Making Sense of Making: Defining Learning Practices in MAKE Magazine[1]

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1. Background

Born from individual basement tinkerers and garage-mechanic hobbyists, the Maker Movement has evolved to support a strong community among makers. Makers increasingly gather together in makerspaces, hackerspaces, tech shops, and fab labs, where groups composed of diverse ages, genders and backgrounds are motivated to learn with and from one another how to use and combine materials, tools, processes, and disciplinary practices in novel ways. The growth of the international Maker Faires' annual showcases of makers' inventions and investigations have become celebrated meccas of maker culture, attracting hundreds of thousands of makers of all ages and interests. And, finally, makers widely disseminate projects, culture, and ideals through *MAKE Magazine* and online communities such as etsy.com, ravelry.com, DIY.org, and others.

The field of education has embraced the Maker Movement as a potential context for innovative and more inclusive STEM (science, technology, engineering and math) education experiences. Making has been hailed by the White House for its potential to encourage youth to become interested and engaged in STEM education, as a potential pathway to providing specific jobs skills to youth to engage in the STEM workforce (e.g. Kalil, 2010), and a wellspring of potential political and economic rebirth (The Economist, 2011). It has been positioned widely in the non-profit sector as key to engaging new and traditional users of informal learning spaces such as museums and science centers, as well as the retooling of libraries (Honey & Kanter, 2013). Educational platforms in high school tech-labs, community makerspaces, and afterschool youth programs have been created to strengthen and associate the many individuals and organizations that seek to integrate and study making as a means of learning (Sheridan et al, 2014).

So what is making, exactly? Is it poised to serve as the on-ramp to STEM careers that the educational policy world hopes it to be? In this chapter we turn to the

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pages of MAKE Magazine for data on which to base our first approximation of some core principles of the Maker community. We draw upon the communities of practice framework (Lave & Wenger, 1991; Wenger, 1998), which asserts an understanding of learning as fundamentally tied to the social and cultural contexts in which it occurs and focuses on the "practices" that define communities (Brown, Collins, & Duguid, 1989; Lave & Wenger 1991; Wenger, 1998; Gutierrez and Rogoff 2003; Greeno, 1997; Hutchins, 2002). This framework implies a process of social learning whereby learners participate legitimately in the practices of the community, local or distributed, moving, over time, from peripheral participation as a "newcomer," towards mastery as an "oldtimer." This results in learners' development of knowledgeable skill and identity as a member of the community.

Thus, assuming that makers are part of a community of practice, we set out to define making in terms of the distinct making practices that are at the center of the community. To find these practices, we analyzed the most popular and nationally recognized textual source of maker community participation: *MAKE Magazine*. In quarterly publication since February 2005 and with a readership of more than 300,000 (http://makermedia.com/press/fact-sheet/), this magazine is perhaps the oldest and most visible textual marker of the maker movement. As an introduction to the inaugural volume, the editors welcomed readers through a declaration of community identification and an invitation to join a burgeoning movement: "More than mere consumers of technology, we are *makers*, adapting technology to our needs and integrating it into our lives. Make is a new magazine dedicated to showing how to make technology work for you" (Dougherty, Make: Vol. 1, p. 7, 2005). Each 200-page volume contains approximately 40 articles, written and edited by makers, including profiles of makers and projects, how-to guides, product reviews, and thematic features. *Make Magazine*, through its longevity and visibility could be considered the archival journal of the maker community; establishing, shaping and reinforcing practices, beliefs and values of the community by way of its contributors, editors and readership.

As a data source, *Make Magazine* is not a direct observational record of the making process, nor is it the only publication associated with the Maker Movement. Therefore, our findings should be interpreted as representing the sample from which they were derived—a primarily adult, male, well-educated and affluent population of makers[1] who, through wide distribution and esteem, have come to represent a broad movement of individuals whose ages, genders, educational aspirations and financial situations vary far more than those selected for representation in the pages of this publication. Despite these limitations to generalizability, we consider *MAKE Magazine* a useful benchmark for identifying and characterizing the qualities and behaviors of this emerging community.

