Learning to Make in the Museum: The Role of Maker Educators [1]

Lisa Brahms & Kevin Crowley

1. Introduction

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 the presence of skilled 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. Many of the visitors in maker spaces are families with young children, who use these institutions as resources for shared leisure and learning (e.g., Ellenbogen et al, 2004; see also Chapter 4, this volume).

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

2. Background: Designing to Support Learning in Museums

The field of informal learning research and evaluation has considered the diverse factors that are thought to influence and support family learning in designed contexts, such as museums. Dominant among these factors have been the personal, social and physical resources (Hein, 1998; Borun & Dristas, 1997; Falk & Dierking, 2000;) that learners recruit and coordinate through their 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. As makerspaces are designed with the intention to support family learning in museums, we must examine these factors—those designed and those intrinsic to the family as a learning unit—in light of the distinct qualities of making as a learning process.

Personal: Research has shown the ways in which learning in the museum is mediated by learners' prior knowledge, interests and beliefs, their motivations, expectations and agenda for their museum experience (e.g. Falk & Dierking, 2000). Through museum visits,

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individuals and groups, such as 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). 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, in the case of families, learning in these designed contexts is a negotiation of parent and child interest, knowledge, and choice (Crowley & Jacobs, 2002; Palmquist & Crowley, 2007; NRC, 2009). With the aid of good design, it has been shown that families may function as a distributed learning system, using the designed environment as a context for sharing, rehearsing, negotiation and developing family members' relative areas of interest and expertise with regard to content and participation (Crowley & Jacobs, 2002; Palmquist & Crowley, 2007; NRC, 2009). For example, many studies of families' behaviors and conversations among adult learning partners and children in museum settings illustrate that adults regularly draw associations between prior shared experiences and shared museum experiences to aid in young children's development of understanding, and to construct shared meaning (Borun & Dristas, 1997; Callanan & Jipson, 2001; Leinhardt & Knutson, 2002).

Social: Museums are socially mediated contexts for learning. This involves within-group social interactions (e.g. within the family), as well as facilitated mediation by others, such as museum educators. In the context of a family visit, children's learning in museums is highly dependent on parent involvement, both tacit and explicit. Research has shown that parents' perceptions and awareness of opportunities to learn in museums, as well as parent-participation during family museum experiences, significantly influences the potential for child and family learning (Crowley, et al., 2001, Gleason & Schauble, 1999). Studies have shown that many parents view museums as contexts for their child's learning (e.g. Crowley & Callanan, 1998; Crowley et al, 2000), and even as contexts for collaborative learning with their children (e.g. Ellenbogen, 2002, Schauble, et al 2002). Yet research reveals barriers to parents supporting their children's learning in museums. These include, but are not limited to parent qualification of what it means *to learn* in a museum, levels of parent knowledge and confidence regarding content, and parent perception of role in their child's or family's learning experience (Schauble, et al., 2002; Swartz & Crowley, 2004; Humphreys & Gutwill, 2005).

Although we know a lot about the ways in which parents and children function as a learning unit within museum settings, there is a notable absence of, and recognized need for research on the role of museum educators in supporting children's learning within the museum, as well as designs to support both parents and educators as effective and supportive learning partners for children in museums (Schauble, et al 2002, Bevan & Dillon, 2010). With the growing presence of maker spaces in museums, there are a small number of studies (e.g. Brahms & Crowley, in review), and frameworks (Bevan et al, 2014; Wardrip & Brahms, in review) that recognize the significant role of educators in supporting museum-based making as a learning process.,

Material: Prior research on 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 discrete setting for learning (e.g. Humphrey & Gutwill, 2005; Borun & Dristas, 1997), and has established principles for effectively designing conventional exhibits for learning. Borun and Dristas (1997) engaged in a multi-site design-based research study of family learning in science centers from which a now canonized list of design principles for conventional museum experiences that support collaborative learning and social interaction among family members. These include, but are not limited to, designing exhibit elements that are accessible to and comfortable for all family members to use; are multi-sided to allow family members to cluster around the exhibit component; allow for the simultaneous engagement of users; and provide relevant "cognitive links" to visitor's existing knowledge and prior experiences (p. 180). Using these principles as a guide, Borun and Dristas determined successfully designed museum experiences to have "attracting power," families' attraction to exhibits; "holding power," the length of time family members stay at exhibit components; and "communication power," families' understanding of the exhibit's intended messages (Shettle et al, 1968).

