Making in the Museum: Launching a Learning Trajectory in an Informal Setting[1]

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How do makers become makers? As an emerging phenomenon of education reform, making is becoming an established feature of many environments and experiences designed for informal learning. Cultural institutions, such as museums, science centers and libraries, are expressing growing interest and investing in the integration of making into exhibits and programs. The growing presence of maker spaces in designed informal learning environments presents the opportunity for making to widely, and potentially more deeply, reach a diverse audience of children, families and youth. Yet, this wave of making is, in many respects, changing the ways in which these institutions function and are used by visitors. Elements such as the use of real tools, loose part materials, and facilitators are in contrast to the tried and true methods of design (e.g. Borun & Dristas, 1997) that have traditionally been used to support learning in such spaces.

In the conversation around making as an educational movement, much attention has been paid to the ways in which making may shape workforce pathways for youth. However, many of the visitors to these designed informal learning environments are families with young children, who use these institutions as resources for shared leisure and learning (e.g. Ellenbogen et al, 2004). In this chapter, we explore making as a learning process in the context of a museum-based maker space designed for family participation. In particular, we focus on young children, and

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their adult learning partners, as an important demographic to consider and for which to design making environments and experiences. Through the presentation of a single case of family making in the museum, we consider the factors that support and engender young children's participation in making as a learning process, and examine the ways by which a young child may establish a meaningful trajectory of participation through making in this context (Greeno & Gresalfi, 2008).

Family Learning in Museums

Composed of diverse ages and genders, families bring to their museum experience practiced methods of cooperation and communication, systems of shared beliefs and values, and recognized motivations and agendas for participation. Through museum visits, families relate and reinforce past experiences and family history, and develop shared understanding (Falk, Moussouri, & Coulson, 1998; Hilke, 1987, 1989; Ellenbogen, Luke & Dierking, 2004; Ellenbogen, 2002). Family learning in museums is primarily initiated, directed and maintained through the interests of family members (Ellenbogen, et al, 2004; Hilke, 1987; NRC, 2009). This agenda, or the cognitive, affective, and social expectations or goals the individual or group members intend to pursue or satisfy through their visit, motivate families to purposefully chart individual and collective pathways of experience through and across museum visits. Studies have shown that the goals of individuals and groups may be multiple (e.g., pursuing learning, leisure, and socialization through a single experience), as well as conflicting (child engagement vs. time constraints), and that family learning in these designed contexts is a negotiation of parent and child interest, knowledge, and choice (Crowley & Jacobs, 2002; Palmquist & Crowley, 2007; NRC, 2009).

Empirical research has demonstrated the varied ways in which parents and adult family members tacitly and explicitly guide, structure and influence children's participation in culturally valued activities in normal environments of family interaction such as the home (e.g. Ochs, 1989; Rogoff, 1999; Plowman, McPake, & Stephen, 2008), as well as in designed environments for family learning such as museum exhibits (e.g. Heath, 1983; Crowley & Callanan, 1998; Crowley, Callanan, Tenenbaum & Allen, 2001; Crowley et al, 2001). Parents indirectly influence children's learning by providing particular tools, toys, or media and by organizing family and peer-oriented experiences that provide new opportunities for conversation (Barron Martin, Takeuchi & Fithian, 2009; Takeuchi & Stevens, 2011). This work establishes that the family is a distributed learning system, who often use designed tools and environments as contexts for sharing, rehearsing, negotiating and developing family members' relative areas of interest and expertise with regard to content and participation (Crowley & Jacobs, 2002; Palmquist & Crowley, 2007; NRC, 2009).

Setting

Makeshop at Children's Museum of Pittsburgh is a collaborative project of the Children's Museum, Carnegie Mellon University's Entertainment Technology Center (ETC), and the University of Pittsburgh Center for Learning in Out of School Environments (UPCLOSE). As leading informal learning, design and research organizations, each partner brings a unique perspective and area of expertise to the project. Through extensive prototyping and iterative development (Brahms & Werner, 2013) and ongoing partnership, these organizations have worked to create a space—in concept and practice—that conveys the spirit of making in ways uniquely accessible to the Museum's core audience of children and families.

