Evidences of Learning in an Art Museum Makerspace

Amy Oates

A thesis submitted in partial fulfillment
of the requirements for the degree of

Master of Arts

University of Washington
2015

Committee:
Jessica J. Luke
Daniela K. Rosner
Leslie R. Herrenkohl

Program authorized to offer degree:
Museology

University of Washington

Abstract

Evidences of Learning in an Art Museum Makerspace

Amy Oates

Chair of the Supervisory Committee:
Jessica J. Luke, Ph.D.
Museology

While makerspaces have gained momentum in recent years, some people are questioning the learning value of these hands-on spaces. This study investigated instances of learning observed in the context of an art museum makerspace, using a framework developed by researchers at the Exploratorium, San Francisco. Additionally, the study examined the efficacy of this framework for measuring learning in a makerspace outside of a science museum context. Twenty-five visitors were observed in the Maker Lounge at the Peabody Essex Museum, Salem, MA. Results show that visitors who participated in Maker Lounge activities evidenced a range of behaviors mapping to the Learning Dimensions Framework, largely similar to evidences of learning previously observed in a science center's makerspace. These results extend the conversation about learning within makerspaces, suggesting that learning can occur across varying makerspace contexts and calling for further research to examine the design, facilitation, and implementation of museum-based makerspaces.

Acknowledgements

One of the rewards of this thesis has been getting to speak with, learn from, and work with other practitioners and researchers of whom I think so highly and whom I have found to be so enthusiastic, creative, brilliant, generous, and kind.

Specifically, thank you to Leslie Herrenkohl from the College of Education at the University of Washington and Daniela Rosner from the College of Human Centered Design and Engineering at the University of Washington for serving on my thesis committee, offering valuable cross-disciplinary perspectives, and pointing me towards learning opportunities that both shaped me and informed this study.

A special thanks to Jessica Luke for serving as my thesis committee chair, setting the highest bar of excellence, and all the while being the consistent cheerleader through this process. Thank you for patiently walking with me from initial study design, through each written draft, all the way to thesis completion.

Tremendous thanks to the University of Washington Museology program for funding opportunities that provided sparks for this research topic and travel for this study's realization.

Thanks to the Visitor Research and Evaluation team at the Exploratorium for allowing me to use the Learning Dimensions Framework in this study and for taking time to talk through my methodology questions along the way.

A huge thank you to Juliette Fritsch at the Peabody Essex Museum for graciously allowing me to conduct data collection in the Maker Lounge and to the entire PEM staff for warmly welcoming me into your "home." I felt privileged to be researching at a site I came to regard so highly as I saw how you are cultivating community in your space and expanding the notions of what an art museum can do. I directly benefited from the trust you have built with the

community, who in turn were willing to trust me and participate in this study.

I am overwhelmingly grateful for each family and child at the PEM who participated in this study. I would have nothing to say had you know allowed me into your making space. I truly enjoyed watching your making session (again and again), seeing your enthusiasm, creativity, and family collaborations. I hope you will continue exploring tools and materials and making things for years to come.

Finally, thank you to friends, family, and colleagues who showed an interest in me by showing interest in this topic, checked on the state of my research and the state of my well-being so faithfully, and rode the waves of setbacks and victories along with me.

Table of Contents

List of Figures

List of Images

CHAPTER 1: Introduction

The “maker movement” has gained tremendous momentum as an outgrowth of recent trends including the 2005 launch of MAKE magazine and the first Maker Faire in 2006 (Maker Media, 2014). Maker Media, a driving force behind this movement, emphasizes that “Makerspaces represent the democratization of design, engineering, fabrication and education,” by providing access to low-tech and high-tech tools (such 3D printers, laser cutters, CNC routers) that people could not often own individually and by making knowledge accessible through collaboration and shared expertise (Makerspace website, n.d.). The maker movement has even caught the attention of President Obama, who declared June 18, 2014 a National Day of Making and hosted what was deemed “the first-ever White House Maker Faire” (White House, 2014 June 17).

Looking across the existing research and definitions, a makerspace, for this study, will be defined by five emphases: a makerspace is a physical space; a makerspace seeks to foster creative, design, and critical thinking habits through tinkering and hands-on problem-solving; a makerspace seeks to engage an individual’s curiosity through self-driven projects; a makerspace seeks to cultivate social interactions through collaboration and knowledge-sharing in the common space; and a makerspace encourages integration between the sciences, technology, engineering, arts, and mathematics (Bevan et al., 2014; Brahms, 2014; Dougherty et al., 2013; Educause, 2013; Gutwill et al., 2015; InformalScience Wiki, n.d.b.; New York Hall of Science, 2013a; New York Hall of Science, 2013b; Petrich et al., 2013; Sheridan et al., 2014; Vossoughi & Bevan, 2014).

Who are the Players in the Maker Movement?

This new trend in spaces dedicated to making and tinkering has caught the attention of a wide range of people with varied interests. Some posit that the maker movement has the potential to impact everything from manufacturing and the economy (Anderson, 2012; Hatch, 2014), to science and technology (White House, 2014; Dorph & Cannady, 2014). President Obama articulated his intentions for endorsing the maker movement, stating, “my Administration is getting tens of thousands of young people involved in making…. [to] ensure that the next great technological revolution happens right here in America” (White House, 2014). In contrast, Vossoughi and Bevan (2014) stress the need for a critical discussion to better clarify the intentions and goals of the national interest in the maker movement, which they assert are currently “divorced from youth agency and activism” (p. 41).

Others are interested in the impact that the maker movement may have on learning and education (Maker Media, 2013; Martinez & Stager, 2013). Dougherty et al. (2013) clearly articulate the aim that Maker Media is pursuing: "Our biggest challenge—and the biggest opportunity for the maker movement—is an ambitious one: to transform education" (p. 3). Maker Media sees the purpose of incorporating making into education to be, “Fostering in each student the full capacity, creativity and confidence to become agents of change in their personal lives and in their community” (p. 4). Such proponents of the maker movement see making as an opportunity to democratize education and empower learners with the knowledge and skills to create the world around them.

Roots of Museum-Based Makerspaces

To date, not every museum-based makerspace or maker-inspired program includes such high tech tools as 3D printers readily available for visitors to freely access, but these spaces do often embody the principles of hands-on making that underlie the maker movement. Museum-based makerspaces serve to serve to cultivate a tinkering approach to problem solving in visitors and serve to spark further interest in makerspace activities in new audiences.

In recent years, funding organizations have provided significant opportunities for many museums to initiate participation in the maker movement. The National Science Foundation (NSF) has supported numerous efforts to develop pilot programs and to research making in museums, beginning with the PIE (Playful Invention and Exploration) Network in 2000 and 2005, the Exploratorium in 2013, the Science Museum of Minnesota in 2013, and the New York Hall of Science in 2014 (National Science Foundation, 2014; St. John et al, 2008). The NSF Assistant Director Joan Ferrini-Mundy has stated that, “What we're most interested in at NSF is how these experiences affect STEM learning: How can making be used most effectively to help students of all backgrounds learn science, technology, engineering and mathematics?” (NSF, Learning Through Making, 2014).

The Institute of Museums and Library Services (IMLS) is approaching the Maker movement with slightly more broad intentions, with an interest in cultivating all 21st Century Skills, which they define to include critical thinking/problem solving; creativity/innovation; communication/collaboration; and literacies (visual, scientific/numeric, cross-disciplinary thinking, linguistic, information, media, and technology) (IMLS, n.d.b). Former IMLS Director, Susan H. Hildreth stated that, “This is a grassroots trend that is igniting new passions and inspiring people to explore new career paths” (Hildreth, 2012). IMLS awarded grants for makerspace programs at the New York Hall of Science and the Oregon Museum of Science and Industry in 2012, the Center for Science and Industry (COSI) in 2013 (IMLS, n.d.c), and the

Pittsburgh Children's Museum in 2012 and 2014 (Makeshop, 2014). Multiple IMLS/MacArthur Foundation Learning Lab grant cycles have also allowed museums to pursue maker-centered activities, including the Museum of Fine Arts, Houston (IMLS, n.d.a), the Dallas Museum of Art, the Madison Children's Museum, the Lawrence Hall of Science, the Science Museum of Virginia, and the Alabama Museum of Natural History (DML Research Hub, n.d.).

Even without funding from NSF or IMLS, many museums are paying attention to the maker movement and seeking ways to create programming that reflects maker influences. In 2014 alone, the annual conferences for the National Art Education Association's Museum Division, the American Alliance of Museums, and the Association of Science-Technology Centers all included multiple sessions on makerspaces or maker activities (NAEA, 2014; AAM, 2014; ASTC, 2014).

Evidenced by the 2014 NAEA conference sessions, art museums are interested in participating in the conversations and in associating themselves with the maker movement. Art museums such as the Hirshhorn Sculpture Museum and Garden, the Columbus Museum of Art, and the Museum of Fine Arts, Houston, the Newark Museum, the Peabody Essex Museum, and the Metropolitan Museum of Art have developed spaces aligned with the maker movement and taken part in programs and events such as Maker Faires.

A Call for Research

Practitioners who have begun exploring makerspaces in museums are sharing best practices with each other as involvement with makerspaces grows (New York Hall of Science, 2013a; Bevan et al., 2014; Dougherty et al., 2013; Martinez & Stager, 2013; Honey & Kanter, 2013). Additionally, practitioners and researchers are highlighting the role that play adds to learning experiences in makerspaces and tinkering studios. In various studies, tinkering has been defined in terms of “imaginative play,” (Brahms, 2014, p. 4), “purposeful play” (ibid, p. 20), and “playing with materials” (Sheridan et al., 2014). Martinez (2013) argues that play is an important component of learning because learners are able to develop confidence in their own abilities to learn and create and she calls for more educators to integrate play into learning settings.

Not everyone has readily accepted the idea that the playful activities evident in makerspaces constitute significant learning. As Petrich, Wilkinson, and Bevan (2013) have encountered, some people have observed tinkering activities and questioned, “Well, it looks like fun… [pause] …but are they learning?” (p. 52). Thus, practitioners and policymakers have called for greater research to answer this question.

Practitioners and researchers are beginning to look at fundamental questions, such as who uses makerspaces, what occurs in makerspaces, and how makerspaces can facilitate learning. Research that has examined learning within museum-based makerspaces and tinkering studios has suggested the significance of playfulness and engagement, self-directed goal-setting, facilitation or peer-to-peer knowledge-sharing, and contextualized learning that crosses subject domains (Bevan et al., 2014; Brahms, 2014; Gutwill et al., 2015; Sheridan et al., 2014). These studies have also noted a lack of support to show that evidences of learning map to specific components of subject domains such as science, technology, or art (ibid).

If makerspaces are to become significant contributions within educational settings or systems, then research must be done that further qualifies and validates these playful activities within learning contexts. Secondly, within museum-based makerspaces, additional research is needed that comprises the full scope of museums. Thus far, the literature exploring learning within museum-based makerspaces has concentrated within science centers or children’s museums. While art museums are interested in and entering participation in the maker movement, no research exists that examines learning comparable to studies that have come out of science centers or children's museums.

Purpose and Research Questions

The purpose of this exploratory study is to expand upon the research base of what is known about learning within museum-based makerspaces, specifically in an art museum context. To this end, the study seeks to identify evidences of learning within the Peabody Essex Museum's Maker Lounge, applying the existing Learning Dimensions Framework with the express purpose of measuring learning in the PEM makerspace. The following research questions inform this study:

1. What is the nature of drop-in visitors' observable learning within an art museum-based makerspace?
2. In what ways does the Learning Dimension Framework (Bevan et al., 2014; Gutwill et al., 2015), which was developed for a tinkering studio in a museum with a STEM focus, apply to an art museum makerspace?