Although the principles and outcomes have and continue to guide quality conventional exhibit design for families, they are insufficient for the full understanding and support of family learning in this new arena of museum-based participation through making. Today's maker spaces are unlike most family-centered exhibits of which the field has grown accustomed. Maker spaces incorporate emerging technologies, champion uncertain engagement outcomes, and, perhaps most importantly, rely on the presence and participation of educators skilled in both the domains of making and in informal learning to facilitate rich making experiences for children and families. . In contexts of shared family learning with emerging technologies, it has been shown that expertise and learner positioning is not only becoming more flexible, but also more complex and distributed within and across contextual features such as people, setting and tool than in times past (e.g. Barron et al, 2009; Takeuchi & Stevens, 2011). This has direct implications for our understanding of maker spaces as setting for family learning. As the field of informal learning embraces making as an essential aspect of the museum experience, designers, educators, and evaluators must re-consider the factors that support meaningful participation in making as a learning process for children and families in museums, and the ways in which the designed environment must change to support such learning.

Two questions, then, guide our case of *making* as a learning process in the museum: (1) what factors support and engender young children's productive participation in making as a learning process? And (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?

3. The Makeshop 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,

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 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 Makeshop 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 projects they can take with them when they leave the Museum.

One final intentional and central factor of the space's design and function is the presence of educational staff members skilled in the domains of making and informal learning. 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, and function as a learning community, sharing and nurturing each

others' making interests and expertise. 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 skills.

4. Becoming a Maker

The following case of a child's participation in Makeshop over time illustrates the ways in which a young child, his family, and Makeshop educators collaboratively coordinate personal, social and material resources to establish a productive learning context and trajectory through making. In addition, it identifies key factors for supporting this kind of learning within and across the contexts of a child's learning life.

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 a multitude of 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" (Engestrom, 1999, Greslafi, 2009, p. 330). Through shared activity and over time, learners participate with intent and greater sophistication in social practices that have structure and history, yet are dynamic and responsive to relative factors, which together influence participation (Greeno & Gresalfi, 2008).

This case was one of a small set of cases that comprised a pilot study of family learning in Makeshop. We realize that it is but one instance of making in the museum, 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 educators.

4.1. Meeting MAKESHOP

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 an interest in 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 enact a familiar routine to further the learning process, or relate an unfamiliar tool or process to a familiar family activity, such as asking Jack to look her in the eye to calm his frustration and make the connection between a hand-tool used in Makeshop to a tool found in their garage.

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 and passion for 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 personal, social and material resources, a rather remarkable productive learning context was co-constructed.

4.2. Establishing a Trajectory of Becoming a Maker

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 envisioned project 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.

4.3. Deepening and Transforming Intentions

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?"

Since Jack was a regular maker in the space, Rachel was cognizant of Jack's now practiced ability to articulate his project ideas. She 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 circuit block with a formal light switch attached to it, 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 incorporate 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 recalled 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, in addition to his developed accessibility, fluency, comfort with the personal, social and material resource of the Makeshop, points towards the ways in which the Museum, and the materials, tools and, especially, the facilitators therein, is becoming an important resource for Jack's learning within and beyond the designed environment.

Discussion

Our analysis of this and other cases of learners' participation in Makeshop suggests that young children are able to form meaningful trajectories of participation in making by recruiting and coordinating personal, 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. These analyses reveal that there are a number of key factors that support, influence, and engender children's paths of participation. This case clearly shows that dominant among these factors is the child's access and evolving relationship to adult assistance and expertise, namely that of the museum educators, and parents, who together work to facilitate the child's museum-based making as a learning process.

Jack, like other young children we have observed, relied on and actively recruited adults' expertise: He engaged the technical, creative, and pedagogical expertise of the museum educators. Equally influential, yet in very different ways, Jack leveraged his mother's intimate understanding of himself and his life outside of the museum, his emotional sensitivities and thresholds, his interests, associations, routines and agendas. Over time, Jack, his mother and the Makeshop staff learned how to function as a distributed learning system, using each other's areas of expertise with regard to Jack and his ways of making meaning to create a rich context for learning. This negotiation of personal, social and material resources enabled Jack to initiate, sustain and meaningfully grow his own interest, intention and ability over time and across the related making contexts of his life.

As a four-year old, Jack's intentions for his making began from a place of personal connection, memory and imagination. 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 association by explaining, "I'm making my own tools so that we [he and his grandfather] can work together." Through his repeated visits to this museum-based maker space, Jack developed much more than a set of tools; he developed *relationships* with the materials, tools, and processes of making, with the designed features and defined spaces of the exhibit, and, most importantly, with the community of museum educators therein.

This community of museum educators grew to know Jack; his intentions for making, his areas of material fluency and even the collection of artifacts made through Jack's regular visits to the museum. This understanding, built and shared among the community of educators, enabled the staff to target and reinforce unique opportunities for deepening Jack's applicable knowledge and skill—such as integrating electricity and a "real" switch into his projects—as it enabled Jack to transform his intentions from objects of imagination into very real and usable personal, social and material resources that he could nurture and apply over time and place. Through the development of these relationships, Jack became a maker.