Makeshop is a maker space designed with the intention of accommodating and supporting the family as a social learning unit. It is designed to be a comfortable, flexible, and responsive space that encourages visitors to instinctively use the to engage in interest-driven making endeavors with physical and digital materials, tools and processes. This is done through the design of the space and material properties, through facilitation, and through the iterative design of supports for learning and engagement.

The space is divided into three general areas, each of which allows a visitor to potentially broaden or deepen their level of engagement and methods of social interaction. The entrance to the space introduces visitors to the concepts of tool, material and process use through the placement of interactive exhibit components that enable visitors to explore these concepts together. For example, visitors are introduced to materials and methods of attachment through an exhibit component of loose-part repurposed material panels made of wood, metal, plastic and industrial wool felt with metal bolts and nuts that visitors may use to creatively build structures of any shape or size. A variety of print and digital resources are always on hand to provide inspiration, deeper explanation about a making process, or simply a shared family reading experience. This introductory space is often used to prototype new ideas on the floor with visitors.

Beyond the entrance area, lie the shop spaces (See Figure 1). In the Open Shop space, visitors can further explore, engage and apply the use of basic tools, materials and processes. The Open Shop features visible and open access to a variety of materials, purposefully chosen tools and designed exhibit components that enable visitors to explore the processes of making, such as learning how to use a standing loom or how to connect a circuit. These explorations can be

momentary or extended, they may lead to further investigation or prompt the desire to make a product that integrates the explored processes.

In the Workshop, a defined space with large windowed sliding doors that allow staff to create a more intimate learning environment, visitors are able to bring their product ideas to life through hands-on building at the intersection of the physical and the digital. Families are encouraged to work together to sketch their ideas, select their materials, and engage in the full design process with the assistance of a knowledgeable educator. Visitors use woodworking processes, sewing machines, circuits and solder, 3D printers and a laser cutter, as well as a variety of digital media production tools to create products they can take with them when they leave the Museum.

The presence of educators skilled in the domains of making, as well as in the facilitation of informal learning, is an intentional and central factor of the space's design and function. Each of the five core staff members have expertise in a different domain of making, such as textiles, electronics, construction, digital media production, and computer programming. This expertise is made accessible to visitors as a resource, as well as shared among the staff. Importantly, this team of facilitators each identify as being members of the community of makers. Within this museum-based maker space, and over time, the team of educators has designed various instruments that are intended to help more novice participants feel comfortable beginning to engage and practice making processes, and with which visitors may support their progress through the development of more advanced skill.

Trajectories of Participation

Conceptualized as a trajectory, learning can be understood as the process by which individuals' and groups' patterns of participation shift and develop in relation to multitude influential factors within a given learning context. Here, context is understood as a "system of social practice that includes patterns of interaction, understandings, assumptions, attitudes, and norms that serve to organize activity" (Cobb, Gresalfi, & Hodge, 2009; Engestrom, 1999, Greslafi, 2009, p. 330). Through shared activity and over time, learners participate with greater intent and sophistication in social practices that have structure and history, yet are dynamic and responsive to relative factors which together influence participation (Lave & Wenger, 1991; Wenger, 1998; Greeno & Gresalfi, 2008). Research studies that have pursued this line of thinking in both formal and informal learning environments, have considered the diverse factors that are thought to influence learning through participation in socially-valued community practices (e.g. Nasir & Cooks, 2004). In regard to family learning with and through designed tools and environments, such as museum exhibits, dominant among these factors have been the social and material resources (Hein, 1998; Borun & Dristas, 1997) that are recruited and coordinated through family participation in a given context over time and in relation to other ecological factors. These factors, in turn, support learning in and through these designed environments and experiences. With this theoretical framing in mind, we examine two related questions through our case of *making* as a family learning process in the museum:

1. What factors support and engender young children's productive participation in making as a learning process?
2. In what ways do young children, in the context of a family learning visit, establish meaningful trajectories of participation in making as a learning process?