Our analyses of one year of the magazine's articles focus on two questions: What are the learning practices of the making community, as represented in *MAKE Magazine*? And who are the makers who contribute to *MAKE Magazine*, and for analytic purposes, represent central participation in making community practice? To answer these questions, we will begin with an introduction to the learning practices of the community that we identified across the articles. To illustrate these practices, we will take a close look at how they are exemplified through an analysis of a single feature article. This is followed by a description of the attributes of the makers who authored each article, and therefore comprise the community of makers

2. Content Analysis of MAKE Magazine

To identify the core learning practices of the contemporary making community, we coded volumes 30 to 33 (the most recent volumes of *MAKE Magazine* when we started analysis), to gain a comprehensive sense of the data (Tesch, 1990), collecting lists and memos of key characteristics, qualities and emergent patterns of maker practice that surfaced through this initial reading. We then engaged in several cycles of inductive coding of two volumes of *MAKE Magazine* (Vol. 30 & 31) until defining patterns of the maker community's practices emerged. From these, we iteratively developed a set of codes reflective of these identified patterns of practice. This included extensive discussion, examination, re-examination and definition of categories.

A coding scheme and manual was created to identify the qualities and quantities of these specific practices, as well as other attributes of the makers featured throughout the volumes, such as gender and disciplinary affiliation. We then re-coded all textual data (n=162 articles). Texts were segmented by main idea being conveyed. Since our goal was to identify and characterize maker community practices, codes were not exclusively assigned to specific text segments, as some segments described multiple practices. Inter-rater agreement, performed on roughly 60% of the data, was 92%. To reduce the data, conceptually ordered matrices (Miles & Huberman, 1994) were created using the coded text, and to more clearly see, compare and contrast examples and dominant factors.

Our analysis revealed a set of seven core learning practices associated with recognizable participation in the maker community: *explore and question; tinker, test, and iterate; seek out resources; hack and repurpose; combine and* *complexify; customize;* and *share* (Table 1). We will explore each of these learning practices in more depth in the article analysis.

<Insert Table 1 about here>

Each of the seven practices are relatively common across articles, with percentages of identified practices ranging from 51% of articles containing the practice *Seek out Resources*, to 28% of articles containing the practice *Combine & Complexify*. Making practices tend to co-occur within an article. Seventy five percent of articles contained two or more practices and more than a third of the articles contained four or more practices. This finding suggests that the practices may be commonly part of a repertoire that characterizes making, or participation in the community of makers, as opposed to specialized practices that some makers use and others do not.

Beyond identifying the practices of making, we were also interested in the identities and affiliations of the makers who publish in MAKE Magazine. Each article was coded as being framed, or not, by one or more of the disciplines of science, technology, engineering, math (STEM), and art. STEM disciplinary affiliation was determined based on the core learning practices of each discipline as they have been described in the most recent consensus reports published by the National Research Council (e.g., NRC 2001, 2007, 2010). In the case of art, where authoritative consensus documents are unavailable or inconclusive, foundational learning research studies supplement these identified practices (e.g. Eisner, 2002; Hetland et al, 2007). If the authors' description of their process or featured product clearly encompassed discernable aspects of disciplinary practice, the entire article was coded as being framed by that discipline. Each article could be framed by one, two or three representative disciplines. In cases where more than three disciplines may have been present, researchers discussed the representation and agreed on which disciplines were dominant.

