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Evaluating the Benefit of the Maker Movement in K-12 STEM Education

Bart Taylor

Texas A&M University, btaylor@tamu.edu

Abstract

The Maker Movement is a community of enthusiasts who personify a do-it-yourself mentality and who embody the model of lifelong learning. The community is comprised of hobbyists, tinkerers, engineers and artists who think critically to design, and engage in hand-on projects for learning and leisure. There is a growing interest to incorporate this model of learning into K-12 education as a way to increase engagement in Science, Technology, Engineering, and Mathematics, or STEM, education through the use of Makerspace modeled laboratories. This article will investigate three criteria in determining whether there is value in integrating the Maker Movement into classroom instruction: 1) perceptions of Makerspaces; 2) comparison of the Maker Movement to 21st Century Learning skills; and 3) the viability of school district implementation.

Keywords: STEM; Maker; Maker Movement

Introduction

Since 2004, K-12 schools have worked to make Science, Technology, Engineering, and Mathematics (STEM) education a priority in order to help keep the United States globally competitive. Many have supported initiatives in STEM education, including President Obama in his 2012 State of the Union Address when he stated, "Think about the America within our reach. A country that leads the world in educating its people. An America that attracts a new generation of high tech manufacturing and high paying jobs" (as cited in Avery, Z., 2013, p. 56). The 113th Congress has already introduced nine pieces of legislation with the express goal of encouraging increased participation amongst various student groups in STEM education. More recently, the Maker Movement has been incorporated into classic STEM education models.

The Maker Movement culture emphasizes learning by doing, construction, and innovation. The trend might be new, but the model is not. Doughtery (2012) explains how "a century ago, psychologist and education reformer John Dewey extolled the virtues of learning by doing, and contemporary science of the brain confirms the importance of tactical engagement and of using our hands in the learning process" (p. 12). The Maker Movement has come about in part because of people's need to engage passionately with objects in ways that make them more than just consumers. Makers, at their cores, are enthusiasts, such as those engaged in the early days of the computer industry in Silicon Valley. The core of the Maker Movement parallels the best practices of STEM education, and it is expanding into education, business and government. The Maker Movement has a simple formula, one based entirely on talking to people who make things, seeing what those people do, and nurturing the diversity of ideas that come together in a community space. Providing students room for inquiry and innovation creates students who have a stronger background in STEM topics but also in problem solving and collaboration, all of which are imperative towards building 21st century skills. A report from the Committee on STEM Education National Science and Technology Council (2013) summarizes the need:

> The health and longevity of our Nation's, citizenry, economy and environmental resources depend in large part on the acceleration of scientific and technological innovations, such as those that improve health care, inspire new industries, protect the environment, and safeguard us from harm. Maintaining America's historical preeminence

> in the STEM fields will require a concerted and inclusive effort to ensure that the STEM workforce is equipped with the skills and training needed to excel in these fields (p.3).

There is a strong case for increased STEM and inquiry-based education, and this need can be fulfilled by the Maker model; however, there exists a significant issue with determining the benefits to education, including the perceptions or reputations of Makerspaces, the fit of Makerspaces into 21st century learning, and the viability of implementing a Makerspace in a school district.

Review of the Literature

The Maker Movement is a grass roots level community of do-it-yourself hobbyists, engineers, and artists who creatively design and build projects for both playful and useful ends. Dougherty (2012) states that "there once was a time when most Americans commonly thought of themselves as tinkerers" (p. 11). The Maker Movement has come about because of a need to engage passionately with the objects and projects that inspire learning as well as access to new digital technology that bridges the barriers of high-tech labs and makes them more accessible to the everyday home engineer. It has further been strengthened by *Make* magazine, first published in 2005, and by *Maker Faire*, a city-wide exposition that showcases the work of local Makerspaces, in 2006 (Dougherty, p. 11). The movement has created a culture of people who have found a connection and a way to express themselves through Making, which has caused an explosion of Makerspaces around the United States. "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" (Halverson, 2014, p. 495). Because of the growing interest in the Maker Movement, many educators seek to bring Makerspaces into the K-12 classroom.