Implications

This study will add to the field's understanding of the possibilities for learning in museum-based makerspaces, while extending what is known to include the nature of learning specifically within an art museum-based makerspace. Additionally, this study will inform the field about the extent to which the Learning Dimensions Framework is applicable across varying makerspaces.

CHAPTER 2: Literature Review

Makerspaces represent a recent trend that has caught the attention of educators, policy-makers, entrepreneurs, and the general public. Claims and assumptions abound regarding the potential impacts that makerspaces afford, but research on this phenomenon is largely nascent. Practitioners trekking into the world of makerspaces are sharing best practices and stories of successful maker experiences as they discover how to effectively develop these spaces, but they recognize that there is a lack of tools for studying makerspaces as well as a lack of evidence-based understanding of the learning that occurs. This literature review seeks to define museum-based makerspaces and to situate museum-based makerspaces within a learning context, outlining what is known about who uses these spaces, how educators are designing for learning in museum-based makerspaces, and what learning occurs in museum-based makerspaces.

Literature directly informing this study includes studies and reports that provide an understanding of the specific activities and media typically found in combination in makerspaces as well research and evaluation reports that look at learning within makerspaces based specifically in museums as well as more generally across all settings. Literature indirectly informing this study includes thought pieces that help define the scope of the maker movement and that suggest the potential impacts of makerspaces; literature that synthesizes the accepted best practices of practitioners; and literature that practitioners and educators are collectively referencing as they shape the scope of their pursuit of makerspaces.

With the increase in attention that the maker movement is receiving within museums, some people within the museum field have raised the question, “What’s so special about maker spaces?,” (Gonzalez, 2014) on the presumption that museums have always been creating similar activities and programming. Thus, attention to what defines a makerspace is in due order.

The Scope of Makerspaces

The literature outlining makerspaces notes the variety of arrangements that a makerspace can take, but it largely agrees on five core characteristics: physical space, low and high-tech materials, user-driven creation, diffuse learning through collaboration, and cross-disciplinary integration (Bevan et al., 2014; Brahms, 2014; Dougherty et al., 2013; Educause, 2013; Gutwill et al., 2015; InformalScience Wiki, n.d.b.; New York Hall of Science, 2013a; New York Hall of Science, 2013b; Petrich et al., 2013; Sheridan et al., 2014; Vossoughi & Bevan, 2014).

First, the literature agrees that makerspaces are physical spaces, as opposed to solely digital spaces. The emphasis in a makerspace is on the hands-on, material-based creation processes as well as physical interactions that often occur with others. For Petrich et al. (2013), attention to environmental design is regarded as one of the three crucial factors for these practitioners as they seek to cultivate engagement in the Exploratorium's Tinkering Studio.

Secondly, the literature notes that makerspaces are equipped with both low and high-tech "diverse tools" (Sheridan et al., 2014, p. 529), "loose parts" (Petrich et al., 2013, p. 56), and "consumable materials" (InformalScience Wiki, n.d.b.) for hands-on production. These materials and tools might include everything from circuit parts, art supplies, and craft materials, as well as laser cutters, 3D printers, and CNC routers. Makerspaces provide access to traditional and emerging tools and materials for fabrication and "introduce the public to aspects of the growing convergence of the physical and digital worlds," as typified in physical computing (InformalScience Wiki, n.d.b.).

Thirdly, the literature emphasizes that makerspaces accommodate open-ended and self-driven projects. Activities in a makerspace may encompass tinkering, exploratory play, or creative production/deconstruction. The Makerspace Playbook (2013) differentiates a makerspace from a hackerspace by stating that, “Makerspaces focus primarily on learning and education, whereas hackerspaces often focus on hobbyists who make to have fun and relax, or who use the space as an incubator for their emerging small business” (Dougherty et al., p. 5). Vossoughi & Bevan (2014) note that, “the aesthetic and playful qualities of many making activities may operate to create a particularly low barrier for participation. Making thus looks and feels different from more traditional, open-ended, inquiry activities” (p. 4). The self-driven nature of makerspace activities allows for a learner’s ownership, empowerment, individual intentionality, and personal meaning making. Educause (2013) summarizes makerspace activity by noting that makerspaces “allow students to take control of their own learning;” likewise, the Making Meaning Report (2013) emphasizes the ways that “Making provides new routes to agency,” as well as efficacy in learning for participants (p. 6).

Fourth, the literature outlines how makerspaces rely on diffuse learning through facilitation, peer-to-peer knowledge-sharing, and collaboration. Petrich et al. (2013) highlight the importance of facilitation of tinkering studio activities. Sheridan et al. (2014) note that participants themselves lead, teach, and learn through collaboration as they join the makerspace’s community of practice.

Finally, the literature agrees that makerspaces allow cross-disciplinary integration of science, technology, engineering, art, and mathematics. The New York Hall of Science’s Blueprint (2013a) recognizes that arts and crafts are “equally important” to science, technology, engineering, and mathematics within makerspaces (p. 1). Sheridan et al. (2014) suggest that a key distinction of makerspaces from other learning settings is the way they “support making in disciplines that are traditionally separate” (p. 526). Additionally, Gutwill et al. (2015) conclude by suggesting the possibility that the arts may add learning significance to the makerspace process, but as of yet, no evidence exists to support or deny this possibility.

Not every museum-based makerspace or maker-inspired program includes such high tech tools as 3D printers readily available for visitors to use, and museum visitors may not be able to undertake extended projects as occurs in a member-based makerspace. Through comparative case study of three makerspaces, Sheridan et al. (2014) note that a primary distinction in museum-based makerspaces is the drop-in nature of participants and the shorter lengths of time spent on activities than in community or member-based makerspaces; however, the authors do note that varying makerspaces often still encompass similar principles, practices, interests, and working processes.

Who are the Makers?

The literature describes who is participating in and shaping the maker movement. Through a textual analysis of MAKE magazine, Brahms (2014) identifies that an affluent male audience is largely driving the content and consumption of the magazine. This textual analysis aided Brahms in creating a framework comprising the seven following practices she found common within the community of makers: seeking out resources, exploring and questioning, customizing, sharing, hacking/repurposing, tinkering/testing/iterating, and combining/complexifying. These findings are similar to the maker profile that came out of the New York Hall of Science case study, resulting in the Making Meaning report (New York Hall of Science, 2013b). This report suggests that makers are commonly marked by a proficiency at complex communication, expert thinking, “pivoting” (the ability to quickly adapt an approach responsively), persistence, and collaboration (ibid, p. 6). Sheridan et al. (2014) completed a case study of three makerspaces, with results suggesting that audiences differ in age and intention and makerspaces vary in arrangement or focus, but similar themes and characteristics emerge across makerspaces.

Martin & Dixon (2013) have begun initial research to understand how youth perceive the maker movement in order to better design educational experiences with a youth-centered emphasis. Preliminary results suggest that youth see themselves as makers if they are actively involved in multi-dimensional projects; youth view making as a process that leads to unique and creative objects; and youth see making as “transcending contextual boundaries,” consistent with the field’s interdisciplinary approach to makerspaces (ibid, p. 3).

Along with looking at who is using makerspaces, researchers and practitioners have also begun to look at who is not using makerspaces; the implications this disparity may have; and ways to address the gap. In a comprehensive literature review, Vossoughi & Bevan (2014) identify a current lack of discussion surrounding issues of educational equity within the literature on makerspaces and tinkering studios. The authors suggest that, “If making is to challenge rather than reproduce existing hierarchies, research may benefit from a deeper engagement with the history of ideas and debates around progressive educational movements and issues of equity” (ibid, p. 40). The Exploratorium has begun to address this gap through the Tinkering After-School program in partnership with Boys and Girls Clubs (Vossoughi et al., 2013). The program thus far has found evidences that tinkering can address equity in education through affording learners with agency, generosity in play, widened definitions of learning, and contextualized learning. Through an NSF grant, Michigan State University and the University of North Carolina, Greensboro, in partnership with Boys and Girls Clubs, are also studying ways to increase access to engineering for under-represented audiences through makerspace activities (InformalScience Website, n.d.a).

Constructionist Learning Activity Design

Many of the activities that educators are designing within museum-based makerspaces find basis in a vast body of research surrounding Constructionist learning activities within physical computing (Eisenberg & Eisenberg, 1997; Resnick, Berg, & Eisenberg, 2000), fabrication (Blikstein, 2013; Eisenberg & Buechley, 2008; Kafai, 1996; Mellis & Buechley, 2011; Worsley & Blikstein, 2013), and programming (Fields, Kafai, & Searle, 2012; Hooper & Freed, 2013; Kafai, Fields, & Searle, 2012; Kafai & Peppler, 2011; Resnik & Rosenbaum, 2013; Roque, 2012; Sylvan, 2004). Much of this literature and research is rooted in the educational philosophies of John Dewey, Friedrich Froebel, Maria Montessori, and Seymour Papert. These learning philosophies emphasize elements of play, inquiry, and physicality in the learning process (Vossoughi & Bevan, 2014). The literature largely agrees that these Constructionist learning activities can yield learning modes that include personal meaning making, complex cognition, creativity and design, engineering processes, problem setting, inquiry, experimentation, and collaboration.

Literature that examines learning across computing and fabrication has considered the role that motivation plays in learning. The literature agrees that learners come to activities with varying interests and motivations. Thus, the literature suggests that multiple entry points, opportunities for scaffolding, and cross-disciplinary integration will encourage greater motivation (Hooper & Freed, 2013; Worsley & Blikstein, 2013).

Some of the research within Constructionist learning has pursued an inquiry-through-design approach in response to what researchers identify as a prominence of "black box" tools. These researchers recognize a growing trend where users do not understand and cannot see how objects function (Resnik, Berg, & Eisenberg, 2000, p. 2). Resnik, Berg, & Eisenberg (2000) examined ways to allow students to design and construct their own scientific tools, and they concluded by proposing that instead of relying on existing technology, the design inquiry process may lead students to a greater critical analysis of the final investigation for which the tool was designed. Kafai, Fields, & Searle (2012) also offer evidence that making technology visible and understood, as occurs through e-textile designs, may be beneficial for learning.

Several studies have attempted to look across disciplinary bounds between fabrication and computing to suggest the benefit of cross-disciplinary activities. Following the Constructionist learning theories of Seymour Papert, the MIT Media Lab has spent years seeking to understand best practices for designing activities that combine low and high-tech technologies (Resnik & Rosenbaum, 2013). Resnik & Rosenbaum (2013) outline several core elements of construction resources found to impact learning, including immediate feedback, fluid experimentation, open exploration, immersive experience, and reflection. Eisenberg & Buechley (2008) propose that, "New fabrication tools and devices do not, in our opinion, threaten to uproot this [craft] tradition but rather have the potential to enrich it tremendously" (p. 62). The authors go on to argue that hands-on, craft, or tinkering activities reciprocally offer valuable learning, even in the rise of the digital, virtual world.