3. Who publishes in MAKE Magazine?

Figure 1 shows the disciplinary-based professional affiliations of each article's author(s) and featured makers. These professional affiliations were determined based on authors' own explicit identification with a disciplinary profession either within the body of the text or within the byline of the article. The majority of authors did not identify as working in the disciplines. Rather, within the context of *MAKE Magazine*, many makers' self-identification was with their diverse and often playful interests outside of their professional affiliations. For example, one author who shows readers how to grow and use bhut jolokia chili peppers in Volume 33 describes himself as “a web geek living in Portland, OR, who loves building tall bikes, brewing beer, and growing unusual edibles” (pp. 88-91, Vol. 33), while another author, the maker of The Electronic Nag from Volume 30, describes himself as “a forgetful, loving husband and the proud father of three beautiful little girls. He has always had to learn how everything works” (pp. 50-53, vol. 30). Those authors who were identified as “other” describe themselves as a polyglot of professions and interests, ranging from students (as young as 8) to teachers (Vol. 30), lawyers (Vol. 30), community organizers (Vol. 31), and even includes a naval officer (Vol. 32), physical therapist (Vol. 31), and “fireworks master” (Vol. 33).

<Insert Figure 1 about here>

Even when authors identify as working in a discipline, it did not necessarily mean that their making activity was aligned to their professional affiliation. When we compared the disciplinary framing of the articles with the disciplinary self-identification of the authors, 61% of makers wrote or were featured in an article that was framed by a discipline other than their stated professional discipline.

Makers, as featured in *MAKE Magazine*, are overwhelmingly men: 89% of the authors or featured makers across the sampled articles of *MAKE Magazine* were men and only 11% were women. Most (64%) of the time when women appear as authors or featured makers, they were part of a team that included at least one man.

The majority of articles were multidisciplinary. Figure 1 shows that these disciplines are present in the activities of makers, yet rarely does each discipline occur independently of others. Science, technology, and engineering were the most common disciplinary framings for the articles, although art was also common. This analysis begs the question of what disciplinary communities makers are most connected to or aligned with. This analysis supports the idea that the activity of making may well lead to participation in the STEM disciplines, or at least the disciplines of science, technology and engineering, but disciplinary affiliations were not comprehensive, either within or among disciplines.

<Insert Figure 2 about here>

4. **How is Making Defined in MAKE Magazine?**

We turn now to a deeper exploration of each of the core practices we identified in *MAKE Magazine*. To do so, we will describe one example of making, the Rocket-Ship Tree house, featured in Make, Volume 31 (pp. 144-151). Rocket-Ship Tree house is the story of a dad, Jon, his friend and colleague Jeremy, and their process of building a backyard play structure for Jon's six-year-old son Eliot. What began with the simple idea of beautifying a small backyard space developed into an elaborate project that spanned two years, evolved to include a host of neighborhood friends, exponentially expanded Jon, Jeremy and Eliot's knowledge base and skill set, harnessed their imagination and creative spirit, and above all, solidified their identities as makers. Through the authors' description of their process and project, we may come to qualitatively understand the identified practices of the maker community.

The rocket ship idea emerged when Jon's wife suggested that Jon install a treehouse for their son Eliot under the trees in the backyard. Jon, a researcher at Microsoft, took the request as a challenge, and through an elaborate and imaginative process, decided to instead build a stationary rocket ship as a play structure for his son. As the vision for the project became more elaborate, Jon recruited his colleague Jeremy to collaborate on the electrical aspects of the rocket ship.

The rocket ship, or RULAV (Ravenna Ultra-Low Altitude Vehicle, named after the makers' Seattle, Washington neighborhood) is a hexagonal prism-shaped capsule, rising 15 feet off the ground, atop a tripod structure. The capsule is 6.5 feet wide, and is framed in welded steel with a riveted aluminum skin. Inside, the rocket contains nearly 800 LEDs forming flashing lights and numeric display panels. The "pilot" controls the rocket using a joystick, switches, knobs and buttons. The rocket "takes off," "rumbles" and "docks," by way of "thrusters" that shoot compressed air and water, accompanied by vibration and sound effects (http://rocket.jonh.net/intro.html).

