Beyond the Maker Movement: A Preliminary Partial Literature Review on the Role of Makerspaces in Engineering Education

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abstract

Makerspaces have grown over the last few years as public awareness of the maker movement has increased. Makerspaces are open to the public as community design studios that cultivate creative and technology-based projects alike. Fabrication labs and makerspaces serve as collective organizations that help facilitate design and prototyping for individuals that may not have access to that equipment or material outside of that physical location. In engineering education, there is a vast amount of research on the use of design-based principles to enrich engineering education in the form of design projects, design competitions, and capstone courses. Makerspaces are environments in which design takes place, yet, the body of knowledge available on the role of makerspaces in engineering education as locations to increase technology and engineering literacy seems limited.

It is the purpose of this paper to present a preliminary partial literature review of some relevant prior work on the role of makerspaces in engineering education. This review explores a select few works on makerspaces within engineering education and synthesizes the findings such as major agreements and debates within the research area. As an introductory literature review, this paper explores the use and definition of the term makerspace and examines the history and evolution of makerspaces as related to the constructivism cognitive framework of learning.

This literature review provides an introductory overview of the role of makerspaces as locations to increase technology and engineering literacy in engineering education. This paper also highlights some areas of research within engineering education that examines makerspaces in depth and their relationship to design-based education. This literature review identifies some gaps in the current research that can lead to the development of novel research questions. The questions will inform future research that will contribute to the body of knowledge available on the role of makerspaces in engineering education.

introduction

Makerspaces have grown over the last few years as public awareness of the maker movement has increased. Makerspaces are open to the public as community design studios that cultivate creative and technology-based projects alike. Fabrication labs and makerspaces serve as collective organizations that help facilitate design and prototyping for individuals that may not have access to that equipment or material outside of that physical location. In engineering education, there is a vast amount of research on the use of design-based principles to enrich engineering education in the form of design projects, design competitions, and capstone courses. Makerspaces are environments in which design takes place, yet, the body of knowledge available on the role of makerspaces in engineering education seems limited.

It is the purpose of this paper to present a preliminary partial literature review of some relevant prior work on the role of makerspaces in engineering education. This review explores a select few works on makerspaces within engineering education, synthesizes the findings such as major agreements and debates within the research area. This literature review explores the use and definition of the term makerspace and examines the history and evolution of makerspaces as related to the constructivism cognitive framework of learning. This preliminary partial literature review is the initial step in discovering some gaps in the current research that can lead to the development of novel research questions. The questions will inform future research that will contribute to the body of knowledge available on the role of makerspaces in engineering education.

background

The concept of the Maker Movement was developed by Dale Dougherty, the founder and CEO of Maker Media in 2005 [1]. Along with the publication of *Make:* magazine, Dougherty initiated the Maker Faire event to support the movement he popularized. Many individuals have provided various definitions for the social phenomena known as the Maker Movement, but Martin's definition is selected for this body of work because of its universal nature. "The Maker Movement represents a growing movement of hobbyists, tinkerers, engineers, hackers, and artists committed to creatively designing and building material objects for both playful and useful ends [2]." There are three major components of the Maker Movement: the act of making, the individuals or makers that participate within the movement, and the makerspace, which is the studio or workshop where making take place [3].

synthesis of findings from a select few works within the makerspace research

Some of the significant agreements and debates within the makerspace literature involve the three major components of the maker movement, which are the activity of making, the individuals or makers that participate within the movement, and the makerspace. Two minor themes span the topic of makerspaces in education that do not fall squarely into one of the three major components of the maker movement. These topics include the relationship between makerspaces and entrepreneurship, as well as the prioritizing one of the three maker movement components over another.

major agreements and debates within the makerspace literature

activities that take place within maker environments

Creating, constructing, building, designing and playing are all forms of making. As it relates to the maker movement, making involves building techniques common to crafter, tinkers, and hobbyist, along with the use of digital technologies such as 3D printers for the construction of various objects [2]. Dougherty has been quoted saying that "experimental play" is at the heart of the maker movement, which is echoed in the literature by the "playful" attribute of the maker mindset [1].

A key element of making is the practice of design. Most makerspaces allow users to construct physical models using computer-aided design and 3D printers to prototype artifacts. In relationship to the construction that takes place in maker spaces, most of the literature states that makerspaces facilitate activities constant with the constructivist or constructivism cognitive framework of learning [2]–[6]. Essentially, "Making as a pedagogy reflects theories of constructionism [7]."