Looking at the literature overall, Kafai, Fields, & Searle (2012) note a lack of research that examines the connections between aesthetics/craft and engineering/science, although several studies have begun to explore connections between the two. Fields, Kafai, & Searle (2012) discuss how aesthetic dimensions can provide important contributions to the process of learning and not only the products created. Resnik, Berg, & Eisenberg (2000) undertook a two-year study, responding to a recognized trend towards "black box" scientific instrumentation where researchers (and students) do not know how their tools or machines function. Through four case studies of school and afterschool programs, in which students used computational devices called Crickets to design their own scientific devices, the authors found evidence that, "students seem to form a much stronger connection with their instruments (and with the overall activity) when they pay attention not just to functionality but also to aesthetics" (ibid, p.14).

Kafai & Peppler (2011) examine existing research that overlaps between media creation and programming, and they argue that significant connections have been overlooked due simply to disciplinary boundaries. They see that youth "move fluidly across these blurry boundaries," and they call for research that supersedes these boundaries as well (ibid, p. 90).

Additionally, Eisenberg & Eisenberg (1997) call for further research that examines the "stuff" of crafts, hobbies, and play for their inherent educational value. The authors argue that, "Everyday materials, simple objects, are more than carriers of potentially powerful scientific metaphors. They are also capable of emotional resonance, of being irresistible sources of wonder to the student of science or mathematics" (ibid, p. 13). The authors suggest that museums could be places where people can experiment with "middle tech," where materials are combined with computation for inquiry and exploratory play (ibid, p. 1).

The research within activity design has largely focused on one particular group of participants who were working on individual activities; however, much of this literature has laid a foundation for qualifying the learning that occurs in makerspaces. Museum-based makerspaces draw largely from these activities and tools but often offer aspects of computing, fabrication, and programming in conjunction with one another, allowing participants to choose and combine digital and analog technologies. Research that measures learning specifically within these self-directed, multidisciplinary spaces is much more nascent, but much of the emerging research is coming out of museum-based makerspaces.

Learning within Makerspaces

Agency by Design is a multi-year research project currently underway out of the Harvard Graduate School of Education's Project Zero that is also looking at learning within making from the lens of agency and self-efficacy (Agency by Design, 2015). Through partnerships with preK-12 classrooms in Oakland, CA, the researchers are examining what they have coined as "maker empowerment," which encompasses elements of a learner's self-discovery in, capacity for, and confidence around making (ibid, p. 4). The researchers preliminary findings thus far lead them to conclude that "the most salient benefits of maker-centered learning for young people have to do with developing a sense of self and a sense of community that empower them to engage with and shape the designed dimension of their world" (ibid, p. 7). This conclusion is emerging from data that highlights learning outcomes related to a learner's development of self rather than development of STEM skills.

Learning within Museum-based Makerspaces

A majority of the research thus far examining learning within makerspaces or tinkering studios has emerged from museums. Three museum-based studies have made significant contributions to understanding of the learning that occurs in makerspaces. These studies speak of patterns of learning similar to those referenced in the larger body of maker literature and within the Constructionist learning research (Bevan et al., 2014; Brahms, 2014; Gutwill et al., 2015; Sheridan et al., 2014). The studies highlight ways that participants form self-driven problems, exhibit motivation and curiosity, persist and take risks, experiment, approach problem solving, demonstrate creativity, and make personal meaning.

Brahms (2014) completed a textual analysis of MAKE magazine, identifying seven core practices to form a community of practice framework that connects makerspace practices to existing learning science theories. She then used this community of practice framework to observe family learning within the Pittsburgh Children's Museum's Makeshop. The study mapped makerspace activities to learning outcomes in order to inform makerspace design. Using twenty video-based observations of circuit and sewing activities, followed by semi-formal interviews with the observed participants, the author coded family interactions within the Makeshop. She then conducted full case studies of five of these family groups, analyzing against the specific core maker practice of "seeking out resources" (ibid, p. 88). The study results reveal that adults contributed significantly to children's making activities. Second, the study concludes that children's making activities were greatly informed by their self-generated goals. Finally, the study suggests that maker practices should be intentionally considered within designed learning contexts. Overall, the study provides a significant example of what makerspace learning can look like for a particular group of learners – young children and family groups.

A second study that has emerged from a museum-based makerspace is a visitor research study in which researchers and practitioners at the Exploratorium collaborated to identify evidences of learning within the museum's Tinkering Studio and to explore connections between facilitation and these evidences of learning (Bevan et al., 2014; Gutwill et al., 2015). The research team observed fifty participants within three activities typical of those offered in the Tinkering Studio: Electricity Boards, Wind Tubes, and Marble Machines (Gutwill et al., 2015, p. 154). Through this study, the researchers, in collaboration with the Tinkering Studio staff, offer a framework consisting of four learning dimensions – Engagement, Initiative and Intentionality, Social Scaffolding, and Development of Understanding – to observe evidences of learning (Bevan et al., 2014, p. 7). The study not only informs how the Exploratorium is designing their tinkering studio but also outlines the understanding of learning across makerspaces, most specifically in museums.

The third study that directly involved a museum-based makerspace is a comparative case study by Sheridan et al. (2014) across three varying makerspaces: Sector67*,* a member-based makerspace located in Madison, Wisconsin; Mt. Elliott Makerspace, a community makerspace located in Detroit, Michigan; and the Pittsburgh Children's Museum's Makeshop in Pittsburgh, Pennsylvania. The researchers used circuit activities as a common reference point in each case study to explore questions about who uses makerspaces, what do people do in makerspaces, and what learning occurs in makerspaces. The authors identify three main conclusions through this study: "Makerspaces' multidisciplinarity fuels engagement and innovation" (ibid, p. 526), "Makerspaces have a marked diversity of learning arrangements" (ibid, p. 527), and "Learning is in and for the making" (ibid, p. 528). The research adds greatly to the field's understanding of learning within museum-based makerspaces, identifying similar outcomes within a museum-based makerspace as in a community-based or member-based makerspace.

Looking at the results across these three museum-based studies provides insight into the learning evident in museum-based makerspaces. First, all three studies suggest that making can lead to engagement and play (Bevan et al., 2014; Brahms, 2014; Gutwill et al., 2015; Sheridan et al., 2014). The Exploratorium researcher/practitioner team identifies "Engagement" as the first of the four Learning Dimensions, noting that engagement is regarded as critical to learning in informal as well as formal settings (Bevan et al., 2014, p. 7; Gutwill et al., 2015, p. 156). The authors define engagement in participants as "becoming emotionally invested and deepening their interest" in the tinkering activity (Gutwill et al., 2015, p. 156). Sheridan et al. (2014) also note that learning within the Pittsburgh Children's Museum's (PCM) Makeshop largely centers on engagement and exposure to new materials, processes, and tools, describing the learning arrangement as “open-ended play” (p. 522).

Second, the three studies find that making fosters initiative and intentionality in participants (Bevan et al., 2014; Brahms, 2014; Gutwill et al., 2015; Sheridan et al., 2014). Sheridan et al. (2014) observe that Makeshop activities often spark families’ interests to the extent that they may complexify projects beyond the suggested activity prompt. The authors also note that participants self-direct their learning paths, using an activity either for exploration and open-ended play or as a tool to design and fabricate objects. Brahms’ research (2014) in the Makeshop led to the suggestion that participants’ varying initiatives and goals should be taken into account as practitioners and facilitators design makerspaces and activities. For the Exploratorium, “Initiative and Intentionality” also encompasses characteristics of persistence and intellectual courage that participants employ in pursuing their goals amidst frustrations or obstacles in the problem space (Bevan et al., 2014, p. 7; Gutwill et al., 2015, p. 158). For example, the authors reference participants whose marble machine fell apart after participants had spent time constructing it. Instead of voicing dejection, the participants suggested alternative ways that they might reconstruct the marble machine more securely.

Within the idea of intentionality, all three studies emphasize the role that process serves, including goal setting and problem solving. Along these lines, staff at the Exploratorium’s Tinkering Studio emphasize that process is valued over an end product in the learning space. The Tinkering Studio designs activities to allow visitors to pursue self-directed ideas, exercise creativity in problem setting and problem solving, confront and solve a conceptual challenge, engage intentionally, and seek innovative solutions. Sheridan et al. (2014) recognize a tension held between process and product in the PCM’s Makeshop. The authors find that the transition is often seamless between participants tinkering with concepts (e.g. circuitry) and then choosing to apply these concepts to end products (e.g. constructing a nightlight).

Third, the three studies each focus greatly on the ways that makerspaces may facilitate collaboration or social engagement. Brahms (2014) notes that children in the Makeshop not only engage in the defined maker practice of “seeking out social resources” (p. 94), but they “also develop a relationship to the content and to the people with whom they are learning through their participation” (p. 96). The Exploratorium specifies “Social Scaffolding” as a core learning dimension within the Tinkering Studio (Bevan et al., 2014, p. 8; Gutwill et al., 2015, p. 159). The authors recognize that the design of the space encourages participants of all ages, and even strangers, and to share ideas, ask for help, gain inspiration, and co-create on activities with each other. Slightly in contrast, Sheridan et al. (2014) find that while creating objects to serve a wider community purpose is a common practice in many makerspaces, the objects that participants create in the Makeshop are typically not shared beyond the family group or the activity space. The authors also observe that adults in the Makeshop primarily serve in a teaching/facilitation role during making activities rather than in a peer-learner role.

Fourth, all three studies conclude that making appears to be conducive to integrated and contextualized learning. For example, Sheridan et al. (2014) observe that families make connections between the activities and materials in the Makeshop and applications outside of the museum, such as replicating similar activities with materials in their homes. The Exploratorium research team emphasizes that the learning dimension of “Development of Understanding” focuses on the evolution of one’s understanding more than on instances of correctly-stated knowledge (Bevan et al., 2014, p. 8; Gutwill et al., 2015, p. 160).

Finally, these three studies agree that integrated learning across disciplines of science, technology, engineering, math, and the arts may be present within museum-based makerspaces, but the authors also recognize that comprehensive research does not yet exist that maps evidences of learning in makerspaces to the core components of each discipline. For example, the Exploratorium research team (Bevan et al., 2014; Gutwill et al., 2015) hypothesizes that elements of crafts or aesthetics may lead participants to deeper engagement and may complement scientific understanding, but they admit that many questions remain unanswered as to identifying or differentiating learning within distinct disciplines. Likewise, Brahms (2014) concludes with stating that the idea that there are connections between makerspaces and STEM involvement is currently only an assumption that requires greater research. Overall, the studies emphasize that more research is necessary to more fully understand what learning can and does look like within museum-based makerspaces; how aspects such as activity design, facilitation, and environmental design affect the learning; and what tools and frameworks the field can use to effectively identify evidences of learning.

State of the Literature

Further research on learning within makerspaces is necessary to validate makerspaces as settings that facilitate significant learning opportunities, both to policymakers, funders, and practitioners. Additionally, within museum-based makerspaces, further research is needed that comprises the full scope of museums. Thus far, the literature exploring learning within makerspaces has concentrated within science centers, children's museums or community-based makerspaces. While art museums are interested in and entering participation in the maker movement, no research exists that examines what learning occurs in this context, comparable to the research which has come out of science centers or children's museums.

Chapter 3: Methods

This study was designed to add to the emerging research on learning within museum-based makerspaces. The goal of this study was to measure evidences of learning within a makerspace based in an art museum and to test the efficacy of an existing framework to measure learning within an art museum. To this end, the following questions guided this research:

1. What is the nature of drop-in visitors' learning within an art museum-based makerspace?
2. In what ways does the Learning Dimension Framework (Bevan et al., 2014; Gutwill et al., 2015), which was developed in a science center's tinkering studio, apply to an art museum makerspace?

This chapter outlines a) the research site, b) sampling procedures, c) the method and instrument used to collect and analyze data, and d) limitations of the study.