4.1 Explore and Question

Makers in MAKE Magazine generally approach a project or making process through the practice of questioning and exploring the context of activity and/or problem space. Makers are curious people, whose interest in and wonder about a particular topic leads to inquiry and exploration. Makers interrogate the past, researching and referencing former projects and ideas related to their future intentions. Contributing authors of articles to *MAKE Magazine* often introduce the reader to their motivation for engagement in the particular project, medium or process of making to be considered, through an explanation of their process of investigating personal and/or collaborative inquiries.

For Jon and Jeremy, the question came as a suggestion posed by Jon's wife to build a simple tree house for their son, yet taken up as an exploratory challenge by Jon, Eliot and eventually, Jeremy. Their exploratory process began with a trip to Boeing Surplus to scrounge for inspiration amidst the piles of used parts. Jon and Eliot brought home a few big sheets of aluminum and some aluminum tube to test their initial idea: a geodesic structure formed entirely by bending and riveting. Yet, the authors attest, "early prototypes wouldn't stand up, proving that we really didn't know much about mechanical engineering" (p. 144). Through their questioning and testing of materials, the makers realized "weight wasn't a design constraint for a rocket that never leaves the ground; it would be just fine to use steel" (pp. 144-146). Thus, they defined the design of the rocket's exterior, or chassis and skin, through an exploration and questioning of the material-constraints.

4.2 Tinker, Test and Iterate

Makers explore materials and processes through purposeful play, experimentation, and ongoing evaluation. Makers are doers, rather than planners. Yet, the doing is iterative and sequential. Makers model designs with software, they build and test paper prototypes, and they evaluate their process to discover what is possible or to improve upon what has come before. Makers try, make mistakes, and fail—a lot. Makers value the iterative process of engagement in making and testing out ideas as much as the finished product. For makers, each successive iteration of a project presents an opportunity to develop applicable skills and grow relative knowledge for oneself and for the community of makers.

The authors' portrayal of the design and development of the tree house's internal electronics showcases their deep investment in their iterative learning process. Jon and Jeremy's original goal was to fill the rocket's interior with an array of flashing LED lights, numeric displays and dials. Jeremy went about designing a circuit board that would light up an 80-segment numeric display that the makers intended to build themselves. The authors describe the intricacies of the electrical system, and attest, "An early prototype worked, but even with only 2 LED digits, it took a week of evenings to construct. We had to carefully modify a prototyping board with a rotary tool, and solder in each component and wire connection" (p. 148). Although they describe the process as "time-consuming, error-prone, and not very fun," the challenge provoked them to persist with their iterative design:

> Sane treehouse builders might decide to scale back their ambitions. We went the opposite direction: why not design our own printed circuit board (PCB) and have it fabricated in bulk? The only

> problem was, we hadn't done anything of the sort before — in fact, we'd only recently learned how to light up an LED (p. 148).

Jon and Jeremy describe an intense readiness to try in the face of the unknown, to test ideas and push beyond their existing boundaries of ability, to persist when challenged, to pursue creative solutions, and to turn to the resources of the maker community for support in order to make progress on their personal project.

4.3 Seek Out Resources

Makers are resourceful. They seek out and rely on the expertise of others. Makers know where and to whom to turn for guidance and collaboration. They willingly seek and give advice and feedback. They interact flexibly with the distributed tools, materials and expertise of the community. This practice of seeking out resources is often enacted through Internet searches and online forums. It is also frequently played out through the recruitment of friends and colleagues with diverse skill sets and knowledge, as well as through the active use of local community-developed resources for discussion, design and fabrication.

Jon and Jeremy overcame the challenge of generating enough customized circuit boards to ignite the inside of their rocket-ship with flashing lights and numbers through a little resourcefulness. The authors declare, "The thriving DIY community came to the rescue" (p. 148). Jon and Jeremy turned to their online community for instruction and feedback when creating their own printed circuit board (PCB). They learned PCB design through online tutorials and discussion boards, used readily available software to hone their previously rudimentary skills, created a working schematic and layout drawing, and virtually sent their design to be professionally fabricated. Although there was a learning curve, Jon and Jeremy researched, discovered and activated community resources to suit their creative and functional needs. In so doing, they developed their own knowledge of electronic processes and related design skills, and they also gained a deeper sense of the wealth of expertise among makers that can be harnessed and channeled.