Martin (2015) states that "there is growing interest among educators in bringing making into K-12 education to enhance opportunities for students to engage in design and engineering practices, specifically, and science, technology, engineering, and mathematics (STEM, or STEAM when art is included) practices, more generally" (p. 30). Peppler and Bender (2013) further support the Maker initiative in K-12 education by stating "there is a growing national recognition of the maker movement's potential to transform how and what people learn in STEM (science, technology, engineering, and mathematics) and arts disciplines" (p. 23), and declare that "making is well aligned with the new standards, which bring engineering into the K-12 curriculum at a national level for the first time" (p. 30). The ideas derived from the Maker Movement do inspire student engagement; however, educators must determine whether the movement will fit into 21st century learning.

The Partnership for 21st century learning, or P21, is a movement that is trying to lead a new educational reform. Wan & Gut (2011) state that the "draw is to get citizens who can succeed" (p. 41) in an era where the economic push for reform shows that "education is the new currency" (p.42). P21 is a framework based on a solid foundation of content and knowledge, and it embraces the ideals of promoting education that focuses on critical thinking, problem solving, communication, collaboration, creativity, and innovation. Because of the overwhelming access to knowledge and learning provided by technology and the internet, students need a new way to understand and interpret this bombardment of facts and information. P21 invites us to create a learning experience that will engage learners in ways that will prepare them with the skills to be successful in the 21st century. "You cannot be an effective critical thinker without something to think critically about" (Wan & Gut, p. 52). Karen Cator states that "educators can leverage technology to create an engaging and personalized environment to meet the emerging educational needs of this generation" (How Do You Define 21st-Century Learning, n.d.). The framework proposed in learning 21st century skills allows us to synergize content with skills, and the outcomes will promote global awareness, financial and economic literacy, civic literacy, and health literacy.

When the Maker Movement is paired with the framework for 21st century learning, several parallels emerge. While making sense of the Maker Movement in educational settings, Burke (2015) reports that:

> One area of balance in makerspaces is in providing group training on specific creative activities while also offering open lab times in the makerspace for individuals to work independently or in small collaborative groups on their projects. Makerspaces can be a mechanism for encouraging students to experiment and learn beyond the classroom and outside of the normal structure of their assignments. Students are encouraged to examine new means of creation and in doing so they strengthen and apply more broadly the learning they experience in their courses. (p. 497)

Peppler, Maltese, Keune, Chang, & Regalla (2015) provide insightful data collected from a three part survey of Makerspaces in the United States and respondents from one site in Korea. The survey received respondents from 51 youth-oriented makerspaces that reported serving a median of 450 visitors annually (Peppler et al., part 1, p. 1). The following three tables provide data that connect STEM education to the Maker Movement and to 21st century learning. Table 1demonstrates an alignment between Makerspaces and several popular educational initiatives in the United States including 94 % in STEM, 89% in STEAM, 79% in Technology Education, 51% in 21st Century Community Learning Centers, and 40% in Career and Technology Education. The data show that Makerspace designers understand current educational initiatives and that Makerspaces support these frameworks.

Table 1. *List of National Educational Initiatives and Percent of Makerspaces that Indicate Alignment*

Educational Initiative	Percentage of Sites that Indicate Alignment		
	Yes	No	Not Familiar
Science, Technology, Engineering, and Mathematics (STEM) (ed.gov/stem)	94	6	0
STEM + Art = STEAM (stemtosteam.org)	89	9	2
Technology Education (ed.gov/connected)	79	9	13
Media Education	57	15	28
21st Century Community Learning Centers (21st CCLC) (www2.ed.gov/programs/21stcclc)	51	11	38
Next Generation Science Standards (NGSS) (nextgenscience.org)	49	21	30

Career and Technical Education (CTE) (careertech.org/cte-vision)	40	31	28
Common Core State Standards (CCSS) in Mathematics (corestandards.org/Math)	38	36	26
Common Core State Standards (CCSS) in Language Arts (corestandards.org/ELA-Literacy)	38	43	19
Information and Communications Technology (ICT)	34	26	40
100kin10 (100kin10.org)	4	34	62

Note. Adapted from the *Survey of Makerspaces*, *Part II*, p. 1, by Peppler et al., 2015.