Sampling

Three criteria were employed to identify the research site. First, the researcher looked across makerspaces and tinkering studios, and then specifically at museum-based makerspaces, to identify core characteristics of these spaces. The researcher identified common characteristics of makerspaces, which led to defining a makerspace as follows:

1. a physical space that
2. seeks to foster creative, design, and critical thinking habits through hands-on, iterative production and problem-solving,
3. seeks to facilitate an individual's engagement through self-driven projects,
4. cultivates social interactions through collaboration and knowledge-sharing, and
5. encourages integration across the sciences, tech, engineering, arts, and mathematics

(Bevan et al., 2014; Brahms, 2014; Dougherty et al., 2013; Educause, 2013; Gutwill et al., 2015; InformalScience Wiki, n.d.b.; New York Hall of Science, 2013a; New York Hall of Science, 2013b; Petrich et al., 2013; Sheridan et al., 2014; Vossoughi & Bevan, 2014).

Second, the researcher drew from the literature and from funding agencies to identify art museum-based makerspaces that fit the above-mentioned characteristics (Gonzalez, 2014; Institute for Libraries and Museum Services, n.d.a; Institute for Libraries and Museum Services, n.d.c; National Science Foundation, 2014). Four sites were found that self-identified as art museums and that fit the criteria for a makerspace: the Peabody Essex Museum (Salem, MA), the Hirsshorn Museum and Sculpture Garden (Washington D. C.), the Newark Museum (Newark, NJ), and the Museum of Fine Arts, Houston (Houston, TX).

Third, the researcher focused on sites that were as similar in nature as possible to the Exploratorium's Tinkering Studio, since the study was using the Learning Dimensions Framework developed in that space. As a result, makerspaces with a program-based structure or an outreach to a specific audience were excluded. In the end, the researcher approached the Maker Lounge at the Peabody Essex Museum (PEM) because the museum's casual, drop-in space appeared to be structured most similarly to the Exploratorium's Tinkering Studio.

Research Context

The PEM opened the Maker Lounge in April 2014 as a space for people "to *do* something *anytime*" (Fritsch, 2014). Staff have approached the Maker Lounge as a prototype in itself, quickly opening the space and iterating how they design the environment and activities as they learn what is effective for engaging their visitors. The room is located in a central portion of the museum and is open to the public everyday that the museum is open. Visitors can enter the

Maker Lounge through two different galleries, both of which include interactive art pieces, priming visitors to work with their hands in the Maker Lounge. Wall signs hung with masking tape and movable furniture help to convey the room's value for rapid prototyping and flexibility.

Image 1: Work tables centrally arranged in the PEM Maker Lounge.

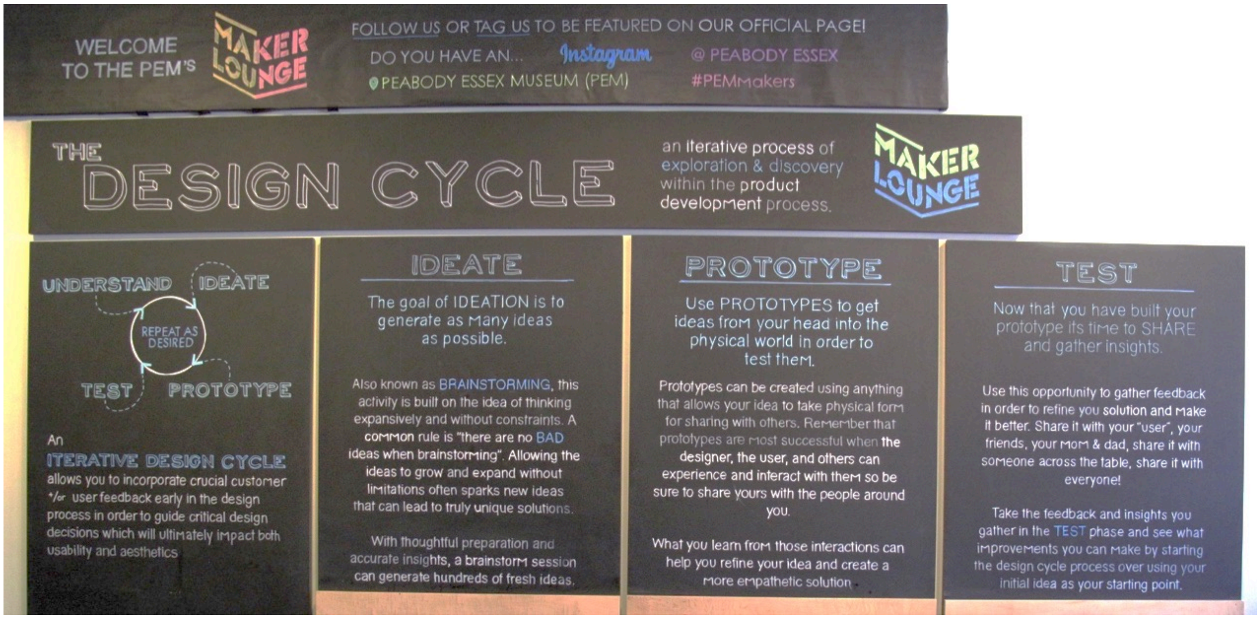
Image 2: Prototypes and a 3D printer welcome visitors into the Maker Lounge.

Image 3: An idea board fastened to the wall with masking tape.

Through self-guided exploration, visitors can take on various design challenges or tackle self-directed problems using a variety of materials and tools. There are few instructions but the room's large text panels introduce visitors to the following steps of "The Design Cycle:" ideate, prototype, and test. Occasionally, resident "makers" have come to facilitate workshops or create design challenges for the space. The residencies have tended to incorporate more technology into activities than the self-guided activities.

Image 4: Visitors' objects left behind on display.

Image 5: Bins with materials available to visitors.



WELCOME TO THE PEM'S MAKER LOUNGE

FOLLOW US OR TAG US TO BE FEATURED ON OUR OFFICIAL PAGE!

DO YOU HAVE AN... Instagram

@ PEABODY ESSEX

PEABODY ESSEX MUSEUM (PEM)

#PEMmakers

THE DESIGN CYCLE

an iterative process of exploration & discovery within the product development process.

MAKER LOUNGE

UNDERSTAND
IDEATE
REPEAT AS DESIRED
TEST
PROTOTYPE

An ITERATIVE DESIGN CYCLE allows you to incorporate crucial customer &/or user feedback early in the design process in order to guide critical design decisions which will ultimately impact both usability and aesthetics

IDEATE

The goal of IDEATION is to generate as many ideas as possible.

Also known as BRAINSTORMING, this activity is built on the idea of thinking expansively and without constraints. A common rule is "there are no BAD ideas when brainstorming". Allowing the ideas to grow and expand without limitations often sparks new ideas that can lead to truly unique solutions.

With thoughtful preparation and accurate insights, a brainstorm session can generate hundreds of fresh ideas.

PROTOTYPE

Use PROTOTYPES to get ideas from your head into the physical world in order to test them.

Prototypes can be created using anything that allows your idea to take physical form for sharing with others. Remember that prototypes are most successful when the designer, the user, and others can experience and interact with them so be sure to share yours with the people around you.

What you learn from those interactions can help you refine your idea and create a more empathetic solution.

TEST

Now that you have built your prototype its time to SHARE and gather insights.

Use this opportunity to gather feedback in order to refine you solution and make it better. Share it with your "user", your friends, your mom & dad, share it with someone across the table, share it with everyone!

Take the feedback and insights you gather in the TEST phase and see what improvements you can make by starting the design cycle process over using your initial idea as your starting point.

Image 6: "The Design Cycle" on the PEM Maker Lounge wall.

The museum intends for the Maker Lounge to be used by all audiences, but all visitors who participated in the study were children, approximately ages 4-16. While some days in the Maker Lounge feature specific design challenges and utilize high and low-tech tools/materials, during the weekend of data collection, the Maker Lounge was available for open design challenges, with minimal activity design, facilitation, or high-tech tools/materials. Visitors who entered the space were to use the wall text or instruction sheets to orient them to the space and activities. Many visitors began a self-directed making session simply after discovering the shelves of previously-created projects and/or the bins of materials/tools.

Data Collection Procedures

Between March 13-15, 2015, visitors were observed during their participation in the Maker Lounge activities at the Peabody Essex Museum. Twenty-five participants were recruited at random; participation was voluntary. Potential participants were selected after they indicated a choice to participate in an activity by picking up a material or tool in the Maker Lounge. The researcher then approached the accompanying adult (since all potential participants were children) to explain the study and to ask whether the adult consented to allow the child to participate. After receiving the adult's consent and the visitor's assent to participate in the study, the researcher used a handheld video camera to record the participant for the duration of his or her active engagement in the space. As this study was concerned with observing evidences of learning within participants, the focus of the observation was on a participant's behavior rather than on the activity itself. In order to focus on the working processes of individual participants as he or she freely moved throughout the activity space, the researcher chose to use a handheld camera rather than a stationary camera.

Data Analysis

Twenty-five video/audio recordings were coded using the existing Learning Dimensions Framework, which had been developed by researchers and practitioners collectively at the Exploratorium to study evidences of learning within the museum's Tinkering Studio. The Framework included four broad learning dimensions: "Engagement," "Initiative and Intentionality," "Social Scaffolding," and "Development of Understanding" (Bevan et al., 2014; Gutwill et al., 2015). Each dimension was further defined by indicators and descriptions of example behaviors. Engagement focused on a participant's motivation to playfully experiment and explore, as well as a participant's display of emotional investment in activities. Initiative and Intentionality focused on a participant's choices to create self-driven goals or problem sets, to design strategies, to actively seek help or inspiration towards achieving the goal, to persevere towards the set goal amidst failed attempts, and to experiment in the midst of uncertainties. Social Scaffolding encompassed a participant's interactions with others in the problem space. Participants might offer or ask for help, indicate inspiration or insight from another's work, or physically attach or build onto someone else's work. Development of Understanding dealt most with factual learning but from a process-oriented perspective. Emphasis was placed on the process of actively seeking to understand concepts, applying prior knowledge, offering explanations through reflection, or vocalizing one's concept realizations.

Since the Learning Dimensions Framework had been created within the Tinkering Studio, one aspect of this current study was to test the efficacy of the Framework in a second museum's makerspace. This study sought to examine how adequately the Framework encompassed learning indicators observed both in an additional space and a different context, specifically an art museum rather than a science center.

Before using the Learning Dimensions Framework to code video recordings, the researcher referenced videos in the Framework's accompanying Library of Exemplars to become familiar with the behaviors that the Framework creators had identified as evidences of learning (Gutwill et al., 2015, p 155). The Library allowed the researcher to develop a shared understanding of what visual behaviors aligned with the Framework's text-based descriptions.

The researcher coded the 25 observations by watching each video and noting any behavior that aligned to one of the descriptions of the Framework's thirteen indicators. Occurrences across the indicators and learning dimensions were then calculated to determine both the frequency of each evidence of learning across all visitors and the frequency of all evidences across each visitor's activity. Additionally, the researcher made other observation notes while watching the videos in order to look at the data for qualitative patterns and trends.

A second member of the research team blindly coded a subset of the data to determine inter-rater reliability. The Learning Dimensions Framework yielded an inter-rater reliability score of 75%.