4.4 Hack & Repurpose

Makers see the world as made of component parts; pieces and platforms that can be opened, deconstructed, modified, and repurposed to create something new, improved, altered, or recombined to better suit the needs and desires of an individual or community. Makers would rather repurpose a found object or salvaged component than buy something new. The community of makers is one that values affordability, accessibility and ingenuity over sleekness and precision. Hacking and repurposing is a practice of problem solving and improving functionality, but is it is also an act of improvisation and creativity, and an opportunity to put the stamp of individuality on a project or process.

To simulate the experience of a pilot's launch, positioning, and landing, Jon and Jeremy sought to create just the right rumble, vibration, and sound effects of the rocket's engine using pressurized gas to produce mechanical motion. To do this, they hacked and repurposed a few commonly found products from a hardware supply store. The "booster" was made from an old paint shaker that creates the perfect vibratory feeling during "takeoff," and the thrusters were made of repurposed automotive engine-cleaning wands, "that aerate water using a supply of compressed air, producing a convincing jet blast of mist" (p. 150). Having mastered electronic programming, the makers nostalgically decided to connect the "boosters" and "thrusters" to the main control panel through electronically actuated valves controlled by a repurposed vintage PC joystick from the computer games of their own youth. Jon and Jeremy intentionally chose to use repurposed materials that were readily available and inexpensive, familiar simulations of more complex system.

4.5 Combine and Complexify

Makers look towards a future of endless innovative possibility. Yet, they do so with the recognition that they are standing on the shoulders of past craftspeople and makers who created tools, products and platforms, both analog and digital, which can be harnessed, combined and adapted to enable future ingenuity. The practice of developing skilled fluency with a diverse set of physical and digital tools, materials and processes of construction, in order to put these existing pieces and processes together differently, is central to making, and enables makers to extend what is possible. Inherent in this practice is an impulse to learn and an acknowledgement that there is always more to learn—that what is not yet known is of deep personal interest, is learnable, usable, and useful to oneself and to the community of makers. The practice of combining and complexifying is a practice of lifelong learning.

Jon and Jeremy liken their ongoing and increasingly complex project to the "opening of floodgates." The authors write, "we realized the rocket's electronics could do far more interesting things than just display a random number" (p. 150). The makers took it a step further by combining individual elements to create an overall effect of a takeoff sequence: "A countdown is displayed on a control panel while audio from the real Apollo 11 sequence is played. At zero, the lights start to flicker, and the rocket starts to rumble from the movement of the paint shaker and the bass from our subwoofer" (p. 150). The authors recount with pride:

> Rarely does building a treehouse require welding, grinding, painting, riveting, bending, crimping, plumbing, brazing, laser cutting, sound design, printed circuit board fabrication, distributed network protocols, an embedded operating system, sewing, and even embroidery (p. 144).

Each newly envisioned feature of the rocket revealed a novel skill or tool for the pair to learn, use and hone. As the project expanded in scope, so did the makers' roster of familiar tools, materials and processes that they could combine to extend what was possible for this and future making endeavors.

4.6 Customize

Making is a personal pursuit. The subtitle of *MAKE Magazine* originally read, "technology on your time." Since its inception, the community of makers has sought to alter technology to suit individual and community needs, and to express personal and collective beliefs. In 2005, founding editor Dale Dougherty identified the communal drive of makers: "adapting technology to our needs and integrating it into our lives" (Vol. 1, p. 7). Through the practice of customization, makers tailor the features and functions of a technology to make it their own.