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Table 2. *Frequency of Sites Reporting Engaging in 21st Century Creativity, Innovation, Critical Thinking and Problem Solving Skills*

	Never	1-2 Times Per Month	Once Per Week	Multiple Time/Week
Think Creatively				
Elaborate, refine, analyze and evaluate their own ideas in order to improve and maximize creative efforts.	4.3	27.7	19.1	48.9
Work Creatively with Others				
Develop, implement, and communicate new ideas to others effectively.	2.1	21.3	25.5	48.9
Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work.	8.5	10.6	27.7	51.1
View failure as an opportunity to learn; understand that creativity and innovation is a long-term, cyclical process of small successes and frequent mistakes. (www2.ed.gov/programs/21stcclc)	6.4	14.9	23.4	55.3
Use System Thinking				
Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems.	12.8	17.0	42.6	27.7
Solve Problems				
Solve different kinds of non-familiar problems in both conventional and innovative ways	6.4	17.0	27.7	48.9

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Note. Adapted from the *Survey of Makerspaces, Part II*, p. 1, by Peppler et al., 2015.

Table 3. *Frequency of Sites Reporting Engaging in 21st Century Life and Career Skills*

	Never	1-2 Times Per Month	Once Per Week	Multiple Time/Week
Flexibility and Adaptability				
Adapt to varied roles, jobs responsibilities, schedules and context.	4.3	29.8	31.9	34.0
Work effectively in a climate of ambiguity and changing priorities.	6.4	23.4	21.3	48.9
Incorporate feedback effectively.	4.3	17.0	42.6	36.2
Deal positively with praise, setbacks and criticism.	2.1	14.9	34.0	48.9
Initiative and Self-Direction				
Utilize time and manage workload efficiently.	6.4	12.8	21.3	57.4
Monitor, define, prioritize and complete tasks without direct oversight.	4.3	25.5	19.1	51.1
Go beyond basic mastery of skills to explore and expand one's own learning and opportunities to gain expertise.	6.4	25.5	31.9	36.2

Note. Adapted from the *Survey of Makerspaces, Part II*, p. 1, by Peppler et al., 2015.