Unlike learning environments such as classrooms and afterschool programs, where teachers and mentors consider and structure their facilitation to take place over months or years, in museums, the practice of facilitation is often considered and structured around the timescale of a moment—transitory interactions with family visitors as they pass through an exhibit. Yet, this case of a child's episodes of making, as well as his engagement over time within a museum-based maker space encourages the field to think differently about the nature of a museum experience, and most notably about the role of museum educators in relation to the other contextual social resources, in facilitating that experience.

Adult-oriented maker spaces are known to function as a community of practice (Sheridan et al, 2014), as adult members purposefully identify, and leverage each other's relative areas of expertise as quintessential elements of individual and community activity. The museum educators in Makeshop, themselves function as a community of practice, tapping each other's skill, cultivating shared understanding about strategies for interest-based facilitation, and importantly, developing relationships with visitors as members of their community of makers. These educators invited Jack and his family to become valued members of this community, blurring the traditional lines of intent and expertise often encountered in museums, where information is presented for visitor consumption, rather than a shared process of production. Here, the mother's understanding about Jack as a learner in and out of the museum became knowledge equally valued as tool or material know-how. Consequently, the technical and pedagogical expertise brought by the educators was essential for furthering Jack's development of skill, knowledge, disposition and intent. Jack's learning trajectory could only have taken place within a community, where an understanding of the personal, social and material resources of the

context is shared, valued and distributed among community members. As maker spaces are incorporated into the fabric of museums, museums must make a fundamental shift in approach that not only allows for, but also fosters elements of community practice.

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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

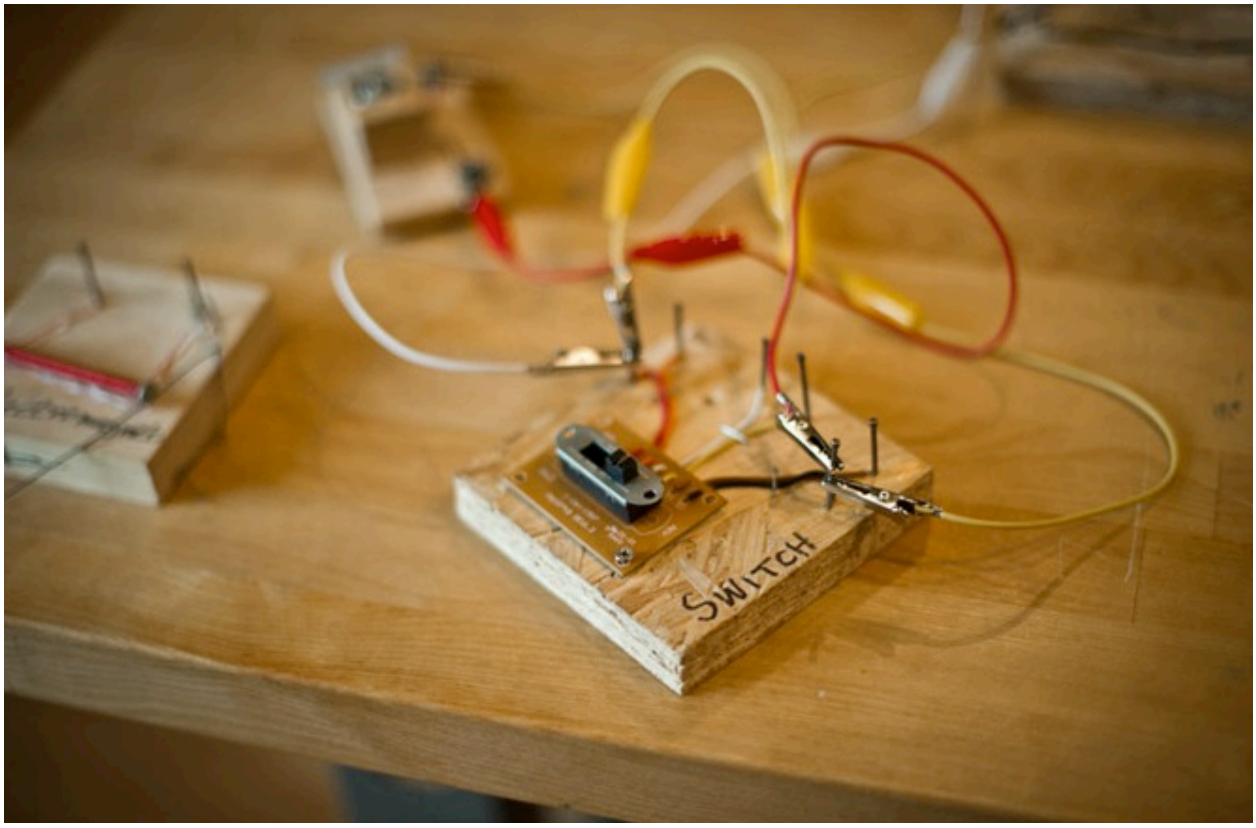

Figure 2. Switch Circuit Block

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