MakerSpaces in Education

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Introduction

Collaboration. Creativity. Engagement. Personalization. Connection. Agency. Access. Equity. These words mark current dialogue in K-12 education. The 2015 K-12 Edition of the *NCM Horizon Report* describes the rethinking of how schools work and the transition of student from consumer to creator, and the creation of authentic learning opportunities for students as key trends and challenges facing contemporary educators. Many educators, administrators, parents and students are recognizing that traditional ways of learning, including passive reception of teacher-delivered content through lecture and rote assessment, do not fit with today's learner, content or digital world. If students are to be prepared for a world of knowledge abundance, digital ubiquity and future careers, authentic, life-long, interdisciplinary and problem-based learning must be part of the school experience for everyone. Perhaps the emphasis on these ways of learning, and the aforementioned trends is the reason for *NCM 2015 Report*'s inclusion of Makerspaces as an important near-term educational technology development (New Media Consortium, 2015).

In a White Paper describing research on Maker-Centered learning, the Harvard Graduate School of Education's Agency by Design noted that hundreds of articles in popular and academic formats have been written about the Maker Movement in the past five years (Agency by Design, 2015). Makerspaces are being developed in communities, schools, libraries and in museums at a rapid rate. But, what are Makerspaces? What are the components of maker-centered learning? And how does this way of learning support the NLM trends in K-12 education? What about voices that have critiqued the maker movement as continuing to privilege some over others? This paper and accompanying website will discuss the traits of Makerspaces, both in K-12 education and in other arenas, and will critically examine trends surrounding Makerspaces and the ways in which Makerspaces can promote equity and diversity for all learners.

What is making?

Over the past few years there has been a growing movement around the making of things. A surge in interest in DIY methods and tinkering has fueled what has become known as making. Making can involve anything from creating electronic robots to jewelry and furniture creation. DIY is more of a cultural trend, spurred by the sustainability movement, usually with the goal of personal fulfillment. Tinkering is an experimental space, where people try out an idea and create a series of iterations in response to previous successes or failures. New technologies are making it easier and more affordable for this type of trial and error experimentation. The Maker Movement embodies both the sensibilities of DIY and tinkering and is the inspiration for Make Magazine. Make Magazine reports on the Making Movement, and contains articles on how to make things, from crafts to electronics. The magazine also covers Maker Faires which are live gatherings of makers showing off their latest creations. In addition to Maker Faires, the movement has spawned Maker clubs and Makerspaces.

What are Makerspaces?

The first Makerspaces emerged in roughly 2005 and found homes in museums, school libraries, public libraries and community centers. In addition to the term Makerspace, they have been called Hackerspaces, FabLabs and TechLabs. There are subtle differences between the terms. According to the Hackerspaces.org website, hackerspaces "are community-operated physical places, where people share their interest in tinkering with technology, meet and work on their projects, and learn from each other." The first recognized hackerspace was the German c-base started in 1995. The term "Makerspace" really came about as a derivative of the magazine Make. The magazine's founder, Dale Dougherty, registered Make's website as makerspace.com and began using the term makerspace in conjunction with open-access public spaces for the purpose of design and creation. TechShops and FabLabs are trademarked names. TechShop began in Menlo Park, California in 2006 as a for-profit chain offering access to sophisticated manufacturing equipment on a subscription basis. FabLabs are an offshoot of an MIT course in 2005 called How To Make Almost Anything. Started by Neil Gershenfelt, the founding idea behind FabLabs is that almost anything can be made if someone is given access to a basic set of manufacturing tools and provided with an introduction to design and engineering. The FabLab Charter dictates the dimensions of the shop space and tools required and are typically run by non-profit organizations.

The Evolution of Educational Makerspaces

"Maker education is a grassroots reaction against one-size-fits-all education designed for mass warehouse-style instruction" (Kurti, Kurti & Fleming, 2014, p. 8) Makerspaces were originally developed to provide adults (primarily middle class white males) with the facilities and resources for tinkering and creative discovery. Learning wasn't the primary objective, but often was the result of making. In an educational makerspace, learning is paramount, but must be initiated by the learner. The teacher may act as a mentor or guide to enable the learner. By encouraging curiosity and questioning students will arrive, on their own, at the destination the teacher had originally planned. Maker education accommodates all learning styles and, as long as the students agree on certain basic principles (laws of physics and other basic, unchangeable scientific facts) they are only limited by their own imaginations. The best learning comes when students are faced with coming up with a solution to a problem and are allowed to do so in their own style at their own pace. By coming up with creative workarounds to immutable facts true innovation happens. (Kurti, Kurti & Fleming, 2014, p. 8)