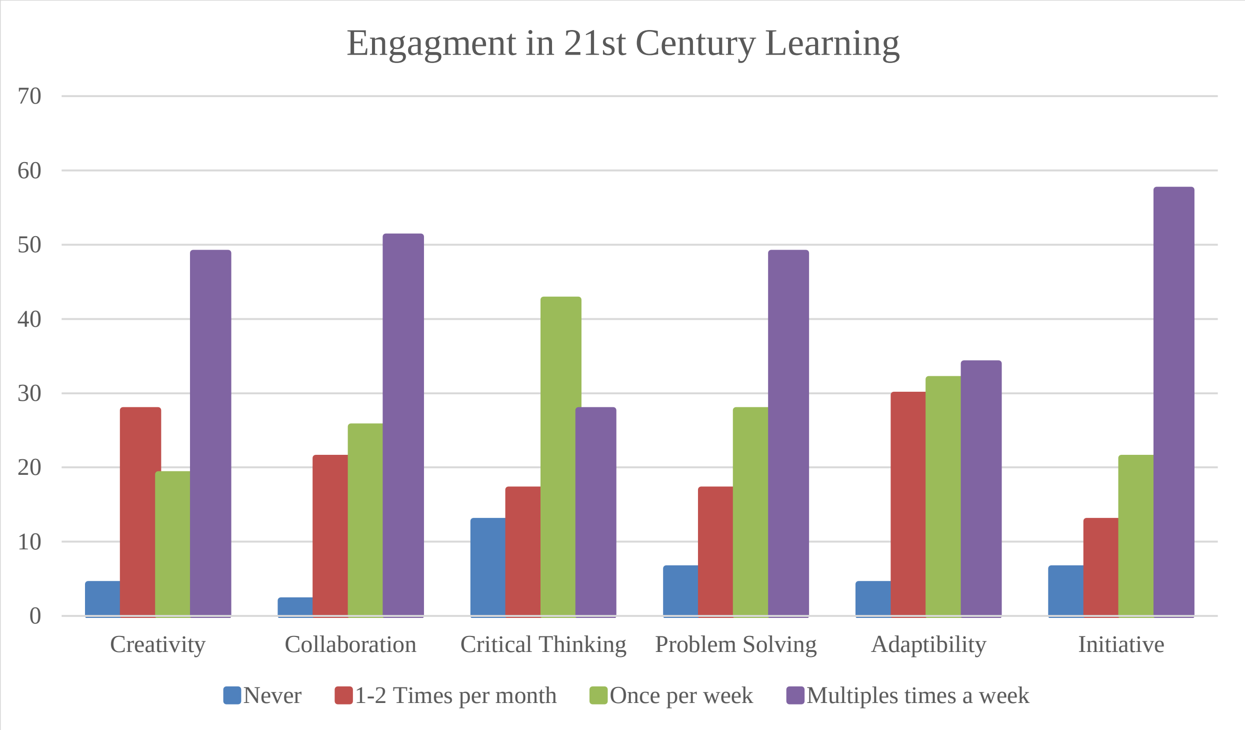
The data presented in table 2 and table 3 show a detailed survey response to questions about the ways Makerspaces support the framework of 21st century learning. Creativity, collaboration, critical thinking, and problem solving are represented in table 2, and flexibility, adaptability, initiative, and self-direction are addressed in table 3. The frequency distributions in both tables detail the frequent occurrence of engagement in 21st century learning skills in Makerspaces.

Educators are excited about the idea of integrating Makerspaces into their classrooms because "Making gives youth access to sophisticated tools for building and for thinking" (Martin, 2015, p. 36), but before they can begin this integration, they must clearly understand what comprises an actual makerspace. Makerspaces are housed in any building that will support the Maker community. They can be found in libraries, local businesses, or university labs, and larger communities can support Makerspaces by housing them in freestanding facilities. Makerspaces provide access to new fabrication technologies and equipment which allows enthusiasts to "not only design their ideas digitally, but to turn those ideas into real objects" ("Making in Education", n.d.). Charter & Keiller (2014) provide data in figure 7 that details activities found in a typical Hackerspace, which is synonymous with a Makerspace. Respondents were asked to rank how frequently specific activities are undertaken using a five-point Likert scale that ranged from "always" to "never." More than 60% of respondents ranked coding, software development, and working with electronic devices "always" or "often", making these by far the most common of the ranked activities (p. 11). Burke (2015) provides data in table 1 and table 2 that list "the 15 most common technologies and activities in library makerspaces" (p. 498). The most commonly represented makerspace activities and technologies we were computer labs and software for digital photo and video editing, computer programming, and 3D animations. Software for 3D modeling and 3D printing were also fairly common.