A Case of Making in the Museum

Here, we present a case of family participation in Makeshop. This case is an illustrative example of the recognized patterns of family participation taking shape in the space that are influencing the Museum's ongoing design efforts to support meaningful family learning through making with physical and digital media. In relating this case, it is recognized that it is but one instance of making, a creative and multi-faceted process that takes many forms. Data collection began through opportunistic observation of Makeshop activities, and became more systematic as subjects were identified and expressed willingness to participate. Ongoing observation and photographic documentation of participant activities was complimented by semi-structured interviews with the child, his parents, grandparents, and Makeshop facilitators.

Jack is four years old. His family has belonged to the Museum as members since Jack was a toddler. His mom remembers that it was around this time that Jack began showing clear signs of an interest in shop tools. "His second birthday cake had tools on it," she recalls,

> "So his love of tools must have begun before he was two years old. He loved tools the way some kids love dinosaurs, you know? By three he was in the garage with my dad [Jack's grandfather] while he worked on things. That was when Jack started taking apart all of his toys. He never wanted to put them back together, or create things. He just liked to take them apart to see what was inside. These days he spends time with his grandfather when I am dealing with the baby [Jack's newborn brother]. They look at videos of tools on YouTube, and fix things around the house.

Jack, his mom, and his newborn brother visit the Museum at least twice a month. Since Makeshop opened to the public, Jack has become a regular maker in the space. Jack brought, and has fostered this developing island of expertise around shop tools through his visits to Makeshop.

The first time Jack visited Makeshop was a weekday in November. "He was surprised, excited, and I think a little overwhelmed" his mom remembers of their first encounter, "it was very different than [other exhibits at the Museum]."Makeshop, with its purring sewing machines, digital programming devices, and array of tools within arm's reach was a distinct contrast from the other interactive exhibits Jack and his family was accustomed to finding upon entering the Museum.

On this particular day, the workshop space had been configured for open woodworking. Adam, one of the educators in Makeshop, greeted Jack by introducing himself, explaining the general concept of Makeshop as a place to have ideas and make things. He invited Jack to begin with the question, "What would you like to make today?" Jack looked up at his mom, initially quite overwhelmed by such an expansive question in this new context of activity. Adam recognized Jack's excited unfamiliarity, and took a different approach to eliciting project ideas by asking Jack questions about himself and his family: "What kinds of things do you enjoy doing? Who do you enjoy spending time with? Do you like to do things inside or outside?" In response to this latter question, Jack looked up at Adam and said, "My grandpa has a lawnmower." With that, Adam asked Jack to tell him more about his grandpa's lawnmower, and Jack began enthusiastically explaining the composition and workings of the device. Soon, Jack and Adam had decided to construct a similar lawnmower out of wood.

Adam asked Jack to sketch the lawnmower he wanted to build on an index card in order to grasp a full understanding of Jack's vision and intention for his project. Jack willingly sat down and sketched a manually powered push lawn mower. Jack and Adam worked together for nearly two and a half hours constructing a life-size lawnmower fit for a four-year-old made entirely out of wood, complete with s spinning "blade" and wheels. In that time, Adam had gently guided Jack through his making process: selecting appropriate pieces of wood and dowels, reviewing the use of basic hand tools such as the hammer, hand-drill and miter saw, as well as the techniques and processes of woodworking as they applied to the design and development of the project at hand, such as appropriate fit between dowels and holes for joinery and movement of parts. Jack's mom was present throughout the process, standing aside to ease Jack's occasional frustration, or relate an unfamiliar tool or process to a familiar family activity.

Through this shared making process, Jack had not only been exposed to, but had practiced and applied mechanical principles and processes, acquired additive skills and techniques, made mistakes and discoveries, experienced visible feelings of excitement, frustration, motivation, accomplishment and empowerment, and produced a unique and personalized product: his very own lawnmower.