Making involves many different activities including learning, yet the nature of that learning beyond constructivism is not fully agreed upon in the literature. Traditional makerspaces are sites of informal learning [2], [3], [7], [8]. Making involves sharing and collaboration and knowledge building within communities of practice [2], [6], [8]–[12]. Some advocate that makerspaces can promote technology and engineering literacy [6], [7].

A key component of makerspaces are the activities that take place within maker environments. These activities include playful exploration, design, and construction in informal collaborative settings of communities of practice. Currently, there is a universal agreement that learning that takes place in makerspaces follows the constructivism cognitive framework of learning, yet there is very little in the literature about research on how this learning is being measured or observed across different makerspaces and the activities being performed in those spaces.

individual and group identities within the maker movement

Individuals and the communities they inhabit are other critical components of makerspaces. Crafters, tinkers, hobbyists, and now students are makers or participants in makerspaces. The topic of maker identity is just now being explored across the literature, especially when it comes to engineering education.

The maker movement has been criticized for claiming to be an open-access community, yet being driven by Silicon-Valley middle-aged, affluent, white, males: "We have also seen how identities of participation have been constrained by early adopter voices [3]." If these spaces were created by white males and are dominated by white males, then the question becomes: Are they really an open and accessible community where everyone and all ideas are welcome to flourish?

Across the science education literature, there are references to Vygotsky and Freire and "a need to question assumptions about who does and does not engage in making, particularly with respect to the deep histories of practice and range of making activities that exist in non-dominant communities [7]." Others express that the maker movement can positively influence identity by giving students the opportunity to bring in elements of their personal identity into the "typically technocratic work of schooling" and thereby "open[ing] doors to students traditionally excluded from technical domains [13]."

Weiner et al. used an identity framework to describe the factors and experiences that led to the adoption of a maker identity [14], [15]. Investigations of diversity and inclusion of makerspaces are numerous and are just begging to take shape [14], [16]–[18] as diversity and inclusion are significant agenda items within engineering education research [19], [20].

The group identity of makers can be described as a community of practice. “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 [3].” These communities interact face to face within physical spaces such as museums, libraries, classrooms or public makerspaces; via online social media where they can share project ideas and knowledge; and at larger live events like Maker Faires and Makeathons. As stated earlier, making involves sharing, collaboration, and knowledge building within communities [2], [6], [8]–[11].

Making as an act is both personal and communal, which influences both the maker’s personal and community identities. The makerspace identity or cultural climate can impact whether new members join or participate in that space [12], [16], [21]. Research is just now being conducted around identity, positionality, intersectionality, and access within makerspaces [12], [18], [22], [23] and could shed more light on the use of these educational spaces to attract and serve a more diverse population. Claims have been made that these spaces can be used to reach underserved populations such as under-represented minorities and female students that are interested in STEM disciplines, yet there are currently no published or readily accessible studies to verify this statement.

physical environments, specific tools and digital technology that support makers

Many makerspaces are open to the public as community design studios that cultivate creative and technology-based projects alike. Halverson et al. define makerspaces holistically as “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 [3].” Makerspaces can have various levels of access and can vary in the types of tools and equipment available to its users.

As these shared spaces become more widespread with the public, more schools, libraries, and colleges are creating and opening makerspaces within their properties. Davee et al. make the distinction that makerspace can be dedicated, distributed or mobile [10]. Dedicated makerspaces are a central physical space dedicated to maker activities, whereas distributed makers spaces are separate spaces found throughout an organization that are used for maker activities. Mobile makerspaces take the form of a small project box or cart used throughout a school or museum, or something as large as a bus similar to a traveling book library or a food truck. There is evidence to suggest that having multiple makerspaces within an institution is an indication of more making within the curricula [24]. Most of the literature covered in this review only discussed dedicated makerspaces and did not treat multiple makerspaces within an institution as distributed makerspace.

Physical location and layout of makerspaces can impact the use of the space especially on university and college campuses [21], [25], [26]. Access to makerspaces can depend on where the space is located, such as community-based organization versus a university campus. Some makerspaces have an open-access policy for the communities they serve, while others require a monetary fee for equipment use [18]. The majority of the university population has access to libraries, but not all have access to engineering halls or labs [18], [25], [26]. On university and college campuses, use of a space could be determined by university status (student, faculty, staff or alumni), as well as department affiliation. With the growth of makerspaces on university campuses, some efforts have been made to develop and implement some best practices to

establish new facilities [21] and to create a classification system of academic makerspaces as a means to compare different makerspaces for planning purposes [27].