Analysis

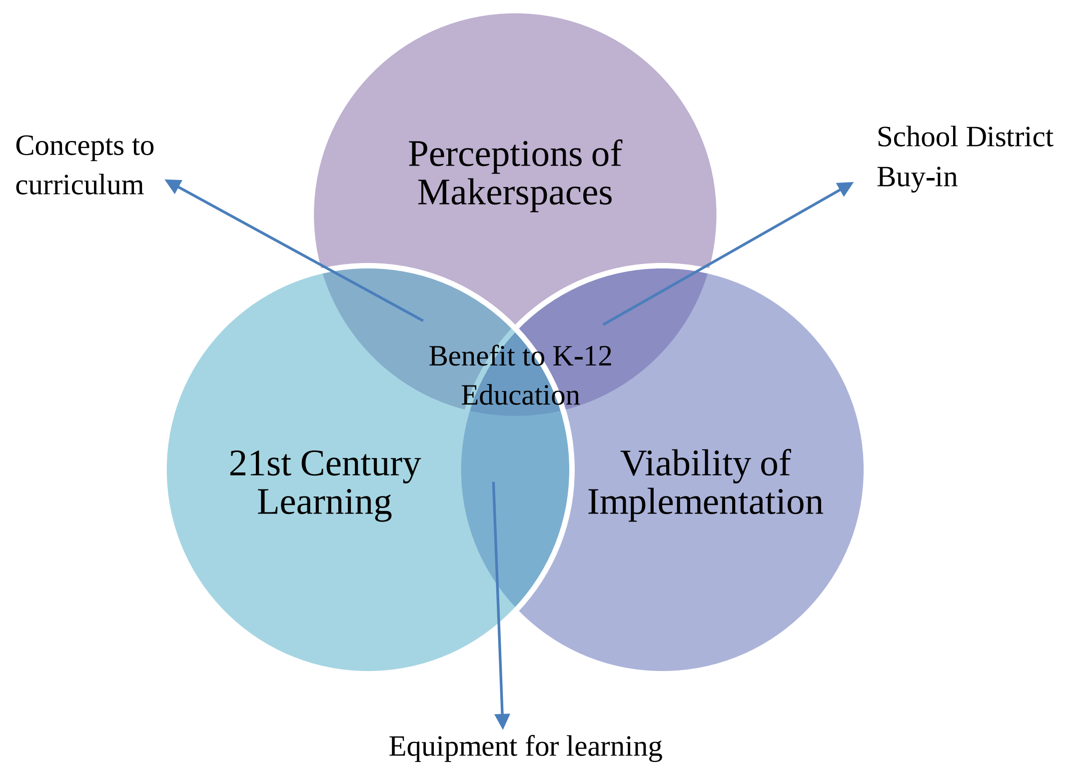
"The Maker Movement is an innovative way to reimagine education" (Peppler & Bender, 2013, p. 23), and because it encourages student discovery and critical thinking, the movement has merit in the educational setting. The data from table 2 and table 3 is represented in figure 1 to show the frequency of the levels of engagement in 21st century learning. Creativity, collaboration, problem solving, adaptability, and initiative all occurrence in a Makerspace multiple times per week, and critical thinking typically occurs once per week.

Figure 1



Considering both the perceptions of makerspaces and the data that demonstrate the engagement in 21st century learning which is encouraged by activities and technologies used in a Makerspace, a clear argument for incorporating the Maker Movement in K-12 education begins to arise. Figure 2 creates a Venn diagram combining perceptions of makerspaces, 21st century learning and viability of implementation. The combination of the three overarching concepts supports the creation of three new ideals that provide additional insights to the goal of incorporating Makerspaces to benefit the K-12 educational setting.

Figure 2



The perception of Makerspaces and 21st century learning leads to the idea of developing the makerspace concepts into a tangible curriculum. The activities that are encountered in a Makerspace, such as software coding and 3D printing, can be transformed into classroom projects that match the goals of a 21st century education. Equipment for learning is derived from the needs of a Makerspace to support 21st century learning and the actual viability if implementation. Computers, software, 3D printers, soldering irons, and tools for the projects and curriculum that are developed will be needed in order to transform a classroom setting into an actual Makerspace. Santo, Peppler Ching & Hoadley (2015) do warn that "large investments are being made to spread maker education, yet there is little understanding of how organizations that are intended targets of such investments learn to develop new maker related educational programs" (p. 1). Equipment for learning will be the highest cost when trying to develop a school district's buy-in of the concepts of makerspaces; however, the positive perceptions that have led people to embrace the Maker movement across the United States and the real viability of makerspace implementation strongly support buy-in at the local level.