Limitations

This study was limited in scope by examining evidences of learning within a single museum space. These findings cannot be generalized to represent all museum makerspaces, nor can the study alone serve to indicate the effective fit of the Learning Dimensions Framework for measuring learning in makerspaces. Additionally, this study was limited to a small sample size, which cannot be taken to indicate a definitive extent of learning within makerspaces.

As this study was specifically addressing learning outcomes, questions relating to audience were not addressed. This study did not gather demographic information about participants and cannot address questions about who was (or was not) participating or why visitors chose to participate in the Maker Lounge activities.

Data collection in the art museum was limited to several consecutive days in which only one, unfacilitated activity was available to visitors. Data collection was conducted during a time between Maker residencies, which often entail more facilitation and activities that more closely resemble typical projects associated with makerspaces that combine high and low-tech approaches. The resulting data may not reflect a full picture of what learning looks like within the PEM's Maker Lounge, nor can the study's results be generalized to represent the learning occurring across all art museum-based makerspaces.

CHAPTER 4: Results and Discussion

This chapter summarizes the study results, organized according to the study's guiding research questions. Data were analyzed using the pre-existing Learning Dimensions Framework, developed within the Exploratorium's Tinkering Studio (Bevan et al., 2014; Gutwill et al., 2015). The Framework includes four learning dimensions and accompanying indicators, which will be described in greater detail within this analysis.

Research Question 1: What is the nature of drop-in visitors' observable learning within an art museum-based makerspace?

The Learning Dimensions Framework allowed the researcher to identify which learning dimensions visitors demonstrated during their time spent in activities in the Peabody Essex Museum's (PEM) Maker Lounge. All four of the Framework's learning dimensions – Engagement, Initiative and Intentionality, Social Scaffolding, and Development of Understanding – appeared in varying frequency across the recorded observations of participant's activities. What follows is a discussion of how each of these dimensions is defined within the Learning Dimensions Framework in relation to how each dimension manifested within visitors' interactions in the PEM Maker Lounge.

Engagement. The Framework defined Engagement to include actions such as making, exploring materials, trying things repeatedly, starting anew after appearing finished, or displaying emotions while in the problem space. Engagement was the most frequently occurring learning dimension apparent in the PEM visitor observations from this study, with 100% of participant visitors (n=25) displaying at least one instance of this behavior. The high frequency of this dimension was due in part to the nature of the participant selection process. Before the researcher would approach a visitor to request agreement to participate in the study, the visitor had to pick up materials and in some way indicate an intention to participate in activities in the Maker Lounge, thus increasing the likelihood that any study participant would proceed to become engaged in the activity.

The Learning Dimension Framework specifies two indicators within Engagement, including, a) spending time in Tinkering activities; and b) displaying motivation, investment through affect or behavior. Both indicators appeared in the majority of visitors. The indicator "spending time in Tinkering activities" was evident in 100% of visitors (n=25). This indicator comprised more than simply being in the space or following scripted prompts. PEM visitors were seen initiating and driving their making process, exploring materials and tools with intense focus, and discovering their own ideas to pursue. Few participants abandoned their work before reaching a self-established conclusion unless their group members necessitated that they leave. Unprompted and unguided, visitors worked without losing interest or attention, not only towards specific projects but also simply exploring the process of making and exploring. For example, a young girl stated that she did not know what she was going to make towards the beginning of her time, but she found a tool that interested her. Her dad explained that the tool could punch holes in cardboard. She spent some time figuring out how to punch holes in the cardboard, and then she worked at using a safety saw to cut cardboard. She eventually found inspiration for a project once she realized that she could pierce a Ping-Pong ball with a wooden skewer, and she then proceeded to make a caterpillar with these materials. Her engagement with exploring the tools and materials led to a deepened experience once she decided on an idea to construct. Several visitors also displayed self-driven motivation as they would announce that they had finished their project but then immediately continue working, adapting, or improving their creations.

Sixty-four percent of participants (n=16 of 25) evidenced the Engagement indicator that related to seeing motivation or investment through affect or behavior. The observed emotions in visitors ranged from pride when completing the intended project, joy upon a surprise or realization about the materials or tools, frustration during points of confusion or unsuccessful construction attempts, and disappointment when they had to leave before they had completed their projects. As an example of pride, towards the end of their time in the Maker Lounge, a mom suggested to her son that they leave the toy motorcycle they had built behind since they had walked to the museum and did not have a bag to carry it; however, the boy replied, *"I want to keep it. We worked really hard."* His statement demonstrated his pride, not only in his end product but, moreover, in the effort he and his mother had invested into the making process. Some emotions were evident through a visitor's exclamations or dialogue, while other affect behaviors were observed through nonverbal actions such as throwing one's hands up when a construction fell or burying one's head in one's arms in a moment of regrouping from frustration.

Initiative and Intentionality. Initiative and Intentionality, which included goal setting, responding to material/environment feedback, persisting, or employing novel approaches, was the second-most frequently occurring learning dimension to appear within the data, at 96% of sample participants (n=24 of 25). Four indicators were used to identify this dimension within the Learning Dimensions Framework: a) setting one's own goals; b) seeking or responding to feedback from materials or environment; c) persisting to achieve goals in the problem space; and d) taking intellectual risks/showing intellectual courage. Two of the four indicators were present in the activity time of more than 50% of participants, while the other two indicators appeared in the data but with less frequency.

The most frequently evidenced indicator within Initiative and Intentionality found 72% of participants (n=18 of 25) persisting to achieve goals in the problem space. For example, one young girl built a tower with skewers and paper cups, and it repeatedly fell or was knocked over. She carefully rebuilt the tower five times, iterating the design to make it better guarded or stronger. First, she set the tower structure within a fence, but she found that the tower itself was not strong and kept falling. Next she added plastic tubes around her skewers for support. She eventually found a solution by driving the skewers through the paper cup, below the tower's base, similar to the way a foundation is laid for a skyscraper. Visitors were often forced to persist to optimize their strategies based on boundaries the Maker Lounge created through the materials made available in the space. The Maker Lounge did not include several commonly used materials that visitors searched and asked for, such as glue or tape, so visitors were forced to think of new approaches to fasten and attach their projects. For example, one boy tried using a rubber band to attach a flat row of popsicle sticks, but he found that the band did not allow the sticks to lay flat as he had arranged them. He later discovered that pipe cleaners allowed him to attach the sticks and secure them in the way he envisioned. At another point, he began to cut paper but then set it aside and took cardboard, which he found allowed him to continue the design as he had envisioned.

"Setting one's own goals" was observed in 56% of participants (n=14 of 25). Several visitors appeared to allow the process of exploring and finding the strengths and limitations of materials and tools to drive the creative activity towards ideas and goals rather than expressing or demonstrating an intended goal at the outset of their making activity. For example, two middle school-aged girls each chose materials and set off to work. One asked the other what she was making, to which the other replied, *"No idea, but I'm going to make three things"* (pointing to the three paper cups she was working with). After cutting a cup and wedging a Ping-Pong ball into the narrowest part, she said it looked like a salt or pepper shaker. She and her mom talked about several possible uses for her design, and the girl stated her intention to make salt and pepper shakers until her friend said, *"If you put a light underneath, they'll glow."* The girl exclaimed, *"Yes!... We're having 'ah-ha' moments,"* and she proceeded to direct the rest of her time towards making mini lamps.

Two visitors did plan out their projects before beginning to work with tools and materials. Often, this planning or brainstorming took the form of sketching designs. For example, one boy spent the first several minutes quietly sketching, which was later identified as the design for his project. Throughout his making process, he referred back to this sketch to guide his design choices, and he used the sketch to explain what he was trying to accomplish when he asked his mom for help.

Social Scaffolding. The learning dimension of Social Scaffolding was defined within the Framework as a) offering or requesting help; b) gaining ideas and inspiration from others' works; and c) physically connecting individual projects to others' projects. This dimension was evidenced in 64% of the participant sample set (n=16 of 25). None of the three indicators were evident in more than 50% of visitors, though two indicators were seen in at least 40% of visitors.

The most common of the three indicators within Social Scaffolding was "Requesting or offering help in solving problems," which was observed in 44% of visitors (n=11 of 25). Visitors requested help both to understand how to use tools and materials as well as how to achieve their goals. Some of the tools were unfamiliar to many visitors, and in handling such a tool visitors were seen to ask their parents what the tool was used for or how to operate it. At other times, visitors asked for help after observing others. For example, one young boy observed his older sister's work, and asked her how she had attached pipe cleaners to egg cartons. Some visitors asked for help when they found themselves stuck. One boy showed his mother his sketch to help explain what he was trying to accomplish and to ask for her suggestion. Another girl was working on her own and repeatedly took her project across the room to her parents or called for them to help her as she struggled to attach all her pieces to her airplane. Outside of simply asking for a shared tool, visitors did not actively engage with people outside of the groups they entered the Maker Lounge with. Instead the majority of visitors requested help from their parents, while a few visitors asked their siblings or friends for help.

The researcher observed the Social Scaffolding indicator "Inspiring new ideas or approaches" in 40% of participants (n=10 of 25). This indicator was evident when visitors spoke of, indicated, or noticed others' works in such a way that seemed to provide an inspiration or a model for the work they were pursuing. For example, a young boy took his mom to the shelf of left-behind creations in the middle of his making process to show her an example of what he had been trying to accomplish as he built a cardboard robot. In another example, a girl and her grandfather were building a toy car with an axle so that it could roll. The girl found a project that someone else had left behind that had rolling wheels. She examined how it was constructed and then exclaimed, *"Oh! That's how they made it!"*

Development of Understanding. The dimension of Development of Understanding included actions such as expressions of realization, testing and iterating, connecting to prior knowledge, complexifying work, or working through confusion towards understanding. This dimension was least likely to appear in the data, evidenced in 32% of participants (n=8 of 25).

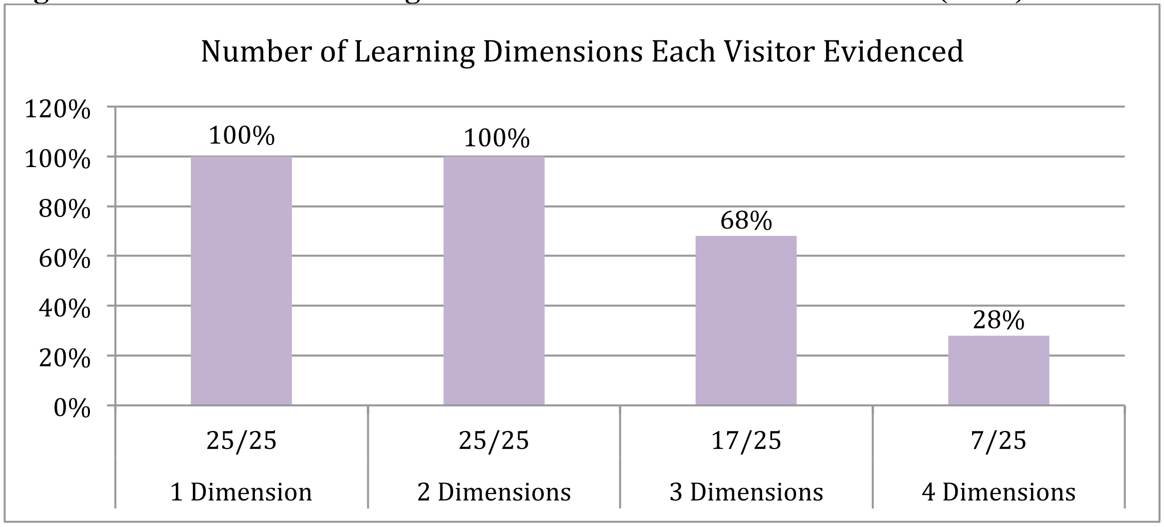
Since the overall frequency for Development of Understanding was lower across the data set, the instances across four indicators were varied, which limited the extent to which examples could be used to characterize each indicator robustly. The most common indicator, “Expressing a realization through affect or utterances,” was evident in a few visitors’ comments such as, *"Oh! That's how they made that!," “Huh!,”* or *“Yes!”*

Two visitors vocally expressed confusion on how to achieve their design goals but continued to search for a solution, evidencing the indicator of “Striving to understand.” For example, one young boy was trying to attach materials similar to how he saw his sister do build her project, and in great frustration, he exclaimed, *“It’s not working,”* and *“I can’t do it,”* and yet he continued tinkering at the work. When his dad asked him if he wanted to leave the project and move on to another room, he adamantly objected, despite his previous comments.