Jack's initial experience in Makeshop was an interdependent activity of making in the museum that was dependent on the fluid and complimentary roles each participant took on during the activity. Jack's project idea was inspired by associated memories of his grandfather; and perhaps triggered by the blending of Jack's discernment of environmental affordances—the array of accessible shop tools—and his discovery, encouraged by Adam, that Makeshop was a space for Jack to participate in ways authentic to his own values, interests and ideas. As a facilitator in the space, Adam brings a history of participation in the domain of woodworking to

each visitor experience he engages. This includes a wealth of domain-specific knowledge, skill, technique and flexibility with the materials, tools and process of woodworking. Throughout the making of Jack's lawnmower, Adam was able to use these resources to facilitate the translation of Jack's memories into a designed physical object through a process of listening, questioning, connecting, explaining, and guiding. In so doing, he enabled Jack to further extend and deepen his interest in shop tools through the purposeful use of certain tools to construct a complex mechanical product. Jack's mom played the pivotal role of supporting Jack's negotiation of meaning and emotion, through the use of analogies, relative explanations, and the practice of familiar routines for managing emotion. Through the coordination and adaptation of social and material resources, a rather remarkable productive learning context was co-constructed.

Two weeks later, Jack, his mom and brother returned to Makeshop. Jack immediately approached Adam. Without hesitation, Jack initiated his own making experience, as he told Adam, "today, I want to make a *wet-dry vac*." Again, they worked for hours to construct Jack's envision product out of wood, this time adding metal nails and screws for attachment and rotation of parts. Jack and Adam made sure to incorporate a small piece of wood that would pivot on a nail at its fulcrum as an imaginary on-off switch. This visit was followed by Jack's return, a couple weeks later with a detailed sketch of a Jackhammer he had drawn at home in anticipation of his visit to Makeshop. Within weeks, Jack had made the Jackhammer, a portable leaf blower, complete with an imaginary "kill switch," and a snow blower for Pittsburgh's impending winter all out of wood and small hardware.

When Jack next visited Makeshop, the Workshop space was temporarily closed to the general public, for use by a visiting school group. Upon realization that he would not be able to use the space he had come to associate with his making process, Jack broke down into tears,

visibly devastated at the prospect of not being able to make the weed-whacker for which he had planned. Rachel, another Makeshop educator, explained to the frustrated four year-old, that there was no reason he couldn't make the weed-whacker out of something other than wood. Rachel recalls that her suggestion not only eased his disappointment, but also opened up new possibilities, as Jack's eyes widened with the question, "really?"

Cognizant of Jack's now practiced ability to articulate his project ideas, Rachel asked Jack to describe the component parts of his envisioned weed-whacker. Jack had no problem verbalizing the need for a handle, shaft, blade, protective shield and, of course, an on-off switch. Rachel asked Jack if he would like to use a small *motor* to make the blade that would whack the weeds, actually spin. Jack had never before incorporated electricity into his projects and his facial expression conveyed hesitation and uncertainty. Reading her child's mannerisms, Jack's mom began generating examples of other familiar devices and toys that used motors, to help Jack more fully understand what was made possible with the addition of a working motor to his project. Rachel pulled out a jar of small motors, handed one to Jack, and began *testing* others to find a functioning motor for the project.

Rachel then invited Jack over to a table in the Open Shop area of Makeshop filled with electronic circuit blocks (figure 2). A staple of Makeshop activity, these components consist of LED lights, small motors, buzzers, and repurposed electronic toy parts, such as propellers and wheels that are fastened to wooden blocks with their wire leads exposed and attached to conductive nails. Children and families connect components to a battery source with alligator test leads. The available variety of components and loose test leads enable visitors to explore through observation, test through trial and error, and further widen the possibilities for learning created from the simple act of closing a circuit. Together, Jack and his mom began testing out different

combinations of components and leads, until Jack was testing and closing circuits independently. Rachel made sure to explain the circular movement of energy between battery source, leads and components, as well as to introduce the concept of a *switch* to Jack during his family's exploration through the integration of formal light switch into the electronic loop. Soon Rachel, Jack, and Mom had extended the concept with components made of other conductive switch materials such as paper clips, brass tacks, and magnets.

With functional knowledge of how to connect a circuit, make a motor run, and a switch, Jack, Mom and Rachel traveled back to the project table, and began selecting materials from a bin of recycled materials such as cereal boxes, paper rolls, and plastic containers, to use for the component parts of the weed-whacker. Together they brainstormed and prototyped different configurations of parts that would allow the blade of the weed-whacker (made of a piece of twine) to spin freely. The intermediate step of testing components and prototyping configurations was difficult for Jack, who asked his mom twice, "can we just attach it, now?" circling the project space in restless anticipation, before Rachel assisted him in securing each piece in place with electrical tape and a touch of solder (figure 3).

