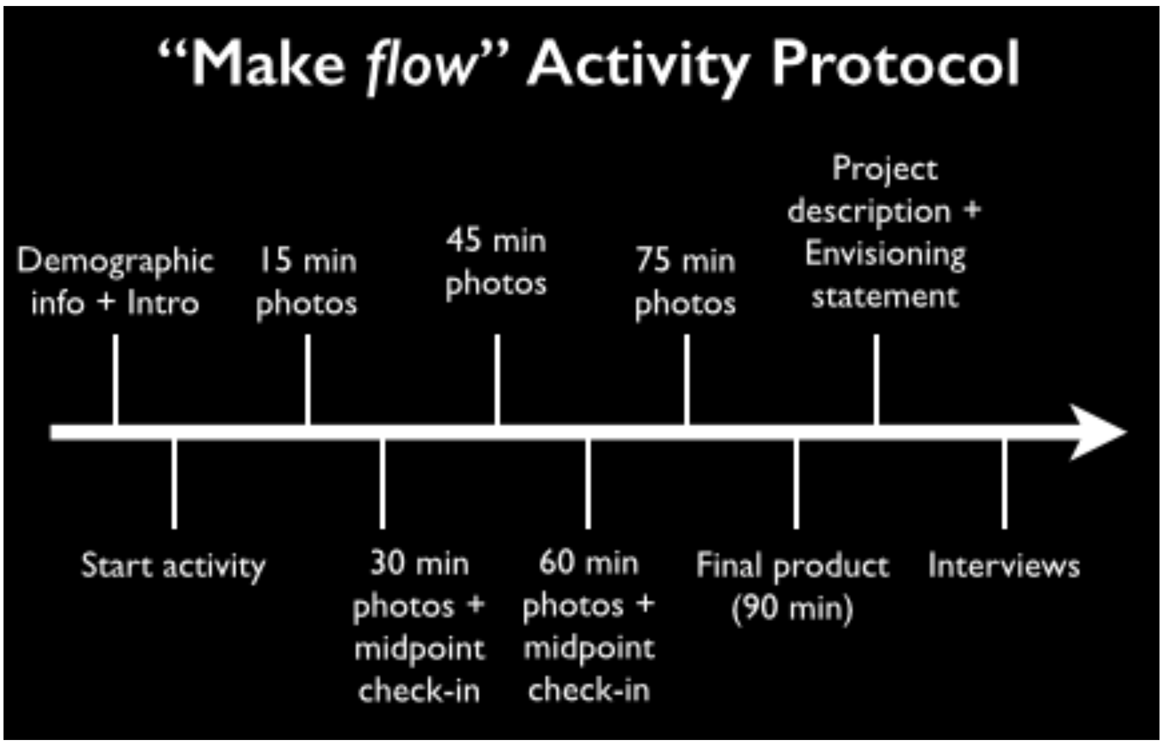
[5] Makeshop facilitators

Jackson, a 10-year-old Black boy, is actively involved in maker activities at Millvale, especially Maker Thursdays. Shawn, a 10-year-old Caucasian boy, participates in several programs at Millvale including the maker programs, book club, and game-making club. Britney, a 14-year-old Caucasian girl, has worked with Millvale since its conception, primarily as a volunteer helping with the game-making program on Saturdays. She has not been exceptionally active in Maker Thursdays, but participates in other maker programming, including a two-week-long wood and metal maker apprenticeship program that happened earlier this summer.

I primarily worked with Luke to coordinate details for the design experiment. While he formally invited a small handful of kids (only two were present), he was confident that some kids would just ‘show up’ as they usually do — Jackson was one of the kids he did not originally invite.

**Data collection**

In this study, I conduct an identical design experiment across three makerspaces. The design experiment is shaped by the following protocol through which I collect a range of data. Broadly, individuals can vary design stances by project, but within a given project design stances lie between individuals and their artifacts. Throughout data collection and analysis, I follow the maker — not necessarily the artifact or timespan. Here is an overview of the design experiment timeline:




I worked with the program coordinators to block off a minimum of 2.5 hours for the design experiment at each site. The raw time for the making challenge was consistent at 90 minutes. I reserved 15 minutes on either end of the making challenge for introductory and reflection materials and an hour for interviews (e.g., 20 minutes for three interviews) with some flexibility depending on number of participants. Assemble was the only site strictly limited to 2.5 hours, which did not become an issue, because there were only two participants there.

I made booklets that included the demographic and maker information, scratch paper, and the project description and envisioning statement prompts. The booklets made it easy to compile all the physical data collected. I break down the timeline in more detail:

**Demographic information and introduction.**

Once all participants arrived, I introduced myself and explained that we would be doing a making challenge, but first wanted them to answer some questions about themselves. I handed out the booklets and requested that they fill out the first two pages of information, which was demographic information (name & age) and making experience and background (see Appendix C). When they completed answering those questions, I proceeded by introducing the making challenge and the make flow prompt (see Appendix D for the script I followed throughout the design experiment). I encouraged them to use the space as they normally would and said that they could choose to work individually or collaborate.

**Document process and check-ins.**

To document participants' process, I took a photo of them every 15 minutes. Again, I primarily followed the maker during this process and not solely the artifact; for example, if at 30 minutes the young maker was collecting materials, then I documented what materials they were collecting and took a photo of the artifact.

Between 15-minute markers, I took jottings and additional photos to document process and movement through space. Matching the methods in my comparative case study, I followed Emerson, Fretz, and Shaw's (1995) ethnographic jottings, fieldnotes, and memoing practices. I took jottings, photos, and (where appropriate) audio recordings for real-time observations, wrote fieldnotes as soon as possible after the field visit, and tracked themes with memos; I also recorded my remote interactions (via email and phone) with each site. I maintained an observational stance throughout data collection.

Originally, I planned to have a single midpoint check-in at 45 minutes, however, during the first design experiment, I altered the protocol to include two check-ins, one at 30 minutes and one at 60 minutes. I shifted the protocol for two reasons. First, I was not sure how feasible it would be to collect at more than one check-in point, but once the first design experiment commenced it became necessary. Second, I found myself unable to wait 45 minutes to have a formal check-in, because I wanted to know what the youth were thinking. In the formal check-ins, I asked each participant: What are you making? How are you making it? Why are you making it? The check-ins were audio-recorded.

As a backup, I video- and audio-recorded the entire design experiment at each site. I did not collect this data with the intention of formally analyzing it for this study, but rather to complement fieldnotes as need. Since I was completing these design experiments back-to-back, the video and audio recordings served as a safeguard to fill holes in my fieldnotes.

**Project description & envisioning statement.**

At the end of the 90-minute make flow activity, I asked participants to complete a project description to accompany their final artifact and an envisioning statement describing what they would like to make next (see Appendix E). The project description provides a concise snapshot of what the young makers made from their own perspective — particularly, how they would communicate it to an outside audience. The envisioning statement provides a window into whether and how the participants plan to continue or build on the current project. The *Learning in the Making* team used both of these tools in our previous design experiments; we are still refining these tools and exploring what they tell us about learning through making.

**Interviews.**

After the making challenge and reflective materials were complete, I conducted individual semi-structured interviews. I video-recorded all the interviews, since we discussed their artifacts. I constructed the interview protocol (see Appendix F) with the activity-identity-community framework and my preliminary understanding of the characteristics of design stances. The primary purpose of the interview was to nail down each participant's design stance, but I also worked to gather information about the making trajectory, the final product, learning, audience, history of making, and identity. The protocol is about half activity-focused and half maker-focused, such that the first half of the questions are about what they made in the making challenge and the second half are about making in their life more broadly.

In summary, for each participant, I collected the follow data:

| | Pre-activity | 15 min | 30 min | 45 min | 60 min | 75 min | 90 min | Post-activity | Duration of activity |
|---|---|---|---|---|---|---|---|---|---|
| Participant | Demographic & Maker info | Photo | Photo + audio recorded check-in | Photo | Photo + audio recorded check-in | Photo | Photo | Project description + Envisioning statement + Interview | Video recording |

## Data Analysis

In analysis, I considered all the above data, except the audio and video recordings of the entire activity. The analytic process I use is iterative and mirrors the research questions of this study. I used the Text Analysis Markup System Analyzer (TAMS Analyzer) tool for analysis. TAMS Analyzer is an open-source qualitative research tool designed for ethnographic and discourse research, and it affords basic coding of text and multimedia data. It is well suited for my analysis, because it allows quick and easy cross-data views using comparative tables or "matrices" (Miles, Huberman, & Saldaña, 2013) linking directly back to data in-context. Also, TAMS Analyzer simplifies conducting several rounds of analytic coding with ‘code sets’, which function as thematic groupings.

Using this tool and following Saldaña’s (2009) coding methods, I completed numerous rounds of coding. In “first cycle coding,” I conducted line-by-line initial coding using elemental methods, primarily a combination of in vivo and descriptive coding (Saldaña, 2009). With this, I created crosscutting codes according to the questions in the interview protocol (see Appendix X for the interview protocol). I looked across participant by question to understanding the variations and similarities. This first cycle coding gave me a sense of the data and their scope.