Two visitors displayed the Development of Understanding indicator of “Applying knowledge.” Both instances took the form of engaging in increasingly complicated or sophisticated work. These complexifications were directly related to the involvement of parents, who helped to facilitate the activity by making suggestions. For example, one boy quietly and steadily tinkered with materials for several minutes, attaching wire, bits of pipe cleaners, and popsicle sticks to a paper tube. Occasionally, he would peer through the tube, and at one point his dad asked him if he was making a telescope, to which the boy replied yes. At the point that the boy stated that he had finished constructing his telescope, the dad suggested that the boy add legs to make the telescope stand up. The boy suddenly became more animated, beginning to talk through his next steps (towards adding legs) and moving more quickly around the space. The dad's recognition of the existing design, along with offering with a challenge to complexify the design, seemed to enliven and deepen the boy's motivation, even though the suggestion presented the boy with a greater challenge to execute than the original work had required. This additional element to the original design turned the boy's fifteen minutes of making into forty-three minutes spent on his project. In another observation, a mom remarks that, *"The challenge would be to make the motorcycle actually roll… that's a big challenge."* Her son accepted this challenge, and they both set off to make a rolling motorcycle. She later challenged him again, asking, *"What can we do to make it roll better?"* Each time, the boy had achieved his goal, but his mom's challenges provided the impetus to push him towards solving more complex problems. These visitors whose parents helped to facilitate the making experience evidenced a greater overall number of occurrences across the learning dimensions and indicators, a more prolonged engagement in the making activity, and more complex designs than most visitors.

Multiple Evidences. The researcher was interested to see how many different learning dimensions each visitor evidenced during his/her time in the Maker Lounge activity. Figure 1 below shows that significant numbers of visitors demonstrated multiple learning dimensions within their time spent on the activity.

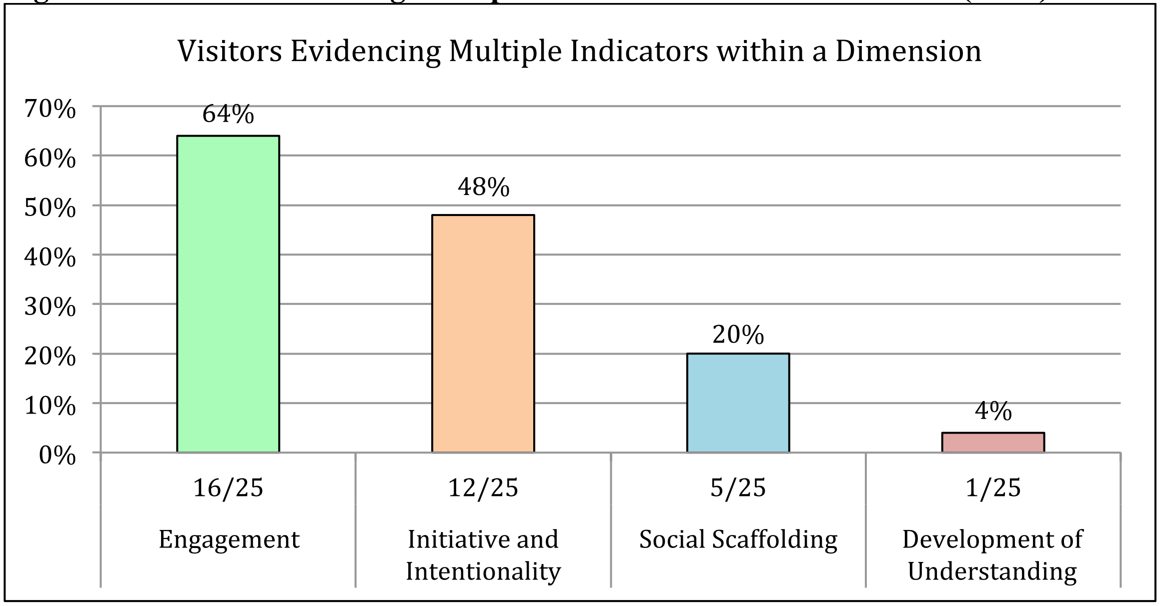
Figure 1: Number of Learning Dimensions Each Visitors Evidenced (n=25)



For the 25 participants who evidenced at least two learning dimensions, 24 visitors demonstrated both Engagement and Initiative and Intentionality, while one visitor evidenced both Engagement and Social Scaffolding. For the 17 participants who demonstrated at least three learning dimensions, eight participants evidenced Engagement, Initiative and Intentionality, and Social Scaffolding; two participants evidenced Engagement, Initiative and Intentionality, and Development of Understanding; and seven participants evidenced all four of the dimensions.

Looking at the learning dimension indicators allowed the researcher to see when participants evidenced multiple indicators within one dimension. Multiple indicators appearing within one dimension strengthened the claim that a learning dimension was present for these participants (Figure 2; see full data table in Appendix A).

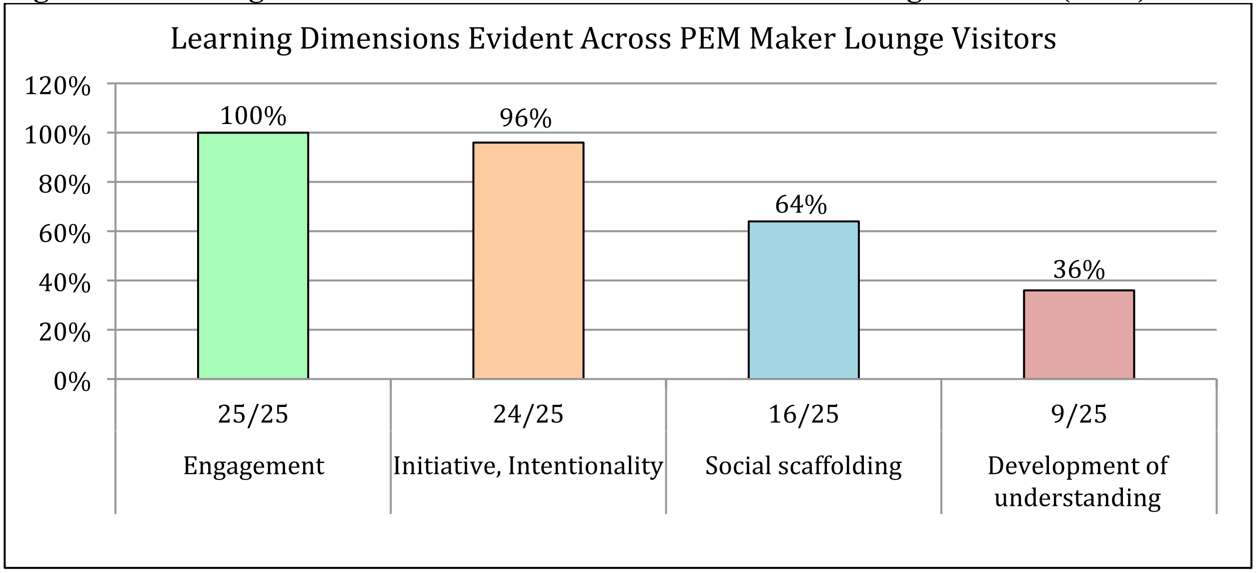
Figure 2: Visitors Evidencing Multiple Indicators within a Dimension (n=25)



Research Question 2: In what ways does the Learning Dimension Framework (Bevan et al., 2014; Gutwill et al., 2015), which was developed for a tinkering studio in a museum with a STEM focus, apply to an art museum makerspace?

The second question investigated in this study related to the extent to which the Learning Dimensions Framework captured evidences of learning within a museum context not specifically focusing on STEM content. At the most general level, while the Framework was developed within a setting that emphasizes scientific processes and knowledge, the data analysis previously discussed within this current study revealed that the Framework allowed for a similarly effective analysis of learning within an art museum context. Figure 3 below displays how all four of the Framework's learning dimensions – Engagement, Initiative and Intentionality, Social Scaffolding, and Development of Understanding – appeared in varying frequency.

Figure 3: Learning Dimensions Evident Across PEM Maker Lounge Visitors (n=25)



Tactile Thinking. The Learning Dimensions Framework emphasized many nonverbal behaviors as well as expressions, which proved particularly advantageous for the Maker Lounge observations. By mapping evidences of learning to observable behaviors, the Framework was able to account for the nonverbal, non-written elements of learning the Maker Lounge activities encouraged. While the majority of visitors were accompanied by parents, siblings, or friends, many observations found participants working deep in concentration with little talking. This quietness was not a result of the museum's environment. Outside of an observed visitor's problem space, the Maker Lounge and the surrounding galleries were filled with visitors freely talking, running, interacting with exhibits and playing instruments. The quiet nature of the observations seemed to be more related to tactile actions that required the full attention of visitors, such as exploring tools and materials, sketching designs, working out ideas, and iterating designs towards goals, rather than any imposed environmental constraint. The act of making seemed to necessitate deep thinking rather than conversation in visitors.

Material-Driven Goals. The Framework also accommodated much of the Maker Lounge visitors' behavior that resulted from the specific emphasis the art museum placed on design problems. As discussed previously, many of the evidences, particularly of Engagement and Initiative and Intentionality, centered on exploring the strengths and limitations of tools and materials and allowing these resources to create and inform the goal pursued. This process where the initial engagement led to goal-setting reflects the description of tinkering offered by the Framework developers, who stated, "Problems or challenges are not assigned but are surfaced and pursued by the learner through initial exploratory engagement with the materials, people, practices, and ideas available in the tinkering setting" (Bevan et al., 2014, p. 2). Maker Lounge visitors often did not appear concerned with identifying or pursuing a specific design challenge, but the material exploration often naturally led them to a specific challenge or goal.

Nonfunctional Design. The learning dimension of Development of Understanding was least often observed within the PEM Maker Lounge. Some of this may have been the result of the limited dialogue the researcher observed in visitors during their activity time, for example, limiting how often the researcher observed "Expressing a realization through affect or utterances" or "Offering explanation(s) for a strategy, tool or outcome." Some of the nonverbal actions that the researcher had expected to see, however, were not apparent in the observations. Only 8% of visitors (n=2 of 25) were seen testing whether their creations were functional. While many visitors were constructing things such as airplanes or cars, most did not indicate any attempt or desire to incorporate functionality into their designs.