The periodic testing, or prototyping that happened throughout the process of the weed-whacker's design and development, as well as in subsequent projects such as the construction of a sewn tool belt, was quite difficult for Jack, as he expressed impatience with the intermediate steps in the process. Yet, his mother later noted that Jack has integrated this practice into his activities beyond Makeshop. When asked if she has seen any changes in Jack's approach to projects or activities at home as a result of his participation in Makeshop, his mom recalls Jack's willingness to "test things out, and use trial and error," as a recent shift in his behavior. "He's always been a perfectionist," she continues,

> "And since he's had to test things out in Makeshop, like the motor, and pinning his tool belt before sewing it with the machine, he's been doing the same with projects at home, like his Legos, and planning, too. He will plan out his Lego structures, and of course he plans the projects he will do in Makeshop! I initiate some of this, before we visit the Museum, but he will go into detail describing the thing he will build in Makeshop, even explaining options, like, 'if they have wood today, or if they have electronics today...' So, we've really noticed these changes, how he doesn't get quite as frustrated if things don't work out the way he initially thought."

This change in Jack's approach to activities akin to making, both in Makeshop and at home points towards the ways in which the Museum is becoming an important and unique setting, itself a resource for family learning.

Conclusions

Our analysis of this and other cases of family participation in Makeshop (Brahms & Crowley, under review), suggest that young children are able to form meaningful trajectories of participation in making by recruiting and coordinating social and material resources. In doing so, children are able to develop and apply skills and knowledge, through which they engage with increasing intent and sophisticated practice. This can happen over the course of moments or months. These analyses reveal that there are a number of key factors that support, influence, and

engender children's paths of participation. These include the accessibility and positionality of adult assistance and expertise, and the design choices of the learning environment.

Jack, like other young children we have observed, relied on and actively recruited adults' expertise, technical assistance, and intimate familiarity in order to initiate, sustain and grow his participation. Jack's mom brought deep understanding about her child's passions and past experiences, his abilities, emotional sensitivities and thresholds, while Adam brought relevant knowledge and skill, strategies for facilitating Jack's development of such knowledge and skill, as well as the dispositional qualities of the making community. Even Jack's grandfather has played an essential role in Jack's museum-based making experience. When asked the inspiration for his project ideas, Jack references his grandfather and the garage full of tools in which they spend time together. On one occasion, Jack even qualified this connection by explaining, "I'm making my own tools so that we [he and his grandpa] can work together." These adults have worked together to become Jack's learning partners, readily available and accessible, yet flexible in their role relative to his learning intentions.

Prior research on family learning in museums has tended to treat the museum environment and the material resources therein, such as exhibit components and signage, as interventions or as a unique setting for learning (e.g. Humphrey & Gutwill, 2005; Borun & Dristas, 1997). Here, we see material aspects of the museum becoming an embedded and adaptive part of the family learning process as family members identify, seek out and purposefully use features of the exhibit, such as tools, certain defined spaces, and even educators, as accessible, familiar and expected elements of a self-determined path of participation.

Jack has established a trajectory of participation in making. Through his participation in Makeshop, Jack has developed skilled facility with tools, acquired knowledge of technical processes, expanded his use and application of materials, and has evolved his relationship with his family members, both in and beyond the walls of the Museum. Through the recruitment of supportive social and material resources Jack has not only participated in practices that are valued by the making community, such as playfully investigating, repurposing, combining materials in new ways, but has begun to participate in such practices in personally relevant ways; connecting, building upon and deepening his and his family members' intentions for making and for learning, as well as their relationship to the museum as a place for such meaningful learning.