Next, I mapped out each participant’s process by time and followed this up with highlighting disciplinary practices and technical skills used in each process. I mapped out individual’s process by time and disciplinary practice. For disciplinary practice, I use existing literature on design processes in Engineering (Massachusetts DOE, 2006), Arts (Winner, Hetland, Veenema, Sheridan, et al., 2006), and Architecture (Wade, 1977). The table below compares the characteristics of each design process — note that I do not compare sequential design processes, but steps, habits of mind, or features that are unique to each respective discipline. Also, the framework in Architecture is not as explicitly developed for education as with Engineering and Arts, so for practical purposes I simplified the in-depth problem solving process Wade (1977) presents.

| **Engineering Design Process** | **Studio Thinking Model** | **Architecture Problem Solving** |
|---|---|---|
| Identify the need | Develop craft | Seek problem(s) |
| Research | Engage & persist | Representation of problem(s) |
| Brainstorm solution(s) | Envision | Define a problem |
| Select best solution(s) | Express | Identify necessary changes |
| Construct a prototype | Observe | Solution choice |
| Test and evaluate solution(s) | Reflect | Imaging & invention |
| Communicate solution(s) | Stretch & explore | Check competing solutions |

| | | |
|---|---|---|
| Redesign | Understand disciplinary world | Final solution selection |

I originally intended to code the practices of each design according to the discipline of inspiration; instead, I opted to compile the design processes of all three disciplines. Practically, the data I collected does not lend itself to deeply teasing out the nuances of each design process, because the making task was only 90 minutes and was designed not to elicit a specific discipline. I did not want to force such a framework on the data. I deduce four disciplinary practices: select problem, brainstorm, iterate, and communicate. I dropped the 'select problem' practice, because the problem (make flow) in the activity was given. Thus, brainstorm, iterate, and communicate represent the disciplinary practices above as follows:

| **Design process** | **Brainstorm** | **Iterate** | **Communicate** |
|---|---|---|---|
| **Engineering Design Process** | - Brainstorm solutions(s)<br>- Select best solution(s) | - Construct prototype<br>- Test & evaluation solution(s)<br>- Redesign | - Communicate solution(s) |
| **Studio Thinking Model** | - Observe<br>- Envision | - Stretch & explore<br>- Engage & persist | - Express<br>- Reflecting |
| **Architecture Problem Solving** | - Identify necessary changes<br>- Solution choice | - Imaging & invention<br>- Check competing solutions | - Final solution selection |

I do not mean for this to be all-encompassing, nor do I mean to make a philosophical or pedagogical argument by compiling the design processes. Rather, I seek to use brainstorm, iterate, and communicate as pragmatic tools to demonstrate the existence of disciplinary practices given the obvious practical constraints of the study.

I delineated technical skills (e.g., circuitry, crafting, and woodworking) by designating tools used as a demonstration of knowledge and new tools used as a demonstrating of learning. Once I coded disciplinary practices and technical skills, I compared them across the participants.

I followed this up with a more in-depth look at the brainstorming phase for two reasons: 1) though I presented it as a completely optional activity, all participants used the blank sheets in their booklet to brainstorm, and 2) the amount of time spent brainstorming varied widely. I referred to the video data (the only case in which I do this) to determine each participant's brainstorming duration and the step immediately following brainstorming.

Finally, I use the above characteristics of design stances (goals and product features) to determine the design stance of each experienced young maker. I assume that all participants have a design stance toward what they make, but that there may exist additional stances than the three *Learning in the Making* identified in pilot data. The table below outlines how design stances were determined using data examples:

| **Design stance** | **Participant** | **Evidence from fieldnotes** | **Evidence from final interview** | **Evidence from final artifact** | **Analytic reflection** |
|---|---|---|---|---|---|
| Aesthetic | Charlie | Facilitator suggested Charlie use wire to add axles to her car, but she disregards his comment saying that "it's just for looks" and it "will all go downhill," so it doesn't need wheels. Later, Mack suggests, "you can probably make your racecar move with motors," but Charlie said it was a "hover car" and gravity could move it. | Charlie explains her car: "I like it... it's a different car, I mean... it's just for decoration, it's not supposed to actually work, just to get the idea that it's supposed to be a car going down there. And I mean, it was fun to make this." | An obstacle course made from recycled materials down which falls the "car" is made out of a toilet paper roll with four bottle caps tied to four corners representing wheels. | Despite many suggestions to make her car "work" better, Charlie persisted that it was meant "for decoration" rather than function. Her goals and product features are aesthetic. |
| Functional | Mack | Mack is testing out one his motor circuit on the platform he built and exclaims, "it works — I know that much!" He is troubleshooting his circuit, and it looks like he will attach the waterwheel to the | Mack reflects on his water wheel: "So the Archimedes screw became a water wheel to push the water about, which pushed the water about, and that kinda | A water wheel made out of recycled materials with a complete circuit and switch controlling the water wheel. | Mack iterated and troubleshot to get his water wheel to "work" as well as possible. He explained his final artifact "kinda doesn't work," but |

| | | | | | |
|---|---|---|---|---|---|
| | | motor now. | doesn't work. It's more of a splash machine.” | Post-interview, Mack added an enclosure to his water wheel to contain the splashing, so it worked fully as intended. | then fixed the pieces that didn’t work post-interview. His goals and product features are functional. |
| Pragmatic | Cody | Cody has been experimenting with different tools and materials for 30 minutes and he found a balloon pump. He challenges himself to solve the problem of using “it to incorporate flow with air flow.” | Cody explains that his main goal was “trying to find what to make with my idea. So when I found the balloon pump I got an idea for the air, for the subject of airflow. Then I was trying to figure out what I could do with the balloon pump to make a project out of it.” | The balloon pumps the balloon and then attaches it to a platform with round pieces of copper glued to the bottom functioning as a “car” running off of compressed air. | Cody experimented with many tools and materials to find a problem (using the balloon pump to show air flow), and then explored possible solutions until he found a suitable one. His final artifact doesn’t work the ‘best’ and has some representational elements, but is a solution to his problem. |

As with the pilot data, some participants seemed to exhibit a primary and a secondary design stance, but every participant a clear primary design stance was exhibited and identified. After determining design stances for each participant, I compared disciplinary practices, technical skills, and other themes by design stance. This gave me a scope of the boundaries of design stances and expanded evidence of such.

## Demonstrating learning through making

In this section, I provide evidence that design stances are viable constructs through which young makers demonstrate learning. I also offer disciplinary-inspired and skill-based demonstrations of learning as evidence that learning happens in makerspaces, even without specific content goals. Finally, I highlight how tools and materials and collaboration support or inhibit learning at each youth makerspace. I draw from findings in my comparative case study to contextualize the connection between these features of makerspaces and learning.

### Design stances

In this section, I explore the design stances exhibited in the making challenge. The most defining feature of design stance was the goal articulated by the young maker; all participants claimed one of three goals: to communicate/represent something, to get something to 'work', or to solve some sort of problem. I outline the design stance for participants with supporting evidence exampling their goal and product:

| **Participant** | **Site** | **Design stance** | **Goal (interview data)** | **Product (final artifact)** |
|---|---|---|---|---|
| Sasha | Assemble | Aesthetic | "For it to all come together" to communicate "my example of flow." | A diamond circuit made of conductive tape, LED lights, and a motor that doesn't work well. |
| Britney | Millvale | Aesthetic | "To best represent flow with water." | A foiled wrapped piece of wood with confetti pieces on it. One pours water to represent how flowing water clears debris. |
| Charlie | Makeshop | Aesthetic | "My main objective was just find different [decorative] stuff and then incorporate it into here. Like this thing [white net used for backstop] I was like 'whoa this is cool let's use it.'" | An obstacle course made from recycled materials down which falls a "car" is made out of a toilet paper roll with four bottle caps tied to four corners representing wheels. |
| Shawn | Millvale | Functional | "Just to show the flow of electricity and air flow and [two other circuit blocks] we were just making these for fun." | A complex circuit including lights, a motor, and a speaker made using circuit blocks. Two speaker circuit blocks built from scratch. |

| | | | | |
|---|---|---|---|---|
| Mack | Makeshop | Functional | "It was just merely to move [the wheel] slowly enough that it could pick the water up in the teeth of the water wheel, and move it about." | A water wheel made from recycled materials with a complex circuit and switch controlling the water wheel. |
| Cody | Assemble | Pragmatic | "…To figure out what I could do with the balloon pump to make a project out of it" | A balloon pump used to inflate the balloon and then attach it to a platform with round pieces of copper glued to the bottom functioning as a "car" running off of compressed air. |
| Jackson | Millvale | Pragmatic | "To make stuff goes with flow…electric flow and flow through wind… there's not a lot that you can listen to with music, so we can make some for other people to listen to." | A complex circuit including lights, a motor, and a speaker made using circuit blocks. Two speaker circuit blocks built from scratch. |
| Sarah | Makeshop | Pragmatic | "I wanted to *know*. Because I wasn't even sure if a connection of electricity can break." | A collection of paper and binder clips, which connect to demonstrate how electricity breaks. |

**Aesthetic.**

A maker at each site exhibited an aesthetic stance to either communicating or representing flow in an artistic way. The girls' products embodied the same aesthetic features: decorative or representational characteristics, but the processes by which they made their artifacts were vastly different.

Sasha designed and created an artful representation of flow using circuitry. She took the most linear process of any participant in the study; she spent a full ten minutes planning and designing her project, then methodically collected materials, and produced an artifact nearly identical to her original idea of light circuits in the shape of a diamond around a motor circuit (see Figure 4 comparing brainstorm with final product).

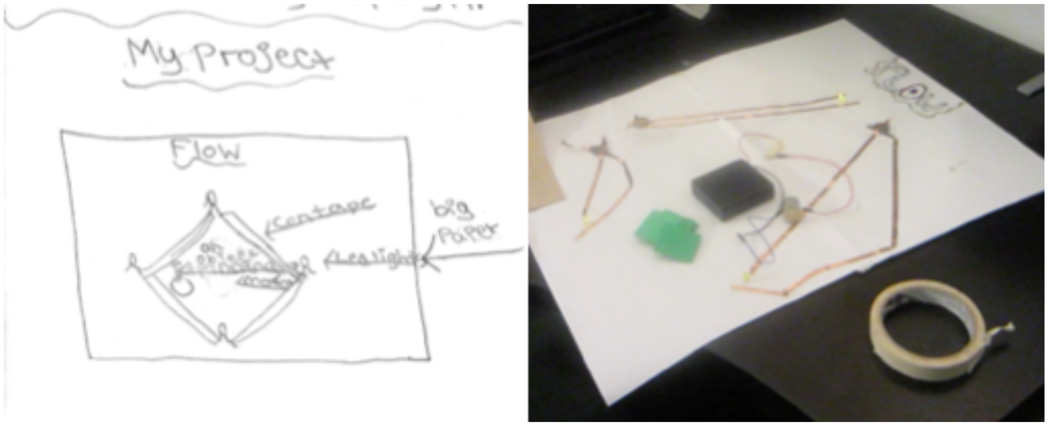



**Figure 4. Sasha's brainstorm (left) and final product (right).**

Sasha explains her process from her sketch to her final artifact: “Basically, it's not the exact same, but it's like kind of the same. It's sort of like a diamond, and then the lights, and then the motor is in the middle and it's gonna have an object on top of it.” Though her project was not completed (the motor and construction-paper object were not installed) by the time we interviewed, she introduced her product with this caveat: I'm not finished with the second [example of flow]. I'm gonna put this motor, and I'm going to make a cube with these [green pieces of paper] and it's gonna be like spinning around over and over again.” Candice, the facilitator at Assemble during the design experiment, informed me that Sasha did complete her product as she planned before she left.