Imaginative Design. Conversely, where there was a lack of functionality, there was often a prevalence of imagination. Visitors created objects that held narratives, that represented more than the visible materials, or that combined recognizable models with unrecognizable additions. For example, after constructing a *"jet blue plane"* out of cardboard, a young boy sketched his design and added the sketch to a wall of similar papers. He proceeded to describe a tiny dot that he had drawn on the sketch (which had not been represented in his cardboard model). He said, *"See this little round thing? It opens up and something pops out and it's a bomb. It's like a little police thing."* The boy had elaborated on his object through his drawing, and then he expanded even further by creating an accompanying narrative. One girl constructed a small airplane, and then she worked at length to secure additional parts to the plane. These additions did not represent familiar airplane parts to the researcher, and yet as the girl worked, at moments she looked perplexed, asked for help, and persisted to connect the parts to the airplane, appearing to have a clear vision of what she was working towards. While her vision did not lead to a familiar representation of an airplane, she was willing to risk in creating something entirely novel. Another young boy attached a Ping-Pong ball to his cardboard construction using wire, and while his creation was not recognizable to the researcher as more than an abstract arrangement of materials, the boy announced to his group that he had made a house with a bridge to a buoy swing. He was able to see beyond the materials and use his creation to represent something he was ultimately constructing in his head. Such behaviors did not map to the Framework's learning dimensions, and yet the researcher was not prone to immediately dismiss these imaginative behaviors from being evidences of learning.

CHAPTER 5: Conclusion and Implications

As makerspaces are becoming more prolific within museums, and as educators, funders, and policymakers are seeking to understand the value of these hands-on spaces, this research study adds to what is known about the learning evident within museum-based makerspaces, specifically within the context of an art museum's makerspace. By conducting visitor observations within the Peabody Essex Museum's (PEM) Maker Lounge, and by using an existing framework to analyze data, the study examined the nature of learning within one art museum-based makerspace.

Conclusions

An art museum makerspace can evidence learning. Visitors who participated in the PEM Maker Lounge activities evidenced a range of behaviors that mapped to the Learning Dimensions Framework. The resulting data suggest that the open-ended, self-directed activities common in an art museum-based makerspace can effectively offer a wide spectrum of learning opportunities. The data also suggest that the learning opportunities available within an art museum-based makerspace are accessible to a variety of learners, which is critical for a space frequented by a range of casual, drop-in visitors.

Data analysis that mapped to all four learning dimensions revealed that evidences of learning in the art museum context were largely similar to the evidences of learning previously observed in a museum with a STEM-rich focus (Bevan et al., 2014). The fact that two sites approaching making from different contexts saw similar outcomes should not be too surprising, given that the original study's site clarified that "STEM is a *means* not an *end* to engagement" (ibid, p. 5). Similarly, the PEM's Maker Lounge gave little indication that art was intended to drive the activity or connect to outcomes. Thus, the results of this current study offer evidence that both arts and sciences might be effectively employed to reach similar outcomes of engagement, initiative and intentionality, social scaffolding, and development of understanding. This conclusion agrees with existing research that has suggested that maker activities and learning do not align with one singular discipline (Agency by Design, 2015; Brahms, 2014).

Clarification about what learning outcomes have been evidenced in museum-based makerspaces can conversely imply what outcomes have not been evidenced. By mapping to evidences of learning that do not align within any particular subject domain, this study reiterates what previous studies have found related to STEM trajectories. Namely, despite a national interest and hope for outcomes related to STEM academic or career trajectories, there is little evidence to date that makerspace activities result in increased STEM interest or knowledge (Agency by Design, 2015; Brahms, 2014).

The Learning Dimensions Framework can provide a baseline for measuring evidences of learning. In addition to examining the nature of learning within an art museum's makerspace, this study examined what tools may be used to identify evidences of learning in makerspaces. By using an existing framework, the study was able to speak to the efficacy of the tool in a site other than the one it was created within. The researcher was able to use the Learning Dimensions Framework to identify evidences of learning that were most and least evident within the Maker Lounge as well as potential evidences of learning that the Framework did not encompass.

Applying the Framework to the data revealed only a small occurrence of visitors who tested pieces or worked towards creating functional objects, an indicator mapping to the

Development of Understanding dimension. The explanation for why visitors did not create functional pieces is beyond the scope of this study; however, it can be noted that the PEM designed the environment of the Maker Lounge as a space for design challenges. The largest wall in the space contained graphics that outlined steps of "The Design Cycle." The steps outlined in these graphics encouraged makers to test and iterate their work, which seems to imply that the PEM values testing and intends to be cultivating Development of Understanding. The fact that few evidences of learning mapped to the indicator of testing does not negate the efficacy of the Framework for a space like the Maker Lounge. Rather, the researcher was able to effectively use the Framework to reveal a paucity of a sought-after learning outcome. With this in mind, other practitioners may find the Framework useful as they seek to measure intended learning outcomes within their own makerspace. Practitioners may use the Framework to help iterate the environment, activity design, or facilitation in their ongoing attempts to create spaces conducive for all intended learning outcomes.

The Learning Dimensions Framework was developed out of what the tool's research/practitioner team both *valued* and *saw* in their space (Bevan et al., 2014, p. 5). Subsequent museum sites, such as the PEM's Maker Lounge, may use the Learning Dimensions Framework as a baseline to recognize what learning is or is not evident, but they may benefit from determining for themselves whether actions or expressions not captured in the Framework should be included as evidences of learning. In the absence of testing and creating functional pieces, data revealed that visitors displayed frequent instances of imaginative behaviors, such as creating objects or accompanying narratives beyond known possibilities. While these examples of imaginative thinking within the making process might not reveal an understanding of engineering or an application of STEM concepts, greater attention to the role of imagination or possibility thinking may reveal that such behavior also contains significant evidences of learning. If one of the hallmarks of makerspaces is innovative thinking, then it may be beneficial to explore whether such imaginative behavior is a habit of mind connected to outcomes such as innovative, creative, or conceptual thinking that makerspaces of all types are interested in cultivating.

Further Research and Implications

As a first direction for future research, this study suggests that further attention be given to the role of facilitation in makerspaces. Between the activity design and the environment, the Maker Lounge seemed to have found a sweet spot between presenting low barriers to entry, which allowed for most anyone to become engaged without needing instruction or prompts, while offering challenges or obstacles to overcome, which kept visitors engaged in the design process. The Maker Lounge was set up so that facilitation was not required, and yet instances where parents provided facilitation resulted in deepened experiences for visitors. Existing research has already begun to examine the relationship between facilitation and evidences of learning (Gutwill et al., 2015). This current study's data validates the connection apparent between facilitation and learning, and it suggests that additional research into the connection between facilitation and learning will be advantageous for developing the deepest learning opportunities possible.

Another avenue for future research surrounds the difference between a makerspace and a traditional studio art space. The Maker Lounge was situated adjacent to another room in the museum where visitors could participate in studio art projects such as painting. The juxtaposition of the two interactive spaces in the PEM begs the question as to what is different about the activities occurring in each space or why have two different spaces in the museum. Both of the PEM's spaces allowed visitors to pursue hands-on, self-initiated projects, and both activities encouraged creative expressions and personal investment, and yet the presence of both spaces suggests that there are differences. The role that materials and tools seemed to play in shaping the learning experience in the Maker Lounge echoes the role that Bevan et al. (2014) designate for aesthetics in tinkering as they write, "Aesthetic dimensions of tinkering play an important role not only in allowing learners creative self-expression and personal investment but in providing constraints, of the learner's own choosing, that structure and also complexify investigations" (p. 3). One question then becomes whether a studio space can provide complexifying constraints as well. Brahms (2014) has stated that, "Makers have developed a set of sophisticated community practices and modes of participation that, as a whole, are unique to making" (p. 30f). Further research exploring the learning outcomes in both an art museum's makerspace and studio space may clarify whether different outcomes occur in each type of space and whether making does present practices unique to makerspaces. Such research may also strengthen the argument for learning in both a makerspace and a studio art space.

This study brought attention to the fact that some of the claims surrounding makerspaces lack supporting evidence. If supporters or practitioners hope to endorse makerspaces as sites aiding the STEM pipeline, then more research might first look for evidence that makerspaces are directly affecting STEM interest or learning. Additionally, a growing body of research is beginning to question other claims related to learning and audience, such as whether making is a preferred and effective method of learning for all people (Ames & Rosner, 2014), whether makerspaces are truly equitable and accessible to all audiences (Fox, Ulgado, & Rosner, 2015; Vossoughi & Bevan, 2014), and whether there are gatekeepers within the maker movement deciding what counts as “making” (Fox, Ulgado, & Rosner, 2015). For instance, while this study found 100% of participants evidencing engagement in the Maker Lounge, the study was not accounting for museum visitors who opted against participating in the space’s activities. Further research might examine who is not participating in makerspace activities and the reasons why they do not.

Lastly, the simplicity of the materials and activities present in the Maker Lounge raise the question as to what caused the Maker Lounge to be so compelling to these young visitors. Most of the materials available – paper towel rolls, cardboard, wire, string, and paper – were likely found in visitors’ own homes and recycling bins. Moreover, visitors were not relying on a facilitator to provide an engaging activity but were rather self-directing the activity. One parent even commented that his son made requests to come to the PEM’s Maker Lounge almost every weekend. With activities and materials that could easily be replicated at visitors’ homes, there seemed to be something else at play compelling and engaging visitors to participate in these activities specifically within the museum space. Further research might look deeper into the role of the makerspace environment itself to better understand why visitors are drawn to the spaces and activities like the Maker Lounge provides.

Museums represent sites where audiences of diverse ages, backgrounds, interests, and prior knowledge come to engage and to learn. As researchers seek to further understand the full breath and depth of learning possible within makerspaces, museums may continue to provide ideal settings for further research about the learning that can occur in makerspaces and tinkering studios for and across a variety of participant learners.

Final Thoughts

This study situated an art museum as a space that is conducive for learning within the current maker movement. The visitor observations discussed suggest that learning within museum-based makerspaces can cross between subject domains such as art or science. At the same time, there may also be apparent differences in learning that are evident in museum-based makerspaces of varying contexts, and each museum may find it advantageous to identify the unique strengths of their makerspace in order to create the most effective learning environment possible. My hope is that this research serves the field by providing a greater understanding of the rich learning that is possible within museum-based makerspaces, by fueling further research into the ways that museum-based makerspace learning is designed and facilitated, and by sparking more museum practitioners to consider creating makerspaces as they work to create deep and meaningful learning opportunities for visitors.

References

Agency by Design (2015). Maker-centered learning and the development of self (white paper). Project Zero. Harvard Graduate School of Education. Retrieved from http://www.agencybydesign.org/wp-content/uploads/2015/01/Maker-Centered-Learning-and-the-Development-of-Self_AbD_Jan-2015.pdf

Ames, M. & Rosner, D. (2014). From drills to laptops: Designing modern childhood imaginaries. Information, Communication & Society, 17(3), 357-70. DOI: 10.1080/1369118X.2013.873067

Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2014). Learning through STEM-rich tinkering: Findings from a jointly negotiated research project taken up in practice. Science Education, 20(10), 1–23. DOI: 10.1002/sce.21151

Blikstein, P. (2013). Digital fabrication and "making" in education: The democratization of invention. In J. & Walter-Herrmann & C. Buching (Eds.), FabLabs: Of Machines, Makers and Inventors. Bielefeld: Transcript Publishers.