As the project evolved, Jon and Jeremy learned about and integrated many maker processes to create a highly customized technological system that combines mechanics, electronics, pneumatics, and software to create a singular experience. Moreover, it is evident that Jon and Jeremy's ambitious rocket ship project was not only motivated by personal aspiration—a tree house for Jon's young son—it became a highly collaborative and joyful pursuit of learning and making that stretched across generations. The authors explain, "It became transparent that the treehouse was just as much an engineering playground for the adults, a place for us to share our joy of making and teach it to the kids" (p. 144). For example, the authors explain, "we even created a rocket version of the classic video game *Pong*, to keep crew morale high during long trips to the Moon" (p. 151). Such associations both personalized the experience and introduced Eliot to an element of the adults' own childhood adventures. The practice of customization can be seen in the incorporation of other personal touches, from the joystick from the makers' youth, to the way in which Jon and Jeremy strongly identify with the process and products of their pursuit, to the intentionality of communicating a shared family and community value through the making process. The authors conclude, "since Eliot was with us every step of the way, he also learned that toys aren't just something you buy, they're something we can build — together" (p. 151).

4.7 Share

Makers openly share and access the stuff of making with the entire community of makers through diverse platforms for presentation, reception, and communication. Often characterized as open source, the make community works to develop repositories of information, kits and systems of communication, which make tools, materials, methods of design and fabrication, and products accessible, customizable, and usable by the entire community. This practice of sharing is at the core of *MAKE Magazine* itself.

Within the pages of *MAKE Magazine*, Jon and Jeremy's story is accompanied by photos and drawings of their process, as well as sidebars in which the authors share tips and resources related to the many processes they engaged and eventually mastered through their project: welding, riveting, brazing, etching and programming. The authors provide advice, compare sources and prices of products, review software, link to related articles previously published in the magazine, and add personal tips to encourage the reader to engage in similar endeavors.

The makers also created their own website to share their project (http://rocket.jonh.net/), which describes the entire process, from conception to blast-off, in detail. The extensive site walks the reader through each step in the process, complete with photographs and videos, as well as open-source links to download the makers' plumbing and operating system designs, and electronic and PCB schematic files. Here, Jon and Jeremy invite the visitors to provide feedback, and even encourage visitors to "schedule a flight" if ever in the Seattle area.

5. Conclusions

As the educational community rushes to understand and promote the spread of making, a first goal must be to define what we mean by making. In this paper we provide evidence that identifies seven core learning practices of making as it is recounted in the pages of *MAKE Magazine*. Our analysis suggests that the practices that characterize participation in making cannot be simply described as practices that come from or point to any one educational disciplinary pathway such as engineering, science, or math. It can be argued that aspects of maker practice are drawn from or resemble certain disciplinary practices, but no one discipline or singular set of established disciplinary practices captures the essence of participation in the making community. Makers have developed a set of sophisticated community practices and modes of participation that, as a whole, are organic and, possibly unique, to making.

So if learners participate in making activities, are they more likely to be interested and successful in STEM? The answer to this question is beyond the scope of the current chapter. Yet, our findings concerning the practices of making do encourage us to ask whether participation in the community of makers would necessarily guarantee a member's orientation towards participation in STEM disciplines. We identified practices that in some ways seem consistent with STEM practices, but also that may have important differences. At the least, we do not see evidence in our work that becoming expert in making would necessarily involve developing practices that foster expertise in STEM disciplines.

On the other hand, as disciplinary practices are applied through the community's making activities, becoming a more practiced maker does encourage community members to tinker at the edges and intersections of other disciplines. Making may promote an understanding, and the purposeful use, of specific facets of disciplinary knowledge and skill that inform and extend making community participation. Consequently, as a multidisciplinary endeavor, making may have the potential to render STEM experiences more accessible, interactive, and motivating for the community of makers, as well as for individuals and communities seeking to integrate making into their own community practice, such as teachers and informal educators. Positioning themselves and their activity at these edges, intersections, and boundaries of participation in disciplinary (and other diverse) communities, makers work to transform the refined and inaccessible aspects of disciplinary participation to become accessible to community members. For example, one scientist described how she makes research-grade equipment out of repurposed common kitchen items (Make, Vol. 31, p. 42). Rather than emphasizing the exotic and refined aspects of disciplinary understanding and practice, makers work across disciplinary boundaries to piece together everyday objects and processes in innovative ways. This boundary-work, drawing connections across disciplines, is central to maker participation.