The Impact of Making on STEM and STEAM

Making is a great way to engage kids in STEM and STEAM pathways, which may lead to careers in engineering, science and technology. Waters and Kesler (2015) wrote, "The Maker student learns content within an authentic context that requires communication, collaboration, research, design, modeling, tinkering, and prototyping." Out-of-school programs help to target underrepresented youth. The push is to create equity in making, as the typical maker has been white, middle class males . Makerspaces have the potential to be catalysts for change. By creating spaces where youth can try out tools and technology to create something of their own, the hope is they will want to come back and do it again. There needs to be consistency in support for kids in these spaces, to encourage them to try again if their first attempt failed. Mentors and advisors are key supporting young makers in their efforts. Educators need to keep this in mind when creating Makerspaces.

Makerspaces in K-12

Schools across the country are taking different approaches to incorporating makerspaces into their facilities. Some are taking creative, cost-effective measures by having spaces serve double-duty, being transformed into a makerspace after school. Materials are stored in containers when not in use and brought out for the after- school transformation. Libraries have been the logical

space to incorporate making as they are a commons area all students would have access to on a regular basis.

Some schools are creating curriculum incorporating design approaches and free thinking into the school day. Other schools are creating makerspaces by designing classes dedicated to innovative exploration. To offset the cost of creating a makerspace, many schools are obtaining grant funding, relying on community support and soliciting businesses in the community to contribute to the makerspace. Business funding is a win-win as the companies will eventually be rewarded with a rich talent pool as the students seek employment in later years.

K-12 Library Case Study

Kaechele Elementary School in Virginia uses their Library Learning Commons (LLC) as a makerspace. Within the 3,426 square foot area are flexible spaces determined by student's interests and needs. Materials have been donated to the space for student use.

Signage indicates the use of an area which is subject to change depending upon the availability of materials. A common area is home to most materials and tools. Students may use the area after an orientation. Requirements to use the space are signing in, working independently, bringing a timer, being respectful and conscious of others. Student's are also responsible for cleaning up and turning in a brief reflection sheet which may be used for data collection.

The Economic Impact of Making: Leveling the Playing Field

Targeted funding is another avenue for levelling the playing field. Cognizant, a Fortune 500 company, created a program called Making the Future. This program provides funding for educational nonprofits and for out-of-school STEM programs. Cognizant is also funding makerspaces, most notably in the New York Hall of Science as well as providing STEM education grants. Cognizant has given out more the $5 million since it began its involvement and has targeted underrepresented groups like girls and minorities.

Scholarships are another way to encourage minorities and girls involvement in making. SparkMacon began a program in May 2015 called Project Renaissance. Over the course of a year participants go to workshops to gain skills in coding, 3d printing and modeling, laser cutting, electronics, arduino, video editing, robotics

and costume creation. First Friday Open Make events give students the opportunity to share projects they have created in the program.

Makersquare LA sponsors a Diversity Scholarship dedicated to increasing the number of women and minorities in tech with a focus on software engineering. As a result of the scholarship for women, there was an equal gender split in the first Austin cohort. Makersquare LA has also been partnering with the Girl Scouts, teaching programming to young girls. Another outcome from this partnership was the creation of a Girl Scouts badge for Programmers. Full ride scholarships have also been made available for women and underrepresented minorities applying to MakerSquare Los Angeles.

The Maker VISTA Project is a part of the federal AmeriCorps VISTA Program. Maker VISTA is a national service project and volunteers devote a year of service working in areas of high poverty. Maker VISTA targets education as the portal through which change may be affected. An example of a maker VISTA project is Ravenswood City School District in East Paolo Alto, CA. They have created a Makerspace Collaborative to facilitate Makerspaces at every school site by the beginning of the 2015-2016 school year. All grades will be supported and the focus will be on coding, robotics and general tinkering. The intent is that STEM skills will now be accessible to low-income and minority students.