Britney created a representation of Girty’s Run using basic crafting materials. She built a stream using a foil-covered board that included paper confetti representing debris, a piece of foil representing a log, and green streamers representing grass. Britney took a more iterative approach and began with a short brainstorm, experimented with materials to create her idea, and continued this cyclical brainstorm-to-experimentation process expanding her water flow idea “until it seemed right.” She describes a chunk of this process:

> I thought well what's the definition, I guess it's like moving it ease and then I tried phrasing it differently like flowy movement. That got me thinking of like water, you

> know flowing, movement, ease, and water just doesn't like struggle usually to go. So, then I drew a waterfall and a little stream. Then I was thinking so what supplies would I have to use for this? So that's my beautiful drawing of the sink-ish thing, and then flowing to the wooden board. So, then like 'oh, then I'll need a wood board and then a sink'. [Turns to the second page of brainstorm] Then I'm like no that sucks, because then I'd have to some how collect the water, and I don't think the wooden board would fit underneath the sink, so I had to change my mind. Then I tried it again. So then I wrote flow: one fluid easy movement. And I thought okay what else would I need? I need water, a packing peanut, because she brought them out and I really wanted to incorporate that into my idea — I had no clue how, but I wanted to. ” (Britney, Interview, 07/31/2014)

Interestingly, in the last couple of iterations, Britney crafted a narrative around her artifact, which became part of her final product. As she poured water down her foil stream taped to a wooden board, it cleared away the “debris” (paper confetti and foil log) and she explained that a creek, Girty’s Run, flows behind her house and often floods, taking debris downstream. Even though Britney crafted the narrative after her product was nearly finished, she reconceptualized her entire project by connecting it to Girty’s Run. She shared:

> Girty’s Run is a creek that goes through Millvale, my backyard. It often floods during the spring and fall it floods a lot. And I've seen stuff like logs, and debris and run off go all through it, and I thought that would be the best way to represent flow, because it flows and it takes all the stuff with it.” (Britney, Interview, 07/31/2014)

Her personal experiences with Girty's Run added a meaningful narrative — and a unique aesthetic feature — to her final artifact. Britney discovered meaning by forming a narrative that expressed the personal connection she made with her physical product.

Charlie built a representation of a racetrack and a car. She began with a vague sketch of a roller-coaster-inspired obstacle course but let the materials guide her trajectory and ultimately scaled her first idea down to make it look "cool." She began with a loose idea:

> My main objective was just: find different [decorative] stuff and then incorporate it into here. Like this thing [white net used for backstop] I was like 'whoa this is cool let's use it.'…I knew that I wanted a tube for (the car) to go into, which I did. I kind of wanted it to spin or something, but after this, I was like whew! noo." (Charlie, Interview, 07/30/2014)

Like Britney with the packing peanut, Charlie also found inspiration in materials that she worked hard to integrate into her product. Later, she elaborated on how unexpectedly difficult her original idea turned out to be:

> Starting it I was like okay I'm determined to finish this now. Because it was a long process getting it to stand up…it's really hard to build a racetrack, and I thought that building a car would be pretty easy, but it wasn't. (Charlie, Interview, 07/30/2014)

As Charlie progressed, she continued to scope her initial idea down when she realized how complex it was. Early in the process, she firmly established the purpose of her car, "since this doesn't work very well and it's just for the looks." She even repeatedly thwarted others' attempts to help her make a car that worked. Thus, the evidence suggests the motive to re-scope her project was more likely in response to her aesthetic design stance and less about a lack of expertise in cars.

In regard to product features, these three artifacts were the only ones in the study that were titled and/or labeled. Sasha used glitter glue to title her project “Flow.” She expounds on her decision to include a title: “If I didn't have the title, people would probably be like ‘what is this?’ They wouldn't know like what I made…[and]… if it's like big and glittery and stuff like that it will get people's attention.” Focusing her design decisions on visual qualities illustrates her aesthetic design stance. Britney took a more narrative approach and entitled her project, “Based on actual happenings of Girty’s Run…THE RUN OFF” to accompany the story that she presents alongside her water flow demonstration. Charlie followed more practical reasons and labeled her car “Sir Oinker’s #27,” “because it’s a race car.”

The functionality of Sasha’s and Charlie’s products anchors two ends of an aesthetic design stance. On one hand, Sasha worked hard to learn circuitry on the fly to get her circuits to work. She recounts this struggle:

> Well, there was conductive tape and my one light wasn't lighting up, so then I like got a new piece, because the paper got stuck to the conductive tape. And paper is not conductive, so I figured out that I needed a new piece, so that it could keep on flowing. (Sasha, Interview, 07/29/2014)

Though in the end her project was finished once the design was complete — regardless of the fact that her circuits did not work reliably. On the other hand, Charlie received critique and feedback from other makers about how to make her “race car” work, but insisted that “it’s a different car, I mean, it’s just for decoration, and it’s not supposed to actually work.” Though she originally expected the car to roll, she was pleasantly surprised what she ended up with: “it gives it character… it kind of looks like an animal. It looks like a pig, so I just put a pink stripe [on it].” While Sasha toiled to get her circuits to work, Charlie fought hard against pressure from her peer makers to make her car work. Sasha's effort toward functionality suggests either that she is exhibiting a secondary functional design stance or that there can be a functional component to a design stance. Charlie takes a more 'purist' aesthetic design stance resisting any effort to make her product work.

**Functional.**

Shawn, from Millvale, and Mack, from Makeshop, exhibited functional design stances, aiming to make projects that "work." Shawn took up a very punctuated version of a functional design stance. After being stuck for over 20 minutes, he selected airflow, drew a motor circuit, and then constructed a circuit that matched his drawing. Shawn explained his process:

> Well, whenever I tried to think of the flow of a stream and I saw that somebody else did that, and then I started to think of something else, and then I thought airflow. Then I saw how Jackson was doing the flow of electricity, so I could help him out with connecting the motor into everything else…I saw that he was also using the circuit blocks, and he was also going to use the motor, which I had needed, so I decided that I would join and do it with him." (Shawn, Interview, 07/31/2014)

Though he did not originally plan to collaborate, he decided to work with Jackson, so they could share the circuit blocks. Together they made a large complex circuit with the circuit blocks. Interestingly, the motor circuit Shawn initially intended to build was connected to, but separate from, the large circuit they built; it was not controlled by the switch and was always running. When he and Jackson completed the large complex circuit, Shawn helped build new circuit blocks, but during the activity he claimed they were just making them, "to take up the rest of the time" and later he elaborated, "we were just making these for fun." He did not link the new circuit blocks they made to his final artifact; instead, his process was complete after they got the large complex circuit functioning properly. At this point, Shawn called his dad over to show off what he made:

> Shawn: ‘Dad do you want to come check out our project?’ He showed what they made to his dad, and his dad asked how it works. Shawn explained it thoroughly in a way that seemed to satisfy his dad, because his dad gave him a high-five and said ‘good job!’. After this, Shawn seemed to get stuck and bored again. I recall him saying, ‘I can’t wait until the pizza gets here'. He didn’t know what to do next.” (Millvale, Fieldnotes, 07/31/2014)

This marked the completion of his making process, but he eventually joined back up with Jackson to build the two additional circuit blocks.

Mack took up a more extended version of a functional design stance by constructing a water wheel to demonstrate water flow. He made the highest functioning artifact out of any of the products across sites. He explains the evolution of his project:

> The first thing that popped into my head when you said flow was gonna be water, so I had to do something with water. Then I thought what's gonna make water do something kinda cool? Should I have lights that look like water? Should have something with actual water? Then I thought, pump! — get water moving. I should get water moving. I want to make it look like water's moving if I'm gonna do flow. Then I thought what's the easiest way to build a pump? Then I thought wait there's only one way I know how to build a pump, and that would of been the Archimedes screw. That requires tubing so you can pick the water up and then transport it. So the Archimedes screw became a water wheel to push the water about, which pushed the water about, and that kinda doesn't work. It's more of a splash machine.” (Mack, Interview, 07/30/2014)

Mack began with a relatively detailed plan sketching out the Archimedes screw and the placement of the motor, water, wires, battery, etc. on his cardboard platform. He carried the same idea throughout his process, yet adapted according to available materials and his testing and debugging. During his process Mack adjusted to various circumstances, for example, he did not have the appropriate tubing for an Archimedes screw, so he decided to make a water wheel instead and he changed the placement of the elements of his circuit to suit the height of the water wheel and the fact that it splashed everywhere. Despite his trajectory change, he did not stray from his idea of making an Archimedes screw. He even introduced his product as an Archimedes -screw-turned-water-wheel: "I made a water wheel that was originally an Archimedes screw, but I could not build the Archimedes screw, because we did not have any tubing at all." Moreover, Mack claimed that he "half achieved" his goal to move water, since he was able to move water, but that "it doesn't work exactly the way [he] intended, it's more of a happy accident." After our interview, he spent another hour working on his project building a plastic encasement around the water wheel to keep it from splashing everywhere, so that it worked the way he intended.

Shawn and Mack worked along similar trajectories to make something that functioned. Their products worked, in that they both successfully completed complex circuits. Shawn integrated some of Jackson's goals (creating electricity flow) into his own idea, but once his circuit functioned and he received approval from his father he was not sure how to proceed. He worked as though making his circuit was an isolated project on which he did not know how and/or care to build; he had a finite goal and once he reached it he was done. Mack seems to receive the challenges as opportunities to extend and deepen the complexity of his project. He referred to the splashing water wheel as a "happy accident," even though it meant more work for him: he had to create plastic encasings and hot-glue insulation for all the elements of his circuits.

