The Maker Movement in Education

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In this essay, Erica Halverson and Kimberly Sheridan provide the context for research on the maker movement as they consider the emerging role of making in education. The authors describe the theoretical roots of the movement and draw connections to related research on formal and informal education. They present points of tension between making and formal education practices as they come into contact with one another, exploring whether the newness attributed to the maker movement is really all that new and reflecting on its potential pedagogical impacts on teaching and learning.

The maker movement has garnered a lot of recent attention in the popular imagination. This year, at the first ever White House Maker Faire, President Obama declared, "I am calling on people across the country to join us in sparking creativity and encouraging invention in their communities" (White House, 2014).

Tens of thousands of kids, adults, and families are drawn to the exciting new technologies, expert marketing, and strong word of mouth that characterize this movement. Maker culture has become a way to express creative and communal drive, and this excitement has led to an explosion of makerspaces around the United States (and the world) across a range of instructional environments, including libraries, museums, independent nonprofit and for-profit organizations, K–12 schools, and institutions of higher education.[1] Some spaces focus on the emergence of new technologies for designing, building, and manufacturing, while others value the return to face-to-face, garage-style work that the maker movement engenders. Across these perspectives, there is growing enthusiasm for the potential for new technologies and old forms of communication to transform the educational landscape.

In this essay we describe activities and features of the maker movement and, more significantly, the emerging role the maker movement is playing

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(and could play) in education. We begin by introducing the maker movement broadly and describing its theoretical roots and connections to prior research in formal and informal education. We then describe three components of the maker movement—*making* as a set of activities, *makerspaces* as communities of practice, and *makers* as identities—each of which inspires different theoretical and empirical approaches, research questions, and areas of study reflected in the two empirical pieces on the maker movement presented in this issue: Sheridan and colleagues' (2014) empirical account of a range of *makerspaces* as communities of practice that afford engagement with both activities and identities and Kafai, Fields, and Searle's (2014) study of how people learn through *making* as a set of activities, with a focus on how the *maker* identity intersects with issues of gender.

Defining the Maker Movement

Before we discuss theoretical roots and approaches to research associated with making and education, it is important to begin with a common frame of reference for understanding the maker movement. While people have been "making things" forever (scholars and practitioners who speak about making often reference ancient practices such as cave paintings to describe our human need to make), the maker movement as it is currently constructed has gained particular traction over the past five years. The *maker movement* refers broadly to the growing number of people who are engaged in the creative production of artifacts in their daily lives and who find physical and digital forums to share their processes and products with others. Popular press books reflect this diversity of practices in their varied definitions of the making phenomenon. For instance, Chris Anderson (2012), former editor-in-chief of *Wired* magazine, defines the movement as "a new industrial revolution." He distinguishes between the maker movement and tinkerers, inventors, and entrepreneurs of prior eras by referencing three key characteristics: the use of digital desktop tools, a cultural norm of sharing designs and collaborating online, and the use of common design standards to facilitate sharing and fast iteration. Mark Hatch (2014), CEO and cofounder of TechShop, one of the first and most successful makerspaces, proposes a "Maker Movement Manifesto" that describes makers' activities and mind-sets organized around nine key ideas: make, share, give, learn, tool up (i.e., secure access to necessary tools), play, participate, support, and change. Like Anderson, Hatch highlights the importance of the construction of physical objects as a feature of the maker movement that makes it distinct from the earlier computational and Internet revolutions.

Dale Dougherty, recently named a White House "Champion of Change," is often credited with popularizing the maker movement through his company Maker Media. Maker Media publishes *MAKE* magazine and hosts three annual world Maker Faires and more than fifty annual, local "mini–Maker Faires." These independently produced daylong events combine the features

of science, renaissance, and craft fairs, including live demonstrations, showcase booths, product sales, and opportunities for attendees to create their own projects. The Maker Education Initiative also offers a free "Makerspace Playbook" to help people interested in building their own makerspaces.[2]

Dougherty (2012) asserts that the term *maker* is universal and core to human identity, "describ[ing] each one of us, no matter how we live our lives or what our goals might be" (p. 11). Thus, he defines the maker movement more in terms of the people who associate with the ethos of making than in terms of how or where making happens. In his view, the movement evolves to encompass the identities and practices of those who align with it.