Government Involvement in Makerspaces

A Congressional Maker Caucus was held on Nov. 18, 2014. The event, titled "Creating a Diverse and Inclusive Maker Movement" discussed the role of women and minorities in making and focused on how to expand participation and diversify those engaged in making. The Congressional Maker Caucus is a bi-partisan group which promotes the maker economy to Congress and formed by U.S. Rep. Tim Ryan, D-13 Ohio, is joining with Reps. Steve Stivers, R-15 Ohio, Mark Takano, D-41 Calif., and Mick Mulvaney, R-5 S.C. Notable remarks from the event include those made by Congressman Mark Takano; "the Maker Movement is changing the economy, lowering barriers for entry. It's also going to transform how we teach our children, because during the innovation process, sometimes failing can be more educational than textbook successes." Also worth noting was the observation made by Dr. Peppler (2014), Assistant Professor of Learning Sciences at Indiana University who also leads the research team for Maker Ed's Open Portfolio Project. Dr. Peppler stated: "Promisingly, our recent surveys of makerspaces, conducted as part of the Maker Education Initiative's' Open Portfolio Project, demonstrate that makerspaces are serving highly diverse populations (in terms of race, ethnicity, gender, and social class). The question

then becomes how do we support these populations over the long-term, leading to consequential impacts on their education and career trajectories."

Women and Making

A report called *MakeHers: Engaging Girls and Women in Technology through Making, Creating, and Inventing* by Intel and Intel Foundation examines the possibility of engaging girls and women in technology through making. Topics covered include why girls make and what role the play in the maker movement. Also included are statistics on how many are involved in making and how to engage girls and women in STEM fields. The findings show that the Maker Movement has the potential to increase the number of women pursuing careers in STEM. Here are some of the specific findings of the report:

> **Key Recommendations to Engage Girls and Women in Making**
>
> **Build** more girls- and women-inclusive maker environments in public places like libraries and schools.
>
> **Design** maker spaces that enable open-ended investigation of projects meaningful to girls and women.
>
> **Develop** initiatives that give girls more access to makers their own age and female mentors.
>
> **Encourage** parents to "embrace the mess" and engage in making with their children.
>
> **Align** making activities, such as coding and making hardware, with current trends and personal interests to attract girls.
>
> **Include** facilitators in maker spaces to create a safe, supportive, inclusive environment for girls and women.

The Impact of Design on the Accessibility of Makerspaces

As described in recent literature, the making movement and makerspaces are not standard (Peppler, Maltese, Keune, Chang & Regalla, 2015). They vary in purpose, location, focus, and audience. Makerspaces can be housed in a dedicated space, as in a school library or specialized workshop. They can be distributed throughout a school or organization, as in the case of the Opal Public Charter

School, where each classroom has a studio space for making (Davee, Regalla & Chang, 2015). Makerspaces can even be mobile, traveling to learners on a vehicle similar to the public library bookmobile, or on a cart within an organization or school. In light of a critical lense of equity and inclusivity, the design of educational makerspaces, wherever they are located, is critically important to their accessibility by all learners.

Writing about the gender gap in his computer science courses, educator and Making proponent Colin Angevine noted that "there's no blueprint for inclusivity. If you build it they will come does not apply here. Instead it's more like a recipe: put in healthy ingredients and allow them to work together" (Angevine, 2015b). According to Angevine (2015b), healthy ingredients for inclusivity in a technology class include encouraging empathy, creating comfortable spaces for all learners, fostering positive culture, teaching with thoughtful pedagogy, utilizing new curriculum and thinking differently on gender, race and ethnicity. These traits also support accessibility and diversity in a making environment.

Making expert Sylvia Martinez echoed these ideas when writing about inclusivity in makerspaces. According to Martinez (2015), makerspaces must be designed to place a value on student voice and choice, be culturally responsive, minimize competition, and not privilege one kind of making over another. These kind of spaces will "serve as catalysts and agents for change within a community rather than remaining objects of change by others" (Martinez, 2015). But how are these traits and ideas practically incorporated into the design of an inclusive makerspace?

In studying the design of makerspaces in order to practically create an accessible environment, the feeling of a space, the rules that guide such a space, and the roles of the individuals involved in making must be addressed (Kurti, Kurti & Fleming, 2014). All students must feel comfortable in a makerspace. This means looking at physical arrangement, paint and wall decoration choice, and student display of work. Additionally, the feeling of a space must foster curiosity, wonder, experimentation and individuality.

Rules and principles that guide makerspace design include the acceptance and encouragement of failure. As making and tinkering is an iterative process, students must be comfortable with failing and failing and failing again. Mistakes are to be tolerated along the way, even if they come in the form of broken equipment, and collaboration needs to be fostered. Spaces must be open and fluid enough for students to work together on projects, and utilize the strengths of their teammates to solve complex problems. In the case of working with diverse learners, the availability and proximity of just-in-time learning resources to support a deeper understanding of STEM principles instead of relying on student background knowledge is an essential design and pedagogical element.