Even after he had presented the project in the interview — a relatively formal endpoint for the task — he spent another hour polishing and refining his water wheel so that it worked properly. Shawn and Mack shared functional goals, but demonstrated different ways in which these goals can be taken up and accomplished.

**Pragmatic.**

A maker at each site exhibited a pragmatic design stance by aspiring to solve a problem through process or product. Cody's, Jackson's, and Sarah's problem-solving processes varied greatly but were guided by exploration of and experimentation with specific tools or materials. Each product was a solution to either an individual or community problem.

Cody's brainstorming manifested as an iterative process of exploration with tools and materials until he "got an idea." Once he got an idea he continued exploring a specific tool, as he elaborates,

> I was trying to look at stuff to get inspiration…What attracted me about the balloon pump was it's bigger and it's more like a tool. I like tools I think they're cool. So when I found the balloon pump it looked great to use and then I thought of the airflow idea… So, I grabbed this out and a balloon to see what I could come up with to make a flow project using the balloon pump with air. So, I tried to experiment with stuff. I thought of flow like I wanted the air to move somewhere, so I tried using like pipes and funnels, and different materials, but that didn't end up working. I finally remembered I had these copper things and I remembered the fact that when you took the balloon off it would blow out air. I remembered I had the copper things. I was looking around rushing to try to find something like a wheel. I remembered these copper things and they were round

enough, so I could put them on this cardboard to make the "car." (Cody, Interview, 07/29/2014)

Cody challenged himself to solve the problem of using the balloon pump to demonstrate airflow. His process was driven by exploring the affordances and constraints of the balloon pump given the resources he had at his disposal. He described that his product was not "complete" describing it as "a prototype because it isn't really that polished," and even putting "car" in air quotes when he first introduced it. Cody recognized that his product did not fully function, but almost in a practical sense; he explains that he wanted to add a holder for the balloon on the platform "because what I have right now it's a rubber band. You have to blow it up using your mouth or the air compressor — the balloon pump — and putting it on the rubber band very hastily and then having it blow out." Here, his functional goals serve a practical purpose of more easily moving the car with compressed air. Even more, when describing his product, Cody reveals representational thinking by interchangeably using "car" with "platform" and "air compressor" with "balloon pump". Though he did not articulate overt aesthetic decisions, he uses the platform and the balloon pump as representations of a car and an air compressor.

Cody's product serves as a snapshot of where he was in his process at the time of interview. He wanted to continue exploring possible solutions of using the balloon pump for flow and asked permission to take it home, but was not permitted.

Jackson opted to explore circuit blocks — something he'd never used before, as he normally works with wood — to "make stuff that goes with flow." He spent a great deal of time experimenting with them and discovering how they worked, so that he could show "everybody that comes to Millvale Library how to use them." At the beginning of the making activity, Jackson revealed his lack of circuitry knowledge: “Jackson asks: “What does this do?” Nicole[6]: “That’s a switch. You press it down and it closes the circuit.” (Millvale, Fieldnotes, July 31, 2014). His lack of expertise, though, did not deter him from continuing to experiment with the circuit blocks. Jackson welcomed collaboration with Shawn and referred to him as his “partner” in interview. While he supported Shawn in his goal to make a complete circuit, Jackson also took broken blocks aside to fix and modify them to make them work again. After he surveyed their inventory and repaired what he could, he began to make more because “there's not a lot that you can listen to with music, so we can make some for other people to listen to.” Jackson went from exploring circuits for himself to understand the problem space, and then contributed his solution to the problem: more circuit blocks. In the process, he also worked with Shawn to compete a larger complex circuit.

Throughout the entire interview, Jackson fumbled with the circuit blocks to try to get the large circuit he made with Shawn to work again. Yet, he did not utter the word “work” a single time. Rather, he spoke of fixing and building circuit blocks “for other people,” and increasing his familiarity with them to show everybody else how to use them. Rather than adopting the functional goals of his partner, Jackson maintained pragmatic community-based goals of contributing to the resources and expertise available at Millvale.

Sarah explored the boundaries of electricity with her unique take on ‘make flow’ by *breaking* it. Sarah reiterated several times that her goal was “to know” more about electricity and its flow, so she conducted an experiment “to know if the electricity would stop at one point and then not go on or if it would just continue to flow.” Further, she explains her process:

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[6] Millvale facilitator

> Well, I knew I wanted to show how the electricity could flow through different objects. This was like one of the pushpin things that you can spread out the sides of it, and I knew that that would work, because I've done that before. Then I didn't see those materials, so I said why not use paper clips, because I knew they would work, and then I got to the idea of how many would it take to see if the connection would break or not. (Sarah, Interview, 07/30/2014)

Her artifact was the solution to the break flow problem she set out to solve: “How long does it take until the flow breaks? I counted and it took 18 little [paper] clips, 4 big ones, and 1 binder clip.” Reflecting on her process, she expands on the practical implications of her findings:

> Well, like my motive behind it was like with the world now we're using so much electricity that I was wondering if at one point from us building on to it — I know it's not possible for electricity to run out, but it will just stop for a while, and then we'll have to build our way back down I guess to a level where we can bring it back…Not only would you have to worry about power outage, but like the power going out, because there are so many things going in there already that are taking up the electricity. (Sarah, Interview, 07/30/2014)

Sarah wanted to know whether electricity flow could break for her own individual goals, but she also elaborates in detail about what her findings about electricity mean for the world around her. Her process resulted in knowledge as product rather than a physical product.

These three makers demonstrated a pragmatic design stance through processes of exploration and experimentation with the goal of solving a problem. Cody opted to solve a personal problem driven by his own interest in balloon-pump-as-air-compressor. In addition to solving his overarching problem, he articulates both functional (to work) and aesthetic (to represent) goals to find the most suitable solution. Jackson ‘found’ a problem through his exploration of circuit blocks: there were not enough and many did not work. He solved a practical problem yielding a tangible solution — more working circuit blocks. Sarah decided to solve an individual problem rooted in her own understanding of electricity. Her product is in the form of knowledge, and she demonstrates how such knowledge is useful for the world. Cody, Jackson, and Sarah were each spurred by a distinctive curiosity to solve a problem and present a solution that required deep exploration and experimentation with a tool and/or material.

**Practices, skills, and domain area**

Disciplinary practices, technical skills, and domain area are established and accepted demonstrations of learning in education. Rather than querying learners about their individual goals and processes (as is the case with design stances), these traditional measures of learning are externally fixed. Thus far scholars investigating assessment methods in making activities are measuring these forms of knowledge (Fields, Searle, Kafai, & Min, 2012; Lee & Fields, 2013; Peppler & Glosson, 2013). In this section, I contribute to this existing research and offer evidence that these types of learning are an inherent part of the natural forms of engagement in youth makerspaces.

**Disciplinary practices.**

I examined how young makers demonstrated three disciplinary practices (brainstorm, iterate, and communicate) through the make flow activity. Recall that these three disciplinary practices are rooted in established design processes and practices of Engineering (Massachusetts DOE, 2006), Arts (Winner, Hetland, Veenema, Sheridan, et al., 2006), and Architecture (Wade, 1977).

***Brainstorm.***

Though I introduced brainstorming and using the blank pages in the booklet as completely optional, every experienced young maker spent some amount of time writing in their booklet; this is the time I define as brainstorming. The way in which participants engaged with this practice, though, varied widely in regard to time and purpose.

| Site | Participant | Design stance | Brainstorm outcome | Brainstorm time | Revisited ideas/plan? |
|---|---|---|---|---|---|
| Assemble | Sasha | Aesthetic | Plan | 10 minutes | Yes |
| Assemble | Cody | Pragmatic | Ideate | 3.5 minutes | No |
| Millvale | Jackson | Pragmatic | Ideate | 7 minutes | No |

| | | | | | |
|---|---|---|---|---|---|
| Millvale | Shawn | Functional | Stuck then plan | 22.5 minutes | No |
| Millvale | Britney | Aesthetic | Plan | 7.5 minutes | Yes |
| Makeshop | Sarah | Pragmatic | Plan | 5 minutes | No |
| Makeshop | Charlie | Aesthetic | Plan | 5 minutes | No |
| Makeshop | Mack | Functional | Plan | 3.5 minutes | Yes |

The young makers used the brainstorming time to either ideate or develop a plan. I do not mean to say that those who developed a plan did not ideate nor that they stuck with their plan, but that the outcome of their brainstorming was a plan. In other words, two makers stopped brainstorming at ideation and began working with materials, while the other six stopped when they had a plan of some sort.

*Ideate.*

Cody and Jackson used this time to write down either words or drawings of ideas they had in regard to flow. When they finished their written brainstorming, they still did not have a direction or plan for their projects. For instance, Cody jotted down some sketches of his ideas (see Figure 5) and then quickly transitioned to "get inspiration" from tools and materials.


**Figure 5. Cody's brainstorm**

Without a clear plan, he began surveying and gathering tools and materials:

> Cody immediately went into the maker room and was just grabbing things: LED lights, battery packs, etc… he even collected fans and solar panels from the back room. Shortly

before the 15-minute mark, Cody found a balloon pump, which seemed to particularly inspire him. (Assemble, Fieldnotes, 07/29/2014)

As Cody describes this process, he repeats several times in check-ins and during the final interview that he was "scrambling through ideas."

Jackson worked in a similar fashion, except he could not freely survey the materials at Millvale in the same way that Cody could at Assemble. Instead, he and Nicole[7] shared tools and materials that came to mind until he asked her to bring the circuit blocks out. Cody and Jackson developed plans as they explored the tools they each selected.

*Plan.*

The rest of the experienced young makers developed a plan during their brainstorming. These plans varied significantly in their level of detail. On one hand, Sasha spent ten solid minutes brainstorming and developing a very detailed plan for her project. She has all parts labeled and even a complete list of materials outlined. On the other hand, Charlie sketched a barely interpretable plan of her roller-coaster-inspired obstacle course (see Figure 6).