Dougherty, Hatch, Anderson, and others emphasize the democratizing nature of making through cheap hardware, easy access to digital fabrication, and shared software and designs. They note the growing availability (based on both quantity and price) of powerful computational and fabrication tools for everyday people, coupled with a renewed interest in local goals and resources as a happy confluence: "The real power of this revolution is its democratizing effects. Now, almost anyone can innovate. Now almost anyone can make. Now, with the tools available at a makerspace, anyone can change the world" (Hatch, 2014, p. 10). At the same time, the maker movement has been criticized for maintaining a "white male nerd dominance" (Grenzfurthner & Schneider, n.d.) that has characterized hacker, tinkerer, and robotics cultures. In a 2013 keynote address at Stanford's FabLearn Conference on digital fabrication in education, Leah Buechley (2013) described the MAKE organization as being focused on a narrow range of maker activities (primarily robotics, electronics, and vehicles) and an even narrower range of makers, with 85 percent of its magazine covers featuring white boys and men.

Despite these critiques, a growing range and number of makerspaces are generating a more diverse and complex picture of the maker landscape. While the maker movement may have initially emerged from independent organizations such as TechShop (Hatch, 2014) and Sector67 (Sheridan et al., 2014), it has since spread to museums, libraries, schools, community colleges, home schooling groups, afterschool clubs, and institutions of higher education.

Making and Education

Progressive educators and researchers have been talking for decades about the role of making in learning. Martinez and Stager (2013) credit Seymour Papert as "the father of the maker movement" (p. 17), implying that constructionism is the theory of learning that undergirds the maker movement's focus on problem solving and digital and physical fabrication. Papert's theory of constructionism places embodied, production-based experiences at the core of how people learn (Harel & Papert, 1991). While constructionism has roots in Deweyan constructivism, which frames learning as the product of play, experimentation, and authentic inquiry, the distinguishing feature of con-

structionism is "learning by constructing knowledge through the act of making something shareable" (Martinez & Stager, 2013, p. 21). Specific tools and programs that have been used in both formal and informal learning spaces are instantiations of Papert's constructionism, including the Logo programming language (Papert, 1980), LEGO Mindstorms kits (Resnick, Ocko, & Papert, 1988), the Scratch programming language (Resnick et al., 2009), and the Computer Clubhouse programs (Kafai, Peppler, & Chapman, 2009). Additionally, educational approaches such as project-based science (e.g., Schneider, Krajcik, Marx, & Soloway, 2002) and problem-based learning (e.g., Schwartz, Mennin, & Webb, 2001) emphasize learning through making.

Just as progressive educators have been talking for decades about learning as the creation of meaningful artifacts, artists and arts educators have long histories of supporting learning in the making across a variety of art forms and media. Though studio art classrooms have long embraced a learning-by-doing perspective, there has been little scholarship that meaningfully incorporates the history of artistic practices into the constructionist frame. In a recent review of the role of digital media in arts education, Peppler (2010) asserts that, "despite the theory's explicit ties to the arts and design, constructionism has not heavily influenced the existing work on the arts and arts education" (p. 7). We argue that art making is fundamentally a representational domain and therefore resonates with a constructionist perspective on learning (Halverson & Sheridan, 2014). Research on making in education embraces the constructionist frame of progressive education while stretching further our understanding of how making things that matter can be a successful lever in formal environments, especially when it includes the tools of artistic practice.

Learning in making is, emphatically, not interchangeable with *schooling*. Learning through making reaches across the divide between formal and informal learning, pushing us to think more expansively about where and how learning happens. In this way we can talk about the who, what, and how of learning without getting hung up on the rules and constraints that govern different settings. This blurring of boundaries is evident in events such as Maker Faires, where participants ranging from adult makerspace members to kids participating in robotics clubs come together to share what they have created. In the upcoming sections we will describe how the maker movement is coming to influence the education enterprise, and discuss some tensions that emerge when these learning experiences cross the formal/informal divide.

How the Maker Movement Is Influencing Education

The influence of the maker movement can be seen across a broad range of spaces and places under the education umbrella. One strand of the initial focus on making and learning originated in higher education settings. FabLabs were created by Massachusetts Institute of Technology (MIT) profes-

sor Neil Gershenfeld (2005) as pedagogical environments that would allow everyday people to solve their own problems by producing (rather than purchasing or outsourcing) the tools they need. Today the Fab Foundation provides support for the creation of new FabLabs around the world, training for new labs, the development of local networks, and international support. Paulo Blikstein's FabLab@School project is a corollary to the FabLab network that adapts this model for K–12 settings worldwide. In these spaces, participants work at the intersection of the digital and the physical, using digital tools to generate designs that can then be built with in-house fabrication tools such as 3-D printers. As a result, FabLabs place the learning focus on principles of engineering, robotics, and design.