The roles of students and educators are also essential in the design of an inclusive makerspace. Educators need to embody collaborative open-ended growth oriented approach to learning (Angevine, 2015a). This type of leadership and facilitation involves living out the principles of makerspaces, and asking questions of learners instead of acting as an expert (Kurti, Kurti & Fleming, 2014). Moreover, educators in accessible spaces demonstrate the importance of understanding students' social and educational histories and trajectories by continually adapting pedagogy and curriculum. These teachers understand that "the most meaningful projects don't just look cool or integrate different disciplines; they can fundamentally change the way a student sees him/herself as a learner" (Angevine, Why and how, not just what, 2015). By designing pedagogy in this manner, students develop their own voice and identity, and gradually take on roles of mentoring other students. Liz Wiseman calls these kind of educators "multipliers" who challenge growth in others through the fostering of creativity and independent problem-solving. (Kurti, Kurti & Fleming, 2014).

Integration and Constructionism in Educational Makerspaces

As written in the *Philosophy of Educational Makerspaces*, "The maker movement in education is built upon the foundation of Constructionism, which is the philosophy of hands-on learning through building things" (Kurti, Kurti & Fleming, 2014, p. 8). Constructionism is a learning theory developed by Seymour Papert, developer of LOGO, one of the founders of MIT Labs and protégés of Piaget. Johan Donaldson, an instructional designer and educational technology educator, describes Constructionism as the theory that "brings creativity, tinkering, exploring, building and presentation to the forefront of the learning process." (Donaldson, 2014). The theory of Constructionism is a natural fit with Horizon's 2015 trends and challenges in K-12 education. In the shift from students as consumers to creators, Constructionism can be seen in the focus on student demonstration of learning through the construction of artifacts. Increasingly accessible technologies and equipment facilitates the construction of these artifacts, and many of these technologies can be found in school Makerspaces. Constructionism is also a contributing factor to the long-term trend of rethinking how schools work. In reinventing the traditional classroom paradigm, project- and challenged-based learning are being emphasized as a way to build collaboration, critical thinking and creativity in students. In creating learning environments that are increasingly student-centered, educational leaders are using the theory of Constructionism to support the integration of technology and disciplines, and to design curriculum around the solving of authentic problems and projects (New Media Consortium, 2015).

An investigation into current literature on makerspaces reveals that making is relevant to all areas in the learning curriculum (Davee, Regalla & Chang, 2015). In addition to supporting STEM fields, the arts, humanities, design and communication fields are enhanced by the incorporation of making. Dale Dougherty, founder of *Make* magazine, has described makerspaces as sharing "aspects of the shop class, home economics class, the art studio and the science labs. In effect, a makerspace is a physical mash-up of different places that allows makers and projects to integrate these different kinds of skills" (Davee, Regalla & Chang, 2015). This observation leads to the conclusion that makerspaces can physically embody interdisciplinary study and multidisciplinary approaches to learning (Davee, Regalla & Chang, 2015).

In the K-12 learning environment, school librarians are increasingly being drawn into the maker movement, perhaps due to the natural overlap between makerspaces and libraries. Both are constructivist spaces that value learning from a diversity of sources and means.

Equity in Educational Makerspaces: A Critical Examination

Makerspaces and the making movement have been criticized as not supporting equity and diversity. After her analysis of the leaders in the high tech industry and the Make organization, Leah Buechley concluded in her 2014 FabLearn conference talk that the maker movement "has failed to broaden participation and representation in its ranks beyond those who are wealthy, white, and male" (Eyeo Festival // INSTINT, 2014). Historically, the STEM field, to which the maker movement is closely related, has privileged certain groups over others, as seen in the distribution of employees in STEM careers. Abstract and formal thought has been valued over concrete and bricolage approaches to learning. The cost of makerspace equipment has privileged those with financial resources. Tools and projects in metals, woodworking, electronics and robotics "have traditionally been and currently still are, white male dominated. The knowledge base and cultural tools officially made available in these spaces privilege a historically masculinized practice." (Barton & Tan, 2015).