**Figure 6. Sasha's brainstorm (left) compared with Charlie's brainstorm (right).**

[7] Millvale facilitator

Her written plan obviously has much less detail than Sasha's, but it functions as a skeleton to which she adds, based on the materials she could find. Charlie explains further, "well the process was just find really cool stuff in the bins and then incorporate it into here." The differences in these brainstorming processes depict two types of planning: methodically detailed versus loosely outlined.

Other makers fell somewhere between these two extremes. For example, Mack sketched his plan to build an Archimedes screw and the placement of materials (see Figure 7). His plan is not labeled as meticulously as Sasha's, but it clearly has more detail than Charlie's. Likewise, Sarah sketched "simple flow" (see Figure 7) outlining her plan to use electricity.

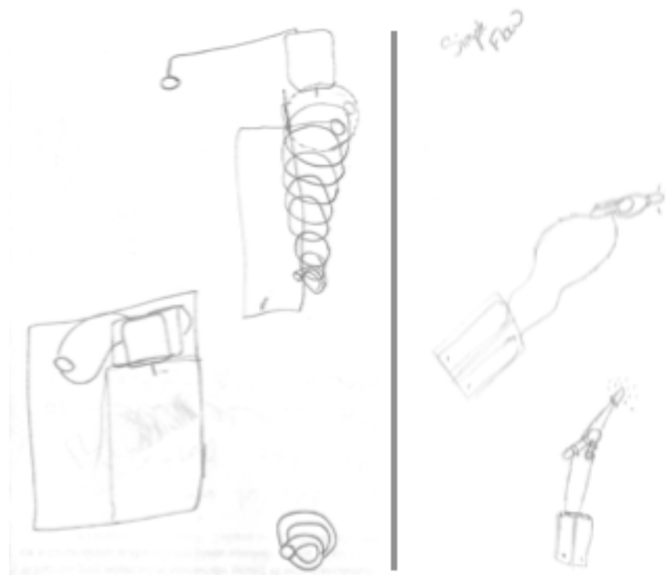

**Figure 7. Mack's brainstorm (left) and Sarah's brainstorm (right).**

Both Mack and Sarah changed their plans when they surveyed the materials and realized they did not have or could not find what they needed to build their original plans. Recall that Mack did not have the right tubing to make his Archimedes screw, so he made a water wheel instead and Sarah could not find the pushpins, so she used paperclips and ended up changing her idea from simple flow to break flow.

Furthermore, the role these artifacts of brainstorming served throughout the making process varied. Most participants did not return to the brainstorm pages in their booklets. Sasha, Britney, and Mack, however, kept their plan on the table next to them as they constructed their products. Britney was the only young maker who added to her original brainstorming work later in her making process. Recall that I previously discussed her iterative brainstorm-to-experimentation process through which she wrote ideas and plans on her booklet and then tried it out, then returned to adapt her ideas and plans “until it seemed right.” It is curious that all the young makers voluntarily spent at least a few minutes brainstorming, but only three referred back to this work later in their making process and one of those three actively used her brainstorming work throughout her process.

*Stuck.*

One maker, Shawn, spent the longest brainstorming time (over 20 minutes), because he got “stuck.” His original idea was to do something with water like a stream, but he ditched this idea: “I saw that one of the other people in there was doing water I didn't want to copy off of them.” Shawn’s fear of copying paralyzed him. He sat with a blank paper in front of him even while Britney and Jackson began their projects around him. After several minutes, Nicole helped him and he finally thought of airflow, and drew a plan to build a motor circuit. Reflecting back on his stuck-ness, he describes learning that “if we actually try different things, then we can actually achieve more things.” As we discussed other projects he made, Shawn describes a struggle he tends to have between the ideas in his head and making them:

I: Have you made the power cube?

S: Not yet, because I'm waiting until I grow up, so I can actually see the materials that I have to work with.

I: What do you mean by see the materials?

S: Like see better and not just visualize, but actually know what materials I'll have.

I: You think you have to be older to do that?

S: Yeah, because right now I'm not really good with inventing things.

I: Why do you think that?

S: Because really there's not many thoughts… (Shawn, Interview, 07/31/2014)

Later Shawn clarifies that he has a lot of ideas, but he is waiting until he grows up to make them. Shawn seemed to be insecure in his making either because of his fear of copying Britney or his apparent belief that making is for grown ups.

***Iterate.***

All young makers iterated irrespective of their design stance. They appeared to iterate on a macro-level through which they changed their making trajectory or on a micro-level through which they troubleshot their current idea, tool, or material.

On the macro-level, young makers changed their trajectory because of either an idea or materials. During the brainstorming phase, Jackson wrote a paragraph about what flow means to him (see Figure 8), but couldn't figure out how to make something that represents it, so he started anew and selected a different trajectory: circuitry.


**Figure 8. Jackson's brainstorm**

With a plan in hand, Mack learned that he did not have the appropriate materials to make an Archimedes screw, so he adapted his plan and replaced the Archimedes screw with a water wheel. Sarah faced a similar challenge; unable to find the pushpin she wanted to use, she not only decided to use paper clips instead, but also changed trajectories from simple flow to break flow. Throughout the process, Britney iterated both her idea and her artifact in order to expand them; she added objects to show the flow of her creek, tried it out, then shaped her product with a story, tried that out, and iterated “until it seemed right.” Similarly, Cody’s reports an iterative process of “scrambling through ideas” and different materials throughout the duration of his project.

Not all participants iterated at such a substantive level. On the micro-level, Sasha’s final artifact looked nearly identical to her sketched-out plan. She iterated briefly to find the right material to attach to her motor and she spent a great deal of time troubleshooting her circuitry work. Once Shawn got his project underway, he troubleshot the circuit blocks until his large complex circuit functioned. Another example of troubleshooting is Charlie’s addition of a “backstop” to her racecar track, because the car kept falling on the ground.

***Communicate.***

Several participants explicitly demonstrated communication practices as part of their process or product. Shawn marked the end of his process by communicating to his dad how the large circuit block functioned. Once he received a high-five from his father, he did not know what to do next and defined the activities that followed as being “for fun.” For Mack communicating his goals and process in interview inspired him return to his product and redesign it. Though he insisted that his project was complete 15 minutes early, post-interview he spent another hour on the project and added the plastic encasement over the water wheel to prevent splashing. With Sarah's paper clip experiment, communicating the solution *was* the main artifact of her making; less important were the materials she used, since the paper clip circuits were not standalone products. Similarly, Britney integrated into her final artifact a narrative expressing the personal meaning behind her representation of Girty's Run.

**Technical skills and domain expertise.**

Despite the open-ended make flow prompt, the young makers exhibited only three main technical skills and four domain areas in their interpretations of flow.

| Participant | Design Stance | Skills | Domain area |
|---|---|---|---|
| Sasha | Aesthetic | Crafting + circuitry | Electricity & air |
| Cody | Pragmatic | Crafting | Air |
| Jackson | Pragmatic | Circuitry + woodworking | Electricity & air |
| Shawn | Functional | Circuitry + woodworking | Electricity & air |
| Britney | Aesthetic | Crafting + woodworking | Water & gravity |
| Sarah | Pragmatic | Circuitry | Electricity |
| Charlie | Aesthetic | Crafting | Gravity |
| Mack | Functional | Circuitry+ crafting | Water |

***Technical skills.***

Participants exhibited three main skills: circuitry, crafting, and woodworking. Each skill comprises sub-skills; for instance, circuitry includes things like soldering, wire cutting, and circuit building. These skills were not necessarily tied to specific design stances. Shawn demonstrated his circuitry knowledge and proudly articulated his knowledge to his father. Sarah and Charlie also exhibited their circuitry and crafting skills, respectively.

Often a combination of skills were demonstrated in a single project; for instance, Jackson and Brandon used circuitry to build their large complex circuit, and also needed woodworking skills to make new circuit blocks. Likewise, Sasha meshed crafting and circuitry to build her diamond circuit. The combinations were not always blatant, for example, Britney primarily utilized crafting skills, but also drew on her recently acquired woodworking skills to make her wood water resistant. She recounts her history with building skill:

> Yeah... we had to put the salad bowl finish on [the sandbox], and on our pens, and on our salad bowl. It helps the wood from like soaking up things. We also made cutting boards, and we'd have to put that on it, so meat juice and stuff doesn't soak in. And this helps the water not soak in. (Britney, Interview, 07/31/2014)

In these cases, previous skills were in fact being demonstrated; however, there were two examples of learning skills during the making activity. Both Jackson and Sasha learned circuitry in the moment as they were building their projects. Jackson received guidance to coordinate the color of his alligator clips with positive and negative and through collaboration with Shawn he learned how to add a switch to a circuit. Sasha asked questions like "how many batteries do I need?" and received guidance like "think of the conductive tape as an extension of the leg of the LED." This just-in-time skill learning happened across participants; for instance, Mack reported learning how to craft with plastics while building his water wheel.

*Domain expertise.*

Participants' interpretations of 'make flow' were rooted in only four domain areas: electricity, air, water, and/or gravity. Design stances did not appear to constrain the domain area in which experienced young makers work. For example, even with something as instinctively functional like electricity, Sasha creatively demonstrated an aesthetic design stance in this content area. All participants, except Charlie, reported learning at least something about the content area in which they worked. Britney explains that she learned "gravity does its part with flow of water, especially down hill, and water helps to clear things, which why water is often used to clean things. It's a powerful source…" Though she had personal experience with the flow of water in her own backyard, it was not until this project that she learned the role gravity plays in helping water flow. Moreover, Sarah's whole project was motivated by her desire "to know," and her product was largely about what she learned: electricity can break. She elaborates,

> With the world now we're using so much electricity that I was wondering if at one point from us building on to it — I know it's not possible for electricity to run out, but it will just stop for a while, and then we'll have to build our way back down I guess to a level where we can bring it back…you would be charging your [phone] and then you would have say the lights on in the house, and then like every thing else plugged in like the TV or game console or something. Not only would you have to worry about power outage, but like the power going out, because there are so many things going in there already that are taking up the electricity. (Sarah, Interview, 07/30/2014)

Based on what she learned from the results of her experiment, Sarah walked away with a sophisticated understanding of electricity and how it works — things she reported not knowing beforehand.