Concurrently, informal learning environments such as public libraries, museums, and independent nonprofits have expanded the notion of what gets made in makerspaces to include projects that range from making books to wearable electronics. These organizations have galvanized the energy of adult-oriented hacker- and makerspaces into learning experiences with an eye toward young people and families. As Kafai, Fields, and Searle (2014) discuss in more detail, informal learning settings are playing an important role in diversifying the maker movement by making tools, materials, and processes more readily available to people who may not initially self-identify as makers. In many museums, the focus on maker culture is a natural extension of a long-standing emphasis on learning-by-doing in art and science. For example, Makeshop at the Children's Museum of Pittsburgh and the New York Hall of Science (2013) have both leveraged their interest in authentic participation in STEM and art practices into the creation of museum-based makerspaces. For libraries, the shift may be more fundamental. Resnick (2014) describes libraries' incorporation of making as requiring a new understanding of what libraries are for, from seeing "the library as a warehouse of information . . . [to] a community workshop, a hub filled with the tools of the knowledge economy" (n.p.). Examples of how a free, open-access space can be transformed into a place for doing include the Chattanooga Library (Resnick, 2014) and the Maker Lab at Chicago's Harold Washington Library (Knight, 2013).

The trend of remaking learning spaces in higher education and informal learning settings has generated inevitable questions in the formal context: What is the role of making in school? How can I put a makerspace in my school? Most of the current models for how to integrate making into K–12 schools emerge from the theoretical ideas in progressive education outlined above. West-Puckett (2014) describes how educators can design classrooms as makerspaces by focusing on student interest and by understanding learning as integrated and connected through projects rather than as an isolated set of skills. And while school-based makerspaces will likely include the newest technological toys, such as 3-D printers and laser cutters, the focus in design for learning is not on tools but on the process and the product. In order to pro-

mote the spread of making in schools, several practitioner projects offer how-to manuals and support systems for those who want to think about the design of an education-focused makerspace.

These efforts are still nascent and, to be sure, run up against a range of structural challenges, including questions of access, scale, and staffing. But perhaps the greatest challenge to embracing the maker movement in K–12 schools, especially in our current accountability environment, is the need to standardize, to define "what works" for learning through making. This is true at the level of the individual student (e.g., Does making really bolster students' STEM competencies?) as well as at the institutional level (e.g., Who is in charge of the space? What should students do there? Should making supplement current curricula or replace it?) Many educators and researchers have raised the question of whether learning through making is a fad, just another way to reconstruct the same challenges we face in our comprehensive, heterogeneous, public school system. In fact, as the maker movement enters the conversation about best practices for teaching and learning, progressive education researchers, institutions, and even those within the maker movement are raising objections to this trend.

The Maker Movement, Formal Schooling, and Progressive Education

Perhaps the greatest fear on the part of those deeply invested in the maker movement is that attempts to institutionalize making—through schools, afterschool programs, etc.—will quash the emergence, creativity, innovation, and entrepreneurial spirit that are hallmarks of the "maker revolution" (Dougherty, 2012). In our view, the question of whether institutionalization will kill the essence of the maker movement depends on the extent to which it is characterized by its democratizing potential. Although there are those who see the maker movement as fundamentally democratizing (Anderson, 2012; Hatch, 2014), we have also seen how identities of participation have already been constrained by early adopter voices. We believe that the great promise of the maker movement in education is to democratize access to the discourses of power that accompany becoming a producer of artifacts, especially when those artifacts use twenty-first-century technologies. This is in line with Blikstein's (2013) call for FabLabs to serve as Freirian opportunities for empowerment and consciousness raising.

However, democratization may only be accomplished if we move beyond conceptualizing making exclusively as a series of activities that can help improve K–12 students' formal schooling knowledge. If we believe that making activities and maker identities are crucial for empowerment, then it is, in part, our job to set up situations whereby all learners have the opportunity to engage. Libraries in particular hold promise for democratization, given their history as free, embedded community resources open to all. Learning through making, most notably with digital technologies, has the potential to help us

reach institutional and policy goals for STEM learning for a range of students. This vision of democratization mirrors Peppler's (2010) description of the digital media arts as a way to bridge the participation gap in technology use among kids of varying socioeconomic statuses. Understanding the relationship among activities, communities, and identities in the context of our institutional landscape is the current grand challenge, and the maker movement is central to new institutional perspectives on learning.

Making, Makerspaces, and Makers—Pillars for Analysis

To facilitate progress toward merging a powerful wave of authentic and engaging practice with the institutions set up to democratize access to learning processes including public schools, libraries, and federal and state policy units, we propose the consideration of three components of the maker movement when framing research questions, design decisions, and policy making: *making* as a set of activities, *makerspaces* as communities of practice, and *makers* as identities of participation. We describe each of the three components below and highlight what kinds of research questions, designs, and institutional practices are enabled and constrained from each perspective.