Yet in light of its potential, making and the ways in which it is publicly represented and positioned with regard to education must be further questioned as a movement of inclusivity and accessibility. For example, we found that makers featured in *MAKE Magazine* are primarily men. We note that the readers of *MAKE Magazine* reflect the same sex disparity, as reported by the Magazine itself – 81% are male. The readers are also less diverse than the broader population, with a median age of 44 and median household income of $106,000. 97% graduated from and/or attend college, 80% have a post-graduate degree and 83%

are employed. (http://makermedia.com/press/fact-sheet/). As the magazine launched, a New York Times Op-Ed hailed it as a haven for men and boys who tinker:

> “Make…is a throwback to an earlier time, before personal computers, to the prehistory of geekiness - the age of how-to manuals for clever boys, from the 1920's to the 50's.…The technology has changed, but not the creative impulse… Make is not just a clubhouse for guys with Skittle breath and abbreviated social skills. Beneath all the home-brewed gadgets and cool software tricks lies a sly and subversive agenda.” (NYT, June 12, 2005).

Our findings suggest that educators, and the making community itself, must take a critical look at who, exactly, is most visible in the community, and what forms of participation are being positioned as central, and therefore valued, by the community. If making is represented as being, for example, mostly male, mostly white, and mostly about hobbyist technology, how does it differ in substantive ways from other recent educational phenomena that were similarly thought to be new supports and motivations to participate in STEM, such as educational gaming or robotics, and that continue to foster a complex relationship to gender and access with regard to design and use (e.g. Kafai et al, 2008)? Will making experiences really become more accessible and motivating to young people and communities who do not see others like themselves and their creative interests reflected in the public face of the movement? The current framing of Make Magazine—as one of the most popular and visible characterizations of the community—runs the risk of perpetuating current trends, making STEM experiences more motivating for only those to whom those experiences are already accessible (see Blikstein & Worsley, 2016 in volume 1 of this series for more on this). As an educational endeavor, our goal should be to create and nurture spaces and opportunities that are accessible and encouraging for *all* youth to engage and to feel as though each of them is a legitimate member of the community.

Making is a multidisciplinary, interest-driven, distributed and evolving form of informal learning. To help realize the educational potential of making, future work must focus on identifying and designing accessible and representative educational platforms, experiences and assessments that draw clear connections between making and educational outcomes, such as STEM success. Currently, our research-based understanding of making is still far behind the growing enthusiasm for making in the educational world, and with it, the ongoing spread and scaling of making to formal and informal learning environments. The pathway from making to, for example, STEM education and STEM workforce participation, although assumed, is not clear, well defined or inclusive. If such connections are a priority for education, then we must study and design with awareness of the intricacies of community participation, what forms they take and where such pathways point.

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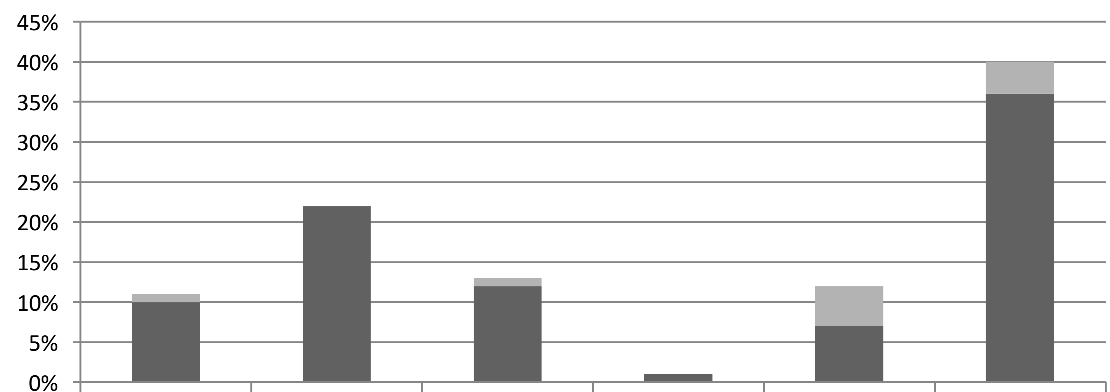
Table 1
Maker Community Learning Practices