In contrast, makerspaces have tremendous potential in leveling the playing field for all learners. Rather than excluding some demographics, the maker movement has the possibility to empower and enable all learners. In researching differing approaches to human-computer interaction in early 1990s, Seymour Papert and Sheri Turkle (1992) applied Feminist theory to scientific thought, and found that "equal access to even to most basic of computation requires an epistemological pluralism, accepting the validity of multiple ways of knowing and thinking" (p. 1).

Papert and Turkle (1992) concluded that the computer itself blends abstract and concrete ways of interacting with technology, and "there is every reason to think that revaluing the concrete will contribute to a computer culture that treats the computer as an expressive medium and encourages differentiated styles of use and relationship with. There is every reason to think that this computer culture will be more welcoming and nurturing to women - and to men" (p. 23). But, how can this theory of inclusivity and pluralism be applied to Makerspaces in order to foster equity and diversity, and to promote the mission of creating "more opportunities for *all* young people to develop confidence, creativity, and interest in science, technology, engineering, math, art, and learning as a whole through making" (Davee, Regalla & Chang, 2015).

In their survey of 51 youth makerspaces across the United States and internationally, Peppler et al. (2015) found that "making encompasses a wide variety of categories, activities, and learning approaches, which are seen in the many different naming conventions that tend to be embraced in today's landscape" (p. 2). Makerspaces themselves are diverse, as demonstrated by differences in what is made and how making is approached, and additionally, the MakerEd team discovered that the population demographics of the makerspaces varied widely by site.

TABLE 1: *Race and Ethnicity Across All 51 Makerspaces*

	ASIAN	BLACK/AFRICAN AMERICAN	HISPANIC/ LATINO	AMERICAN INDIAN & ALASKA NATIVE	WHITE	OTHER
MEAN ACROSS ALL MAKERSPACES	14%	20%	18%	0.3%	42%	5%
MEDIAN ACROSS ALL MAKERSPACES	7%	10%	10%	0%	44%	0%
STANDARD DEVIATION	19%	21%	24%	0.9%	30%	16%
MIN. ACROSS ALL MAKERSPACES	0%	0%	0%	0%	0%	0%
MAX. ACROSS ALL MAKERSPACES	94%	95%	88%	5%	98%	100%
POPULATION BY HISPANIC/LATINO ORIGIN AND BY RACE FOR THE US IN 2010	4.8%	12.6%	16.3%	0.9%	63.7%	9.3%

(From Peppler et al., 2015, p. 2)

Moreover, through tinkering, multiple pathways to problem-solving and development of a range of solutions rather than one right answer is fostered. Thus, makerspaces, through their use of different materials, promotion of different ways of thinking, and service to a diverse population of youth, demonstrate inclusivity and have the potential to form "a firm foundation for future policy and educational efforts seeking to deepen learning in these spaces over time" (Peppler et al., 2015, p. 4).

However, researchers have noted that conversations of equity and culture have not been in the forefront of maker discussions (Vissoughi, Escude, Kong & Hooper, 2013). Broadened access to technology and economic value of making have been the topics of current conversation. However, according to the Stanford

Research team, “equity lies in the *how* of teaching and learning: specific ways of designing making environments, using pedagogical language, integrating students’ cultural and intellectual histories, and expanding the meaning and purpose of STEM learning” (Vissoughi, Escude, Kong & Hooper, 2013). Pedagogy of the makerspace, with a redefinition of learning and teaching, emphasis on the individual and recognition of student background and voice, will foster equity in the makerspace.

One of the ways to support inclusive pedagogy in educational makerspaces is the employment of Culturally Responsive Teaching (CRT). CRT is defined as using the “cultural knowledge, prior experiences, and performance styles of diverse students to make learning more appropriate and effective for them; it teaches to and through the strengths of these students.” (Geneva Gay, 2000). In this way of teaching, all students are valued and brought into learning conversations.

Final Thoughts and Recommendations

In the 1940s, John Dewey delivered a lecture to Columbia University students in which he said, “The world is moving at a tremendous rate. No one knows where. We must prepare our children not for the world of the past, not for our world, but for their world - the world of the future” (Davee, Regalla & Chang, 2015). With their emphasis on interdisciplinary studies, creativity and critical thinking, and learning for all students, makerspaces are becoming increasingly a part of K-12 learning environments. Halverson and Sheridan (2014), in their seminal work on the maker movement in education write, “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” (p. 503). In the educational goal of preparing all learners for an unknown future, makerspaces are positioned to positively contribute in powerful ways.

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