Making refers to a set of activities that can be designed with a variety of learning goals in mind. Making can happen in a variety of places that may be labeled "makerspaces" as well as in classrooms, museums, libraries, studios, homes, or garages. This approach is the closest to other constructivist- and constructionist-based design work that focuses on engaging participants in learning content and process. Work from this perspective engages the intersection of computer science, design, art, and engineering. This research has also demonstrated how making activities result in participants learning principles of engineering, circuitry, design, and computer programming (e.g., Jacobs & Buechley, 2013; Kafai, Peppler, & Chapman, 2009; Resnick et al., 2009; Sheridan, Clark, & Williams, 2013). As education researchers, we are good at asking the questions "What is learned here?" and "How does this learning translate to the disciplines and domains that we care about in K–12 education?" And while this line of research has not mapped directly onto the standardized metrics currently in place to measure adequate student progress in public schools, it is possible to envision a world in which the learning outcomes measured in these studies will be valued in institutionalized learning settings. As a result, we see strong connections between the making approach and what we recognize as the values of the institutions of formal schooling, such as all students demonstrating mastery of core competencies. In this way, making activities can affirm school-based approaches to teaching and learning. Kafai, Fields, and Searle (2014) demonstrate that making can also challenge our understanding of what counts as a legitimate learning activity. They describe e-textiles as a "disruptive" making activity that brings both "hard" and "soft" skills to the maker ecology, opening up our understanding of what counts as making.

Makerspaces are the communities of practice constructed in a physical place set aside for a group of people to use as a core part of their practice. While making activities are a part of the community, they do not fully constitute it. Our research suggests that communities of practice emerge around makerspaces as members co-participate in a range of activities, including taking walks, playing board games, caring for resident pets, and attending Maker Faires and community events unrelated to making. Sheridan and colleagues (2014), offer a case study perspective on three unique makerspaces that captures a range of places that we would characterize by this name: a stand-alone membership organization, a community space, and a drop-in space located within a museum. This line of research supports the many organizations and individuals who are interested in creating makerspaces but lack the conceptual tools to understand what can be learned there, how it can be learned, and what is constrained and afforded through participation.

In these spaces, learning happens as a consequence of individuals beginning as legitimate peripheral participants and moving toward becoming full participants. But learning is not guaranteed; nor is it regulated. This is crucial from an institutional perspective that takes the education of all kids as a core part of the mission of schooling. A makerspace approach values individuals moving in and out of a space freely. As a result, the unit of analysis is not necessarily individual learners over time but, rather, what happens in the space and how to design the space to enable distributed expertise and open configurations of learning.

Makers describes the identities of participation (Wenger, 1998) that people take on within the maker movement. The New York Hall of Science (2013) report "Making Meaning (M2)" explores the question "What makes a maker?" using profiles of young makers as a means to explicate what identities of participation look like. While Dougherty (2012) asserts that everyone is a maker, it is not clear that individuals and groups automatically take on identities of participation within the maker landscape. Some participants in making activities may not consider themselves makers and therefore self-select out of public conversations. This is especially important given the critiques raised by Buechley (2013) and others about the white male dominance that is often asserted in public constructions of the maker identity. Kafai, Fields, and Searle (2014) describe how maker identities are made available through the use of technologies like e-textiles, which "open doors to students traditionally excluded from technical domains" (p. 535). Specifically, they focus on how the aesthetic component of making affords students the opportunity to bring personal identity into the typically technocratic work of schooling.

The two articles in this symposium begin to explore the maker movement by empirically addressing each of the three components of our framework—*making* as learning activities, *makerspaces* as communities of practice and designed learning environments, and *makers* as identities of participation that afford new

forms of interaction between self and learning. We are encouraged that these pieces begin the research conversation on the maker movement with subtlety, rather than simply asking whether making is "good" or "bad" for learners and instructional environments. The maker movement stretches across the formal/informal instructional divide, creating an opportunity in research and in practice to understand learning and schooling as related but independent concepts. With this work, we propose to change the conversation from being about the design of schooling as informing learning to, instead, the design for learning as informing schooling. Bringing the maker movement into the education conversation has the potential to transform how we understand "what counts" as learning, as a learner, and as a learning environment. An expanded sense of what counts may legitimate a broader range of identities, practices, and environments—a bold step toward equity in education.

Notes

1. The makerspace.com directory currently lists more than 100 makerspaces worldwide, while hackerspaces.org lists more than 1,000 hackerspaces.
2. See http://makerspace.com.

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