*Flow as a domain area?*

While the goal of the study was not to 'teach' flow, two participants reported learning about flow itself as a concept. For example, Britney ended our interview claiming that she planned to look up flow in the dictionary, because she realized there are so many different ways of looking at it that she didn't "know the definition." Cody explains that his brainstorming happened, "before I actually knew what flow was and the depth of it…I think what I learned from this is what flow actually is. To me flow is how something moves, the way it moves and how it moves." After completing his experiments, Cody's biggest takeaway was learning about flow. Before he made this comment, I had not even put much thought into flow being something to learn.

**Features of the makerspace**

The theoretical convergences and activity-identity-community framework both support that the context in and community with which one makes is crucial to the making process. Here, I consider how tools and materials and collaborations support or inhibit the making activity in this study.

**Tools and materials.**

The availability and visibility of tools and materials impacted the experienced young makers' design process in different ways.

***Availability.***

Availability of tools didn't seem to be a limiting factor in this activity. None of the participants claimed that they couldn't find a tool or did not have access to the right tool; instead, they claimed this about the *materials*. Sarah and Mack are prime examples of this constraint as they searched for pushpins and tubing, respectively. Neither of these materials is particularly expensive, especially compared to many of the tools that the young makers did *not* request yet scholars and practitioners often suggest adding to new makerspaces. Reflecting back on the tool-centered focus on makerspaces, this study echoes the findings of the comparative case study suggesting that perhaps tools are not the focal point of making for the maker.

***Visibility.***

Most of the kids spent a significant amount of time looking for resources, which really impeded their process. Sasha, who had a shopping list of tools and materials, spent several minutes looking for LED lights and even after requesting help it took a few extra minutes to find them. She was one of the few makers who knew exactly what she needed, yet it took her an exceptional amount of time to find these items.

Visibility of tools and materials was important, particularly for Cody and Jackson, who relied on what they could see (or imagine) to make a plan. Cody repeatedly walked into the maker room and back room, which are separate from the making area at Assemble, simply to look at the tools and materials for inspiration. Likewise, Jackson often had to remember or imagine tools and materials, primarily because many of these resources at Millvale are not visible. It's curious that no one at Makeshop relied on this method to make a plan; in Makeshop most of the tools and materials were clearly displayed and visible. With this set-up, Charlie easily revisited the craft kart multiple times throughout her making process to find materials that "look cool" to add to her racecar track.

Facilitators at Millvale and Makeshop pulled out materials or directed to materials that the kids could use. In Jackson's case, this gave him a direction to explore (re: circuit blocks). Britney also integrated the suggested materials into her project. She tied in two materials (packing peanuts and foil), because Nicole[8] had set them out. She confirms that she added "a packing peanut, because she brought them out" and further elaborates, "It wasn't until Nicole started like playing with the aluminum foil trying to see if anyone wanted it."

**Collaborations.**

A collaboration emerged at each of two sites — Millvale and Makeshop. I did not give any explicit instructions about collaborating, but inevitably someone at each site asked, to which I responded that they could choose to work together or alone.

At Millvale, Jackson and Shawn teamed up to work with the circuit blocks, even though they did not know each other. Jackson welcomed this collaboration, since it was natural for how

[8] Millvale facilitator

he works in the space and because Shawn had circuitry knowledge that Jackson needed. Shawn explained that the collaboration was for practical purposes, as there were not enough circuit blocks for them both to build the circuits they wanted. It was interesting how closely these two worked together, yet took two completely different design stances toward what they made. The product for Jackson was the holistic collection of what they made: new working circuit blocks and a complete circuit that will equip him to help others in the future. Yet for Shawn the product was just the large complete circuit.

At Makeshop, Charlie and Sarah collaborated toward the end of the project, primarily because they were friends. They both explained that the collaboration was rooted in the fact that Charlie "needed an extra pair of hands" installing the support beam for her racecar track. Over several minutes, Sarah transitioned from her experiment to fully helping Charlie: moving her materials to the same table as Charlie, but still working on her experiment; helping Charlie, then returning to her experiment; and finally solely helping Charlie. Interestingly, they both have different takes on the collaboration, Charlie described:

> C: Sarah actually helped me. And then we achieved our goal.
>
> I: Yeah, so can you talk about how Sarah helped you?
>
> C: Yeah I was struggling, I needed extra hands, and then she just came in and she helped like hold things together and gave me suggestions, which I really appreciated.
>
> I: What kind of suggestions did she give you?
>
> C: Like things to put another support beam right here [parallel to the table] or to have this [the 'track'] overlap. (Charlie, Interview, 07/30/2014)

Sarah explicated:

> S: When I helped her I was like... it looked like she needed an extra pair of hands, and like she's my friend, and she looked like she needed extra hands of like keeping it steady and stable. Like helping her through the process of making it. Because she knew what she wanted, but she needed a couple extra hands just to hold it up.
>
> I: So did you help her work through any of her ideas?
>
> S: No not really, like she knew what she wanted. Just like towards the end I added like the net at the bottom, I added just so the car doesn't fall off. (Sarah, Interview, 07/30/2014)

Charlie viewed the collaboration much more collectivistically than Sarah. Also, each recalled different enhancements recommended by Sarah (Charlie mentioning the support beam and Sarah mentioned the net).

At Assemble, only two makers participated in the study, so it's hard to make any site-level conclusions about collaborations. Even so, the collaborations that occurred at the other two sites provide evidence that in youth makerspaces makers work together for different reasons. The first collaboration was born out of necessity (i.e. there were not enough circuit blocks to share) and the second was rooted in an existing friendship. Moreover, Jackson and Shawn's collaboration was for an entire project, while Charlie and Sarah's was for a small chunk of the project.

## Conclusion

In these design experiments, I examined how young makers demonstrate learning in youth makerspaces. I contribute to the growing body of research on learning through making in two key ways: 1) provide evidence of learning in the making that naturally happens in youth makerspaces and 2) establish design stances as a viable lens through which we can conceptualize this type of learning.

As I have outlined, there is a growing body of research examining how youth learn through making, but much of it is not situated in makerspaces. This gap begs the question: are youth *really* learning in these spaces? I crafted the design experiments to capture the way in which making naturally occurs in youth makerspaces. I instructed the young makers and facilitators to use the space as they normally would, but focused their making on a single prompt. Through participation in the 'make flow' challenge, young makers demonstrated learning through design stances, disciplinary practices, technical skills, and domain expertise; the forms of learning exhibited differed in regard to process and product. In particular, young makers demonstrated disciplinary practices, technical skills, and domain expertise in their making process and design stances through their making product.

Young makers across this study demonstrated potentially measurable forms of knowledge through their making process. In this informal, out-of-school context, young makers employed valued practices from well-established fields, namely brainstorming, iterating, and communicating. Of most interest in this study was the range of ways young makers voluntarily brainstormed and how the artifacts of their brainstorming directly or indirectly shaped the rest of their making process. For years scholars (Parnes & Meadow, 1959; Rawlinson, 1981) have situated brainstorming as a valuable piece of creative problem solving, which is likely why disciplinary-based design processes integrate brainstorming. Not only does this study demonstrate that makers brainstorm, but also spotlights an area of future research: how does brainstorming function as part of the making process? Furthermore, many of the iterations I observed in this study were fueled by a need to resolve a disconnection between what young makers wanted to do and what they were able to do. I note a similar struggle with college students aligning their design vision of their mobile technology projects with the affordances of the tool itself (Litts, Martin, & Gagnon, 2014). This trend suggests a place for intervention in the design process not only for designers of making activities but also more broadly for designers of other creative production processes. The practice of communication served a reflective purpose and in some cases triggered new directions or iterations. For one young maker, rather than yielding a tangible artifact, communication functioned as the product of her making, which challenges scholars and practitioners to carefully define what they consider artifacts of making. It is important to note that the disciplinary practices were a reduction of three disciplines, which suggests that making itself might be its own discipline with its own disciplinary practices. Further research is needed to explore this intersection between learning and making as a discipline.

What’s more, young makers explicitly utilized technical skills and domain knowledge throughout their making processes. It is curious that the making challenge was exceptionally open-ended and unstructured — only bound by ‘flow’ and the 90-minute timespan — but participants only used a total of three technical skills and four domain areas in their projects. These did not evidently vary by design stance. Perhaps the available/visible resources in these youth makerspaces along with their unique community ethos influenced the skills and content areas. Beyond simply *demonstrating* learning, young makers reported learning new skills and content spontaneously as their projects required. Given the open-ended nature of the making challenge, I did not empirically measure this type of learning — there was no way to predict what direction youth would go. As a next step, I wonder if there are "just-in-time" assessments to correspond with this "just-in-time" learning.

All the young makers in this study exhibited a clear design stance in their making. I used these data to provide evidence for the three design stances we suspected in our pilot data. I found that design stances are bounded by the goals and artifacts young makers articulate and produce. The connection between design stances and making process were not clear in this study. Functional design stances are what we seem to expect in learning through making, and they're easy to assess: does the product work or not? Mack, who produced an elaborate water wheel, was the only one who exhibited the design stance we so often typify in the rhetoric around making. Other scholars have hinted at the importance and value of understanding the diverse perspectives learners bring toward their making. Fields, Kafai, and Searle (2012), in their research with high school youth, illuminated the tension between aesthetic and functional approaches to making and advocated a "third approach" of meeting aesthetic desires that match the affordances of a given technology. Design stances build on this work by demarcating the "approaches" as having unique features, namely goals and artifacts. This work has great implications for the way in which we imagine assessing making activities, particularly those that naturally take place in makerspaces. The existing content- and disciplinary-based methods of evaluation (Fields, Searle, Kafai, & Min, 2012; Lee & Fields, 2013; Peppler & Glosson, 2013) have utility in measuring a specific type of learning. Design stances, however, are tools that help us understand the range of learning that happens in makerspaces and can potentially be used to measure this learning.