Makeshop, and its position within a children's museum, is a uniquely enabling environment for making as a learning process for young children. It affords visiting families essential resources for meaningful making, including skilled and trained staff, accessible materials and tools, and a comfortable space for extended and repeated activity. Perhaps more important, however, is the role the Children's Museum, as an informal learning institution, has come to play in the learning lives of this family and others like it. As a site for making, the Children's Museum has become a reliable, multifaceted, and supportive learning context for families with young children: a space, distinguished from everyday activities and routines, where parents and children can practice and participate together, where the process of learning is valued over the outcome, and where personally relevant and communally recognized learning moments and pathways may be formed and shared.

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Figures

Figure 1. Wide view of Makeshop at Children's Museum of Pittsburgh, the Open Shop space can be seen in front and the Workshop space can be seen in the distance

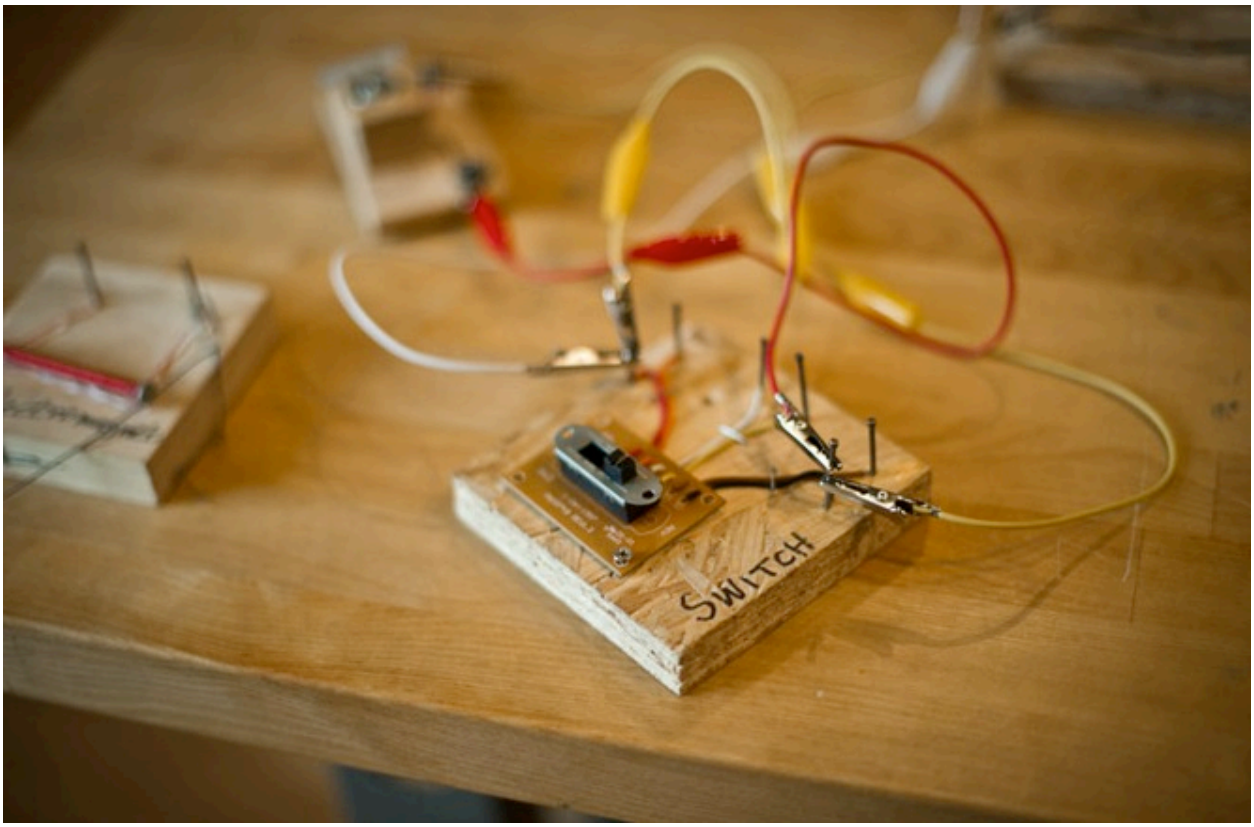

Figure 2. Switch Circuit Block

Figure 3. Jack and Rachel assembling the weed-whacker.