Maker Community Practice	**Definition**	**% of articles coded as exemplifying a practice**
Explore & Question	Interrogation of the material properties of the context in order to find inspiration or to determine intention for a process or project.	49%
Tinker, Test & Iterate	Purposeful play, experimentation, evaluation and refinement of the context.	29%
Seek out Resources	Identifying and pursuing the distributed expertise of others, includes recognition of one's own not-knowing and desire to learn.	51%
Hack & Repurpose	Harnessing and salvaging component parts of the made world to modify, enhance, or create a product or process.	38%
Combine & Complexify	Developing skilled fluency with diverse tools and materials in order to reconfigure existing pieces and processes and make new meaning.	28%
Customize	Tailoring the features and functions of a technology to better suit personal interests and express identity.	43%
Share	Making information, methods and modes of participation accessible and usable by members of the community.	42%



	Scientist	Technologist	Engineer	Mathematician	Artist	Other
Female	1%		1%		5%	4%
Male	10%	22%	12%	1%	7%	36%

Figure 1. Author's Professional Disciplinary Affiliation

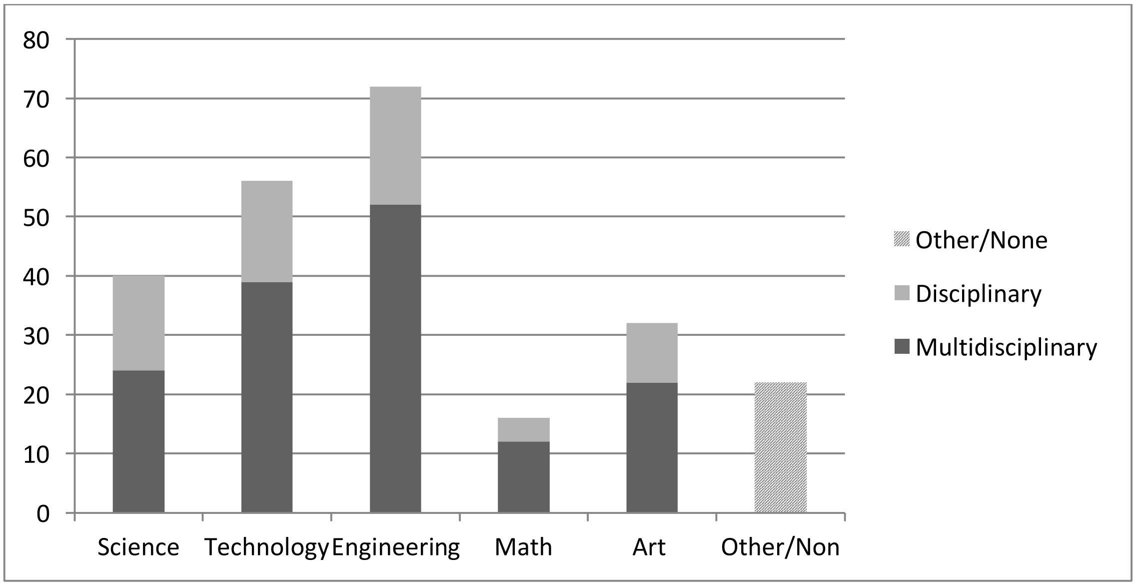


Figure 2. Disciplinary Framing of Articles and Co-Occurrence