Brahms, L. J. (2014). Making as a learning process: Identifying and supporting family learning in informal settings (Doctoral dissertation, University of Pittsburgh). Retrieved from http://d-scholarship.pitt.edu/21525/1/L_Brahms_ETD_2014.pdf

DML Research Hub (n.d.). Retrieved from http://dmlhub.net/newsroom/media-releases/new-grants-help-museums-and-libraries-connect-youth-friends-learning-and

Dorph, R. & Cannady, M. A. (2014). Making the future: Promising evidence of influence. Berkeley: Lawrence Hall of Science. Retrieved from http://www.cognizant.com/SiteDocuments/Cognizant-making-the-future.pdf

Dougherty, D., Thomas, P., Chang, S., Hoefer, S., Alexander, I., & Mcguire, D. (2013).

Makerspace Playbook. Maker Media. Retrieved from http://spaces.makerspace.com.

Educause (2013). 7 Things You Should Know About Makerspaces. Retrieved from http://net.educause.edu/ir/library/pdf/eli7095.pdf

Eisenberg, M. & Buechley, L. (2008). Pervasive fabrication: Making construction ubiquitous in education. Journal of Software, 3(4), 62–68. Retrieved from http://l3d.cs.colorado.edu/~ctg/pubs/JSoft08.pdf

Eisenberg, M. & Eisenberg, A. (1997). Middle tech: Blurring the division between high and low tech in education. In The Design of Children's Technology (pp. 1–20). Retrieved from http://l3d.cs.colorado.edu/~ctg/pubs/MiddleTech.pdf

Fields, D., Kafai, Y., & Searle, K. (2012). Functional aesthetics for learning: Creative tensions in youth e-textile designs. In The Future of Learning (Vol. 1, pp. 196-203). Retrieved from http://www.isls.org/icls2012/downloads/ICLS2012%20Program.pdf

Fox, S., Ulgado, R., & Rosner, D. (2015, March). Hacking culture, not devices: Access and recognition in feminist hackerspaces. Paper presented at CSCW '15, Vancouver, B. C. DOI: 10.1145/2675133.2675223

Fritsch, J. (2014). Personal communication on December 12, 2014.

Gonzalez, D. (2014) What's So Special About Maker Spaces, Anyway? Retrieved from http://museummaking.com/post/97592623345/whats-so-special-about-maker-spaces-anyway

Gutwill, J. P., Hido, N., & Sindorf, L. (2015). Research to practice: Observing learning in tinkering activities. Curator, 58(2), 151-68.

Hildreth, S. (December 20, 2012). Makers on the Move in Libraries and Museums. UpNext: The IMLS Blog. Retrieved from http://blog.imls.gov/?p=2494#sthash.R1S4H1Yf.dpuf

Hooper, P., & Freed, N. (2013, October). The spiro inquiry: Exploring maker educational practices with a geometric drawing tool. Workshop for FabLearn Conference, Stanford University. Retrieved from https://dl.dropboxusercontent.com/u/422054/DigiFab_IDC2013/Papers/IDC_2013_Hopper_Freed.pdf

Honey, M., & Kanter, D. E. (2013). Design, Make, Play: Growing the Next Generation of STEM Innovators. Hoboken: Taylor and Francis.

InformalScience Website (n.d.a). Making for Change: Becoming Community Engineering Experts through Makerspaces and Youth Ethnography. Center for Advancement of Informal Science Education. Retrieved from http://informalscience.org/projects/ic-000-000-010-172/Making_for_Change

InformalScience Website (n.d.b). Wiki: Making and Tinkering Programs. Center for Advancement of Informal Science Education. Retrieved from http://informalscience.org/research/wiki/Making-and-Tinkering-Programs

Institute for Libraries and Museum Services (n.d.a). 21st Century Learning Lab Locations. Retrieved from http://www.imls.gov/news/21st_century_learning_lab_locations1.aspx

Institute for Libraries and Museum Services (n.d.b). Museums, Libraries, and 21st Century Skills. Retrieved from http://www.imls.gov/about/21st_century_skills_list.aspx

Institute for Libraries and Museum Services (n.d.c). Talking Points: Museums, Libraries, and Makerspaces. Retrieved from http://www.imls.gov/assets/1/AssetManager/Makerspaces.pdf

Kafai, Y. (1996). Learning design by making games. In Kafai, Y. B., & Resnick, M. (Eds.), Constructionism in Practice: Designing, Thinking, and Learning in a Digital World.

Mahwah, N.J: Lawrence Erlbaum Associates.

Kafai, Y., & Peppler, K. (2011). Youth, technology, and DIY: Developing participatory competencies in creative media production. Review of Research in Education, 35(1), 89–119. doi:10.3102/0091732X10383211

Kafai, Y., Fields, D., & Searle, K. (2012). Making technology visible: Connecting the learning of crafts, circuitry and coding in e-textiles by youth designers. In The Future of Learning (Vol. 1, pp. 188-195). Retrieved from http://www.isls.org/icls2012/downloads/ICLS2012%20Program.pdf

Maker Media (2014). Fact Sheet. Retrieved from http://makermedia.com/press/fact-sheet/

Makerspace Website (n.d.). What's a Makerspace? Maker Media. Retrieved from http://spaces.makerspace.com

Makeshop Website (2014). Recognition for Makeshop. Pittsburgh Children's Museum. Retrieved from http://makeshoppgh.com/about/recognition-for-makeshop/.

Martin, L. & Dixon, C. (2013, June). Youth conceptions of making and the Maker Movement. Paper presented at Interaction Design and Children Conference, New York. Retrieved from https://dl.dropboxusercontent.com/u/422054/DigiFab_IDC2013/Papers/IDC_2013_Martin_Dixon.pdf

Meehan, R. J., Gravel, B. E., & Shapiro, R. B. (n.d.). A card-sorting task to establish community values in designing makerspaces. Retrieved from http://fablearn.stanford.edu/2014/wp-content/uploads/fl2014_submission_55.pdf

Mellis, D. A., & Buechley, L. (2011). Scaffolding creativity with open-source hardware. Proceedings of the 8th ACM Conference on Creativity and Cognition. Retrieved from http://dl.acm.org/citation.cfm?doid=2069618.2069702

National Science Foundation (June 17, 2014). Learning Through Making. Retrieved from http://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=131761

New York Hall of Science (2013a). A Blueprint: Maker Programs For Youth. Retrieved from http://nysci.org/wp-content/uploads/nysci_maker_blueprint.pdf

New York Hall of Science (2013b). Making Meaning Report. New York: New York Hall of Science. Retrieved from http://informalscience.org/images/research/2013-05-24_Making%20Meaning%20Report.pdf

Norris, A. (2014). Make-her-spaces as hybrid places: Designing and resisting self constructions in urban classrooms. Equity & Excellence in Education, 47(1), 63-77.

Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun but are they learning? In Honey, M., & Kanter, D. E. (Ed.), Design, Make, Play: Growing the Next Generation of STEM Innovators (pp. 50–70). Hoboken: Taylor and Francis.

Resnick, M., Berg, R., & Eisenberg, M. (2000). Beyond black boxes: Bringing transparency and aesthetics back to scientific investigation. Journal of the Learning Sciences, 9(1). Retrieved from http://web.media.mit.edu/~mres/papers/bbb.pdf

Resnik, M. & Rosenbaum, E. (2013). Designing for tinkerability. In M. Honey & D. E. Kanter (Eds.), Design, Make, Play: Growing the Next Generation of STEM Innovators. Hoboken: Taylor and Francis.

Roque, R. (2012). Making together: Creative collaboration for everyone. (Master's Thesis, Massachusetts Institute of Technology). Retrieved from https://llk.media.mit.edu/papers/ricarose-thesis.pdf

Sheridan, K., Halverson, E., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014).

Learning in the making: A comparative case study of three makerspaces. Harvard Educational Review, 84(4), 505-31.

St. John, M. (2008). Playful Invention and Exploration Final Evaluation Report: Executive Summary. Retrieved from http://www.inverness-research.org/reports/2008-12-PIEexec-sum-fullrpt/2008-12-Rpt-PIE-ExecSumFINAL-120208.pdf

Sylvan, E. (2004). Integrating aesthetic, engineering, and scientific understanding in a hands-on design activity. Retrieved from https://llk.media.mit.edu/papers/sylvan_IDC2005.pdf

The PIE Network (n.d.). Promoting science inquiry and engineering through playful invention and exploration with new digital technologies. Retrieved from http://web.media.mit.edu/%7Emres/papers/pie/

Tinkering Studio Blog. Retrieved from http://tinkering.exploratorium.edu/about

Vossoughi, S., & Bevan, B. (2014). Making and tinkering: A review of the literature. Retrieved from http://www.sesp.northwestern.edu/docs/publications/1926024546baba2b73c7.pdf

Vossoughi, S., Escudé, M., Kong, F., & Hooper, P. (2013). Tinkering, learning & equity in the after-school setting. Paper presented at FabLearn, Stanford, CA.

White House (June 17, 2014). Presidential Proclamation – National Day of Making. Retrieved from http://www.whitehouse.gov/the-press-office/2014/06/17/presidential-proclamation-national-day-making-2014

Worsley, M., & Blikstein, P. (2013). Designing For diversely motivated learners. Retrieved from https://tltl.stanford.edu/sites/default/files/files/documents/publications/2013.IDC-WB.Designing.pdf

Appendices

Appendix A: Indicators Evidenced in PEM Maker Lounge Visitors

Indicators Evidenced in PEM Maker Lounge Visitors

Learning Dimension		Engagement		Initiative, Intentionality			
Indicator		Spending time in Tinkering activities	Displaying motivation, investment through affect or behavior	Setting one's own goals	Seeking or responding to feedback	Persisting to achieve goals in the problem space	Taking intellectual risks, showing intellectual courage
Visitor	1	🟩	🟩	🟧	🟧	🟧	
	2	🟩	🟩			🟧	
	3	🟩	🟩	🟧			
	4	🟩	🟩			🟧	🟧
	5	🟩				🟧	
	6	🟩	🟩			🟧	🟧
	7	🟩	🟩	🟧		🟧	🟧
	8	🟩		🟧			
	9	🟩	🟩	🟧	🟧	🟧	🟧
	10	🟩	🟩	🟧			
	11	🟩	🟩			🟧	
	12	🟩		🟧			
	13	🟩	🟩				
	14	🟩	🟩	🟧		🟧	🟧
	15	🟩	🟩			🟧	
	16	🟩		🟧		🟧	🟧
	17	🟩	🟩			🟧	
	18	🟩		🟧			
	19	🟩		🟧	🟧	🟧	
	20	🟩				🟧	🟧
	21	🟩	🟩	🟧	🟧	🟧	
	22	🟩		🟧		🟧	
	23	🟩				🟧	
	24	🟩	🟩			🟧	
	25	🟩	🟩	🟧		🟧	
Indicators/ Visitors		25/25	16/25	14/25	4/25	18/25	7/25
% Indicators/ Visitors		100%	64%	56%	16%	72%	28%

Appendix A (continued)

Indicators Evidenced in PEM Maker Lounge Visitors						
Social scaffolding			Development of Understanding			
Requesting or offering help in solving problems	Inspiring new ideas or approaches	Physically connecting to others' works	Expressing realization through affect or utterances	Offering explanation for a tool, strategy, outcome	Applying knowledge	Striving to understand
🟦	🟦				🟥	
🟦						
🟦	🟦					
						🟥
🟦	🟦	🟦	🟥			
🟦						
				🟥	🟥	
🟦						
	🟦		🟥			
	🟦					
	🟦					
🟦						🟥
🟦	🟦					
🟦						
	🟦		🟥			
🟦	🟦					
	🟦		🟥			
				🟥		
🟦						
11/25	10/25	1/25	4/25	2/25	2/25	2/25
44%	40%	4%	16%	8%	8%	8%