To further our understanding of design stances, I recommend two lines of inquiry for future research. First, we need to trace design stances across more participants and contexts. In interview, some young makers reported having similar design stances across a variety of making activities, while others took up a different stance for each making activity. Further research here can shed light on how we can design both making activities and learning environments to explore specific design stances. There is also some evidence (in pilot study and this design study) that there are secondary stances, but we need more focused research to determine how these are taken up. More longitudinal studies can explore a learner-centered perspective of stances, where the learner is the unit of analysis and where we explore the range of design stances exhibited by a specific learner. Second, we need to empirically explore how we can use design stances as an assessment tool. Since design stances can vary by individual and depend on context, they're complex tools. Design stances link young makers' goal(s) to their product(s), seemingly regardless of their process(es); thus, we can assess the relationship between goal and product in a given making process. This study is the first step toward establishing design stances as markers of learning in youth makerspaces.

## Discussion

The maker movement echoes early philosophies of educational researchers who argue for hands-on, problem-based, real-world forms of learning. Making is a 21$^{st}$-century manifestation of Papert's constructionism and the New London Group's multiliteracies. Papert (1980), for instance, introduced the idea of programming at the intersection of physical and digital worlds to teach math. The maker movement instantiates this idea with myriad more accessible technologies like paper circuits (Qi & Buechley, 2010), Squishy Circuits (Johnson & Thomas, 2010), and e-textiles (Kafai, Fields, & Searle, 2012). What makes this grassroots movement so interesting is how it embodies learning theories for which educational researchers often design. Scholars, though, have a limited understanding of how makerspaces — the physical communities of the maker movement — function as learning environments.

In this dissertation, I sought to contribute to our understanding of makerspaces as learning environments and learning through making by investigating the question: *how is learning demonstrated in makerspaces?* I conducted a comparative case study (Stake, 1995) of three youth makerspaces and dissected the activities, identities, and communities that define these contexts. Comparing three different models of youth makerspaces (museum, afterschool, and mobile/library) yielded four crosscutting features (activity scale, tools and materials, equipping facilitators, and community partnerships) to aid designers, scholars, and practitioners in building, studying, and managing these spaces. I also presented a series of design experiments examining the range of learning that is demonstrated in youth makerspaces and piloting a potential framework (design stances) for conceptualizing this learning. The findings of these two studies and insights from this dissertation generally have valuable implications for practitioners and designers of informal learning environments, the emerging field of making in education, and learning scientists more broadly. In this conclusion, I consider limitations to the studies I conducted, outline implications for each of the three audiences above, and suggest future directions based on how this study illuminates the learning demonstrated in makerspaces.

**Limitations**

I consider limitations in this study collectively as the comparative case study and design experiments were conducted at the same sites and mutually informed each other. I discuss limitations in three main branches: methodological, youth makerspace cases, and young maker participants.

Given that the field of making in education is in its infancy, we're still very much in an *exploratory* phase. Hence, I designed this study to suit the *how*-based exploration underlying my research questions to acquire a general sense of a phenomenon (learning in youth makerspaces) that we know little to nothing about. The exploratory and descriptive findings of the present study, though, open the door to explanatory studies in the future. For example, in this study, I established the existence of design stances and their corresponding features, and further research can expand these findings in more generalizable ways — perhaps in understanding their use as assessment tools. The nature of the methodologies I use in this study inherently constrains its generalizability. Both the case study and the design experiments are constrained by duration. Makerspaces are places of rapid development, which is not accurately represented in this study. Considering the vast changes that occurred in each space during the observational period, there is a rich opportunity for more longitudinal studies to trace the development of makerspaces. In the design experiments, the making challenge only captured about 90 minutes of a making process. Crafting the making activity in this way afforded enough of a glimpse into makers' trajectories to determine whether or not design stances exist, yet to understand the nuances of design stances we need to observe longer making experiences. These snapshots of makerspaces and making still contribute valuable insights to the field of making in education, especially since there is currently no research examining youth makerspaces as learning environments.

The youth makerspaces that participated in this study are of a range of models (museum, afterschool, and mobile/library). My goal was not to necessarily make claims about the affordances and constraints of these models, but to given an overarching sense of how youth makerspaces support learning. The diversity of the sample warrants claims across youth makerspaces more generally. Over the course of data collection, though, it became evident that there was more depth and breadth to each site than I was able to record within the confines of my study design. Taken together, findings are intended to provide a window into what is possible in youth makerspaces rather than make generalizable claims about all youth makerspaces. All three cases were situated in a city with nationally recognized making initiatives, so findings are best understood in this context.

Young makers who participated in the design experiments covered a range of ages, backgrounds, and experiences. I sought “experienced” young makers, which I defined as either identifying as a maker or having participated in the makerspace for at least six moths. This definition provided necessary bounds, however, it also elicited an unintended outcome in which youth who satisfied these prerequisites did not fit my personal idea of what a maker is. I included young makers in the study regardless of this discrepancy. Scholars researching making in education are presently grappling with what makes a maker (e.g., NYSCI, 2013) and my dissertation work underscores the need for research in this area. Limitations in this study constrain the generalizability of findings, yet highlight opportunities for future research, namely, studies looking at more makerspaces and including wider ranges of young makers.

## Implications

In this section I outline four main implications of the findings of this dissertations for three different audiences. First, I suggest considerations to practitioners and designers about managing resources in out-of-school learning environments. Second, I outline the ways in which findings scope the current disciplinary perspectives in the emerging field of making in education. Third, I elucidate how practitioners, designers, and scholars can adopt design stances as assessment tools. Finally, I describe the utility of the activity-identity-community framework for learning scientists.

### Managing resources in out-of-school learning environments.

The way in which resources are managed in youth makerspaces has direct implications for how we envision them as learning environments. Looking at the comparative case study and design experiment there is an obvious tension around tools and materials, particularly between availability and visibility. Findings in this dissertation push back on much of the tool-focused rhetoric around makerspaces; a 3D printer does not make a space a makerspace. On the contrary, young makers look for opportunities to make in makerspaces, emphasizing the need for tools and materials to remain within eyesight. The *visibility* — not availability — of tools was what mediated the making process in the design experiments. Across makerspaces, young makers largely had the same tools and materials available to them; however, at each site they were more or less visible. None of the young makers opted to make projects with the tools we glorify in the maker movement (e.g., 3D printers or laser cutters), yet they all exhibited learning in their making processes.

Practitioners can leverage available tools and materials — even if they aren't the highest tech — to support making processes. Strategically keeping resources within eyesight during the making process is of most importance. A good example of this is Makeshop, where nearly all tools are visible and reach-level is intentionally scaffolded. What's more, one practice I observed often across makerspaces was facilitators placing tools and materials within eyesight and reach. During the design experiment the fruit of this practice became more prominent. Makeshop facilitators prepared the tools and materials in a ready-to-use fashion; for instance, the hot glue gun and soldering iron were plugged in and turned on just in case the young makers needed to use them. At Millvale, as facilitators set out tools and materials the young makers began to integrate them into their project ideas. The young makers at Assemble took up this practice themselves: one collected and set out his own tools and materials during his brainstorming. Not only does this finding illuminate the significance of resources in these learning environments, but it also has implications for programming and curricula. Across all the data in this dissertation, the visibility of resources most clearly shaped the ideation and envisioning processes. As practitioners contemplate what resources to make visible, they should also consider when they would do so. Further research is needed to make empirically generalizable recommendations about this point; though, the present studies suggest that practitioners should make the most careful considerations in the beginning of the learning process.

For designers of learning environments, there is a serious need for achieving a robust insight to how tools are used and made in makerspaces. In the next several years, 3D printers (and many other new media) are likely to reach some level of ubiquity; Staples (Senese, 2012) has recently began offering 3D printing for their customers, and many in the maker movement (e.g., www.formlabs.com) are on a mission to make more affordable and accessible 3D printers. Though certain tools, like 3D printers and laser cutters, are becoming more and more accessible, we first need to understand how to design learning environments that capitalize on their use as objects-to-think-with. Taking this route will help us prevent what I like to call 'the SMART board phenomenon'. There was a huge international push in education to integrate SMART boards into every classroom in an attempt to be 'innovative', but not many of these classrooms are actually using the SMART boards for much more than a projection screen. While this points to a clear need to couple implementation of new technology with adequate professional development resources, I think the issue lies much deeper. In the spirit of Papert's mathetics (1980), I believe we need to first ask 'how do we use these tools to learn?' rather than 'how do we use these tools to teach?'. Perhaps, this is why many of the more hyped-up technologies generally went unused in the youth makerspaces in these studies. Keeping a constructionist view of learning at the center of the conversation requires educators to intentionally and purposefully design learning environments, right down to knowing why each tool is present and remaining open to removing tools as they prove to be irrelevant.

**Disciplinary perspectives toward making.**

Thus far stakeholders have primarily legitimized making and makerspaces in education by connecting them with existing disciplinary practices and processes. Learning theorists entice us to consider making through disciplinary-based perspectives. Papert (1980) initially used building in service of mathematics and the New London Group (1996) adopted design as a tool to teach technological literacies. Stakeholders across the maker movement argue that making and makerspaces broaden the accessibility of STEM practices, especially to audiences underrepresented in these fields. Scholars also argue that new technologies are, in turn, (re)shaping our understanding of STEM disciplines. The most prominent example of this is how e-textiles connect with STEM-based fields, particularly engineering, and are expanding our conceptions of these fields (e.g., Buechley, Eisenburg, Catchen, & Crockett, 2008; Eisenberg,

Eisenberg, & Haung, 2013; Fields & King, 2014; Kafai & Burke, 2014; Peppler & Glosson, 2013). Within this conversation, other scholars illuminate how the artistic nature of making is contributing to our reconceptualization of STEM fields (Halverson & Sheridan, 2014a, 2014b; Peppler & Kafai, 2005). The findings of this dissertation resonate with the disciplinary-centric nature of the maker movement; however, they also push scholars to think beyond such.