The tools and equipment available, along with the design and layout of each makerspace, can depend on the community it serves. One of the most common features of any makerspace is the use of digital tools for the creation of physical artifacts [2], [3], [6], [9], [25]. Along with 3D printers, many maker workshops include other rapid prototyping tools that can be used on material like wood, metal and plastics, such as computer numerical controlled (CNC) routers, welders, laser cutters, computer-aided design (CAD) stations, printed circuit board (PCB) mills, and embroidery machines for textiles [2], [25]. Low tech tools and equipment include microcontrollers and basic electronics; hand tools; art and craft supplies; whiteboards and tables or spaces dedicated to collaborative work [2], [10], [21].

Makerspace environments, specifically the physical location, equipment, and digital technology, depend on the maker community it supports. Makerspaces open to the public will differ from educational institutions in terms of the access to the space, the physical layout, types of tools available, as well as the types of projects that can be undertaken by its community's members.

minor agreements and debates within the makerspace literature

Two minor themes span the topic of makerspaces in education that do not fall squarely into one of the three major components of the Maker Movement. These topics include the relationship between makerspaces and entrepreneurship, and the emphases of one maker movement component over another.

relationship between makerspaces and entrepreneurship

While the purpose of making can vary for everyone, some individuals use makerspaces to take advantage of the rapid prototyping equipment to manufacture small goods to sell as a hobby. Some of the literature expresses the possibility of makerspace as an entry point for entrepreneurship [7]–[9], [28]. Makerspaces allow for the possibilities of small-scale production and grassroots innovation [9]. Van Holm suggests the maker movement will influence entrepreneurship by attracting more people to product design, building new "diverse" networks, and lowering the costs for prototyping [28]. While it is true that access to the design equipment within makerspaces can lower the costs for prototyping, there is currently no research to substantiate the maker movement influence on entrepreneurship. Across media, various individuals have claimed that makerspaces are associated with community and economic development, yet there are currently no published or readily accessible to the researcher studies to verify this claim. There exist public entrepreneurial-oriented makerspaces which are financed by commercial industries that manufacture and sell the design and fabrication tools, but entrepreneurship is not typically associated with makerspaces used in educational settings. [7], [8].

prioritization of one maker movement component over another

The three major components of the maker movement can be reduced to the activity of making (what or why), the individuals or makers that participate within the movement (who), and the makerspace studios (where). The literature is divided on how these components are discussed and considered. These components are often expressed or acknowledged, but not always given equal weight in the literature. Some researchers have mentioned the danger in emphasizing one component over the others [3], [6]–[8] is that it can reduce the discussion of the topic to a conversation about digital technologies that misses the essence of the maker movement: the social phenomenon of crafters, tinkers, hobbyists, and students who are creating technology-based projects within community design studios.

discussion

The maker movement is no longer a fad and has established itself in society, and in particular, the community of education. Currently, the constructivism cognitive framework of learning is widely accepted as the making pedagogy, yet there is very little in the literature about research on how learning is being measured or observed across different makerspaces and the activities being performed in those spaces. Engineering education researchers can use the informal setting of makerspaces to look beyond the formal classroom to conduct research [29] to answer the questions left unanswered: Can the use of makerspaces be used to enrich student learning? Since makerspaces were conceptualized by and are dominated by affluent white males, are makerspaces really an open and accessible community where everyone and all ideas are welcome to flourish? Can makerspaces at institutions for education, such as schools, libraries, and colleges, create more inviting spaces? Will the use of these educational makerspaces change the landscape of the maker movement? Will these spaces do a better job serving a more diverse population? Could these spaces then be used to reach underserved populations? What about under-represented minorities and female students that are interested in STEM disciplines, but have shied away or left fields of engineering entirely because they felt as if they did not fit in or belong?

Makerspace environments, specifically the physical location, equipment, and digital technology, depend on the maker community it supports. There exists the possibility of makerspaces to act as entry points for entrepreneurship. Can makerspaces support the entrepreneurship mindset of students if used in educational settings? The role of makerspaces within engineering education could be that they act as an informal setting for under-represented minorities and female students to explore engineering in a safe and supportive environment.

conclusion

This preliminary partial literature review of some relevant prior work provides an introductory overview of the role of makerspaces in engineering education. Some of the findings from a select few works address major agreements and debates within the makerspace literature and involve the three major components of the maker movement; which are the activity of making, the individuals or makers that participate within the movement, and the makerspace. Two minor

themes span the topic of makerspaces in education that do not fall squarely into one of the three major components of the maker movement. These topics include the relationship between makerspaces and entrepreneurship, and the prioritization of one maker movement component over the another. This preliminary partial literature review is the initial step in discovering some gaps in the current research that can lead to the development of novel research questions. These questions will inform future research that will contribute to the body of knowledge available on the role of makerspaces in engineering education.

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