Conclusion

The Maker Movement is a community driven learning model that is engaging learners across the United States. It "keeps us young because it's always fresh" (Dougherty, 2012, p. 14). The values of this learning movement of tinkerers and do-it-yourself enthusiasts align with 21st century learning framework and standards in STEM education, creating a foundation for life-long learning. The importance of adopting this style of learning into the K-12 classroom setting is needed. Halverson (2014) states that "learning through making reaches across the divide between formal and informal learning, pushing us to think more expansively about where and how learning happens" (p. 498). Taking into account the perceptions of Makerspaces, their alignment with 21st century learning, and the viability of implementing them in classrooms, a valid need for the Maker Model in K-12 classrooms becomes clear.

Makerspace concepts can be transformed into a rigorous and robust classroom curriculum. Learning equipment can be furnished to support a classroom laboratory makerspace and the buy-in for a school district and surrounding community can be positively influenced by the data. Santo, Peppler Ching and Hoadley (2015) state that "participation in educational networks plays an important infrastructural role in inspiring, validating and orienting towards maker education" (p. 8). The Maker Movement has a place in education, and classroom makerspace laboratories are the place to start. Martin (2015) contends that "making gives youth access to sophisticated tools for building and for thinking" (p. 36). The value in learning created from fostered by the Maker Movement model can create connections between students and STEM education. The Makerspace model will allow students to connect the hands and the mind in a cognitive and physical capacity, preparing them with 21st century skills. The Maker Movement is a forward thinking model for education and will enhance any campus when it is implemented correctly.

References

Avery, Z. K., & Reeve, E. M. (2013). Developing effective STEM professional development programs. *Journal for Technology Education, 25,* 1.

Burke, J. (2015). Making sense: Can makerspaces work in academic libraries?. *Computer Workstations, 73,* 67.

Charter, M., & Keiller, S. (2014). Grassroots innovation and the circular economy: a global survey of repair cafés and hackerspaces. *The Centre for Sustainable Design.*

Dougherty, D. (2012). The maker movement. *Innovations, 7(3),* 11-14.

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review, 84(4),* 495-504.

How Do You Define 21st-Century Learning? (n.d.). Retrieved from http://www.edweek.org/tsb/articles/2010/10/12/01panel.h04.html

Making in Education. (n.d.). Retrieved from https://makermedia.com/about-us/making-in-education/

Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research (J-PEER), 5(1),* 4.

National Science and Technology Council. (2013). A Report from the Committee on STEM Education National Science and Technology Council. *Federal Science, Technology, Engineering and Mathematics (STEM) Education 5-Year Strategic Plan.*

Peppler, K., & Bender, S. (2013). Maker movement spreads innovation one project at a time. *The Phi Delta Kappan, (3),* 22.

Peppler, K., Maltese, A., Keune, A., Chang, S., Regalla, L., & Initiative, M. E. (2015). Survey of makerspaces, part I. *Open Portfolios Maker Education Initiative.*

Peppler, K., Maltese, A., Keune, A., Chang, S., Regalla, L., & Initiative, M. E. (2015). Survey of makerspaces, part II. Open Portfolios Maker Education Initiative.

Peppler, K., Maltese, A., Keune, A., Chang, S., Regalla, L., & Initiative, M. E. (2015). Survey of makerspaces, part III. Open Portfolios Maker Education Initiative.

Pines, E., Sullivan, P., & Nogales, L. (2015). Broadening participation through engagement in the maker space movement. *ASEE Annual Conference and Exposition Proceedings.*

Santo, R., Peppler, K., Ching, D., & Hoadley, C. (2015) Maybe a maker space? Organizational learning about maker education within a regional out-of-school network. *HRL Makerspace Expansive Learning Fablearn Submission.*

Wan, G., & Gut, D. M. (2011). Bringing schools into the 21st century. *Dordrecht; Springer.*