Across both studies, the presence of disciplinary approaches and practices was evident. I observed that facilitators' disciplinary approaches affected the ways in which they interacted with youth in their makerspaces. Young makers also exhibited disciplinary practices throughout their making processes. These findings further substantiate the disciplinary connections present in the field of making in education. Taking these findings in their contexts, though, challenges scholars to broaden our scope of disciplines. I demonstrate the utility of leveraging other disciplines, like architecture, to guide our understanding of learning through making, particularly in makerspaces. Though architecture overlaps immensely with art and engineering, its distinctively pragmatic nature is particularly relevant in making. This dissertation is the first work drawing on architecture to conceptualize learning in makerspaces, and it appeared to be a theme across sites; the founder of Assemble and a key facilitator at Millvale both have backgrounds in architecture and bring that approach to their making. As a field, scholars should consider the value of other disciplinary perspectives in understanding making in education.

As we continue to explore the disciplinary-value of making, I challenge scholars to consider that making itself is a discipline with its own values, approaches, and practices. With the design experiments, I synthesized existing disciplinary practices as a frame to examine what practices young makers exhibit in their making. In our continued efforts to connect learning and making, we need to explore this interdisciplinary intersection and determine whether making has its own bounds. Facilitation of making experiences is an example of a defining characteristic of making as a discipline. Across youth makerspaces, facilitators utilized their respective disciplinary-based approaches and even teaching backgrounds, but were still ill equipped to support young makers. I noted implications for developing facilitators' pedagogical *making* knowledge and provided additional evidence that perhaps making is a discipline. As the research on making in education progresses, we need to resolve with which disciplines making overlaps and ascertain whether making is simply interdisciplinary or a unique discipline.

**Design stances as assessment tools.**

In addition to shifting our discipline-based approach to education, learning through making beckons new forms of assessments. Current assessment tools simply do not capture the complex, interdisciplinary learning that happens through making. Learning through making scholars (Fields, Searle, Kafai, & Min, 2012; Lee & Fields, 2013; Peppler & Glosson, 2013) have begun to experiment with assessment tools for making experiences, and in this dissertation I contribute design stances as potentially robust tools. I identified and described three design stances within the context of makerspaces and with further research we can determine whether additional design stances exist in other learning environments. The design stances are clearly bound by the goals articulated and artifact produced by learners. I outline the markers of each design stance:

| | **Aesthetic** | **Functional** | **Pragmatic** |
|---|---|---|---|
| Goals | Interpretive: artfully represents something | Production-oriented: make something that "works" | Solution-oriented: solve a problem |
| Product targets | ▪ Communicates meaning through form<br>▪ Beautiful, rich, and/or interesting product | ▪ Efficient and/or bug-free performance<br>▪ High-quality product | ▪ Fulfills a practical need<br>▪ Form and function of product exist in service of a solution |
| Disciplinary | Art | Engineering | Architecture and |

| | | | |
|---|---|---|---|
| inspiration | | | interdisciplinary |

My dissertation work demarcates design stances as a construct to ascertain how we might conceptualize learning in informal contexts, but they have exciting implications for assessment.

Inspired by learner-centered design (Bransford, Brown, & Cocking, 2000) in the learning sciences, I suggest a learning-centered assessment through which we cooperatively assess learners according to their individual goals. Using design stance as an assessment tool requires a more flexible perspective toward assessment than the traditionally fixed and standardized perspective dominating our education system. Reimagining learning and assessment in this way is not unique to makerspaces — games scholars contend with similar assessment challenges. Gaming analytics (El-Nasar, Drachen, Canossa, 2013), for example, draw on player-generated data to understand players' processes and learning throughout a specific game. Emergent fields in education and learning sciences are driven by new technologies that afford and require different methods of assessment; I situate design stances within this broad effort.

**Activity-identity-community framework.**

Integrating cognitive and sociocultural learning theories, I developed a framework to link making with learning. The activity-identity-community framework elucidates three threads of the maker movement that are being significantly confounded. I applied the framework in this dissertation to explore and illustrate its function as an analytic frame for youth makerspaces. In this context, the activity-identity-community framework scopes and clarifies lines of inquiry around making, makers, and makerspaces in such a way that aligns with learning theories. I also use this framework to identify gaps in current research around making in education; most scholars are focused on learning through making, some are beginning to examine makerspaces, but little is known yet about makers.

This three-pronged framework not only delineates features of informal learning environments, but also encourages learning scientists to take up more integrative approaches to education research. Recall that the activity-identity-community framework reaches across learning theories that are traditionally divided. In this dissertation, I expound the framework as a design and analytic tool for shaping and studying out-of-school learning environments. I conduct a robust application of the framework that has implications for education research more broadly. Dissecting learning environments according to activities, identities, and communities affords an inter-theoretical approach to education research. We need fresh frameworks like this to match the proliferation of innovative technologies and new structures of learning environments. Other contexts, like games-based learning environments, also sit at the intersection of learning theories. By bridging constructionism and multiliteracies I submit an integrative and cohesive framework to education design and research. The activity-identity-community framework is still in preliminary stages and needs to be employed across a range of learning contexts, but has the potential to support more integrative lines of inquiry in the learning sciences.

**Conclusion**

Makerspaces are seemingly proliferating toward ubiquity; it is imperative for researchers and practitioners to build a better understanding of makerspaces as learning environments and of the making that happens within them. To suit this novel form of learning, we need to develop appropriate tools of design, assessment, and analysis. In this dissertation, I advance these efforts with a new framework for learning, an innovative assessment tool, and insights for designers and practitioners of makerspace-inspired learning environments. Interdisciplinary learning is demonstrated through naturalistic engagement in makerspaces. I propose an integrative activity-identity-community framework through which we can design for and analyze this learning and establish design stance as a potentially robust assessment tool. Taken together, these devices equip researchers to continue the empirical effort to legitimize learning through making. Likewise, as we re-envision teaching and learning through this lens, we need to continue to experiment with strategies and techniques for making learning, particularly in makerspaces.

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## Appendix A: Site director interview protocol

Tell me a story about how you got involved in [site name].

- How did you get involved at [site name]?/Why did you found [site name]?
- What interests you about {site name]?/ What was your motive behind it?

Tell me about one of the most interesting projects you've been involved with at [site name].

- What was your role in this project?

Tell me about how your own relationship to making.

- What's the coolest thing you've made recently?
- What's something you'd like to make, but haven't yet?

How do you support youth making at [site name]?

- What is your goal in doing so?
- What sort of people usually participate at [site name]?

How do you think making and learning intersect?

Is there anything else you would like to share about your site or otherwise?

**Appendix B: Program coordinator interview protocol**

How did you get involved at [site name]?

- What specifically interested you about {site name]?

How did you get involved with the [program name]? Why?

- What is the goal of the [program name]?

Tell me about one of the most interesting projects you've been involved with at [site name].

- What was your role in this project?

Tell me about how your own relationship to making.

- What's the coolest thing you've made recently?
- What's something you'd like to make, but haven't yet?

How do you think the 'make flow' activity fits into what typically happens at [site name]?

- What were your hesitations?
- What was most challenging about it?
- What surprised you most about it?

I'm going to walk through the products the youth made and I want you to tell me what you think the strengths and weaknesses are and whether you think it's typical of the projects you see youth making at [site name].

- Strengths, weaknesses, typicality

Is there anything else you would like to share about this activity or otherwise?

## Appendix C: Demographic Information & Making Experience

Name ____________________________

Age ___________________

**In the questions below, circle the response that best fits you.**

**How often do you make things?**

| 1<br>Never | 2<br>Rarely | 3<br>Sometimes | 4<br>Often | 5<br>Always |
|---|---|---|---|---|

**How often do you come to Assemble?**

| 1<br>Never | 2<br>Rarely | 3<br>Sometimes | 4<br>Often | 5<br>Always |
|---|---|---|---|---|

**Have you been to other places like Assemble?**

Yes No

**Do you make things at home?**

Yes No

**Do you see yourself as a maker?**

Yes No

## Appendix D: Make Flow Activity Protocol

[Pass out booklets]

Before we start, I would love for you all to answer some questions about making. Please write your name and age and answer the questions about making.

[Wait until complete]

Today, I am going to give you making challenge to work on for 90 minutes. Feel free to work in the space here as you normally would.

While you're making, I am going to come around and take pictures and maybe ask you some questions. After 90 minutes is up, we will come back together to chat and share about what you've all made. Any questions? Are you ready?

The challenge today is to: make *flow*. Whatever *flow* means to you. If you need to spend a few minutes brainstorming what you think of when I say *flow*, then you do that now. If you want, you can use these booklets to write, sketch, draw, or reflect on what you're making if you want or need.

[Every 15 minutes take a snapshot photo to capture the state of each artifact. A midpoint check-ins (at 30 and 60 minutes) with each participant asking: what are you making? For whom are you making it? How are you making it? Why are you making it?]

Time is up! Now let's come back together. Open your booklets to the back and notice there are two questions there. Let's take some time to answer them now.

[Wait until complete]

Now, you're welcome to have some free make time. I will pull you aside one by one to ask you more questions about what you made.

# Appendix E: Project Description & Envisioning Statement

**Project Description:**

Imagine someone is going to come look at what you made while you're gone. What would you want that person to know about what you made? Write two sentences.

**Envisioning Statement:**

What do you want to make or do next? Write a sentence or two or draw a sketch for your answer.

## Appendix F: Youth maker interview protocol

What did you make?

For whom did you make it?

(Why did you make it?)

Tell me a story about how you made it.

What were your goals for making this?

Do you think you achieved these goals?

How does it work?

What does it communicate?

Tell me about a moment you got stuck while making it.

Did you ever ask for help? From whom? Why? How did they help you?

Did you use any new tools or materials while making it?

In the beginning, I asked you to make flow, how did you ‘make flow’ by making this?

How well do you think you made flow? Why?

What did you learn from making this?

What typically happens to the stuff that you make here?

Does it go somewhere or does someone come look at it?

What do you imagine doing with this piece?

How did you get involved in [site name]?

How long have you been coming here?

What’s your favorite thing about this space?

Do you make things other places? [Where? With whom?]

Tell me about the coolest thing you’ve made.

I see here you [do/don’t] identify as a maker. Can you talk a little about why this is?

Is there anything else you would like to share?