FEATURE ARTICLE

The Value of Higher Education Academic Makerspaces for Accreditation and Beyond

by Vincent Wilczynski, Aubrey Wigner, Micah Lande, and Shawn Jordan

Institutions of higher education are incorporating makerspaces and skills on their campuses in support of institutional goals and accreditation requirements.

HIGHER EDUCATION ACADEMIC MAKERSPACES

UNIVERSITY AND COLLEGE CAMPUSES are constantly evolving, adding new facilities, resources, and programs to best serve students, faculty, and staff. Over the last decade many institutions have added academic makerspaces to their campuses, a development that allows individuals from across the university to come together to collaborate, design, fabricate, and learn in shared spaces. First popular in engineering departments, higher education academic makerspaces now have expanded to support multidisciplinary learning across all aspects of the university.

The evolution of higher education academic makerspaces to serve the entire university community is just one illustration of their ability to support a broad spectrum of institutional goals. Given the increased emphasis on documenting outcomes achievement and continuous improvement processes by regional and programmatic accrediting organizations, institutions are also finding value in the accreditation benefits associated with these spaces.

We use the term "academic makerspace" to describe the facility, staff, resources, and associated community that support creating, learning, and fabricating in an academic setting. Recognizing that elementary and high schools, as well as other education-based programs, house makerspaces, we use the term "higher education academic makerspace" for those spaces that are located on college and university campuses and generally accessible to the broader university community. Unlike a lab, which is often dedicated to a single activity, open only to specific students, or tied to a particular course, makerspaces are used for curricular, extracurricular, and personal activities (Ali et al. 2016; Wilczynski, Zinter, and Wilen 2016).

The size of higher education academic makerspaces ranges from 100 to over 1,000 active members (noting that not all members are in the space at any one time) in spaces spanning a few hundred to several thousand square feet. In addition to the availability of design and fabrication tools such as 3-D printers, laser cutters, mills, sewing machines, and soldering irons, higher education academic makerspaces also provide training in the use of these traditional and digital tools. Often higher education academic makerspaces are open to all members of the university, thereby serving an important role as a common location for individuals with diverse backgrounds to meet and work together. It is estimated that there are more than 150 makerspaces on university campuses, with the number growing each year (Barrett et al. 2015; Bryne and Davidson 2015).

A distinction of higher education academic makerspaces is found in the culture and community that form within. The underlying culture of makerspaces, both in academic and nonacademic environments, is one of collaboration, sharing, and additive innovation (Jordan and Lande 2016). Sharing one's work with others creates an open community and collaborative culture in which members are excited to assist one another and willingly exchange design knowledge. The diversity of users creates opportunities for members to work with and learn from others who have unique experiences and skills. The existence of these spaces and focused programs to integrate members has led to many unique collaborations among colleagues who may not have otherwise had the opportunity to work together, including the development of multidisciplinary courses (Ali et al. 2016). The open nature of these spaces promotes an intentional collision of random ideas, a design structure that has benefited many industries (Gertner 2012).

The appearance of higher education academic makerspaces on campus resulted from the traditions, contributions, and developments of many disciplines. For example, open and collaborative learning studios have been fundamental to art, design, and architecture programs. Similarly, hands-on design and open-ended problem solving have been key aspects of accreditation-driven engineering education initiatives. The open and collaborative nature of specific engineering teaching labs has also contributed. In an exploration of the future of engineering education, Smith et al. (2005) identified project-based learning as a growing pedagogical approach to the teaching of future engineers. Through the (renewed) emphasis on hands-on, project-based learning, collaborative spaces have emerged to help transform undergraduate engineering education.

Influenced by these factors, higher education academic makerspaces developed from the growing need for widely accessible technology and the increasing availability (and affordability) of design tools, including hardware and software. Given this context, some of the first higher education academic makerspaces were housed in schools of engineering. In the past several years, many university libraries have launched makerspaces with design and fabrication tools for patrons to use while relying on in-house, on-campus, and digital resources for training, facilitation, and support. Examples exist where libraries administer checkout processes for tools and equipment, similar to their traditional role in doing so for print material and other media. This development illustrates the wide spectrum of the higher education academic makerspace movement on university and college campuses.

As further examples of the scope of this movement, engineering and other discipline professionals have joined together to share knowledge and explore best practices related to higher education academic makerspaces. For example, in 2014 Arizona State University hosted a symposium focused on this topic, and the MakeSchools (n.d.) alliance was formed to catalyze academic making. In 2016 the White House convened a meeting on higher education academic makerspaces in conjunction with the 2016 National Week of Making and the National Maker Faire. International symposiums devoted to academic makerspaces were held in 2016 and 2017, with each event attracting hundreds of participants from across the world and over 100 papers written (ISAM 2017 Papers, Presentations, and Videos 2017; *Proceedings of the 1st International Symposium on Academic Makerspaces* 2016).

Learning within academic makerspaces is a nascent research topic within higher education. While the engineering education literature is rich in anecdotal reports on the impact of makerspaces, the newness of the field has limited quantitatively data-rich records of impact. Partnerships between schools of engineering and schools of education have been established at some institutions to study this topic, and it is expected that this field of research will rapidly advance as institutions apply collected data to better understand how such spaces impact student learning (Rosenbaum and Hartmann 2017). In the absence of such detailed reports at this time, it is proposed that the existence of a thriving community in an active higher education academic makerspace has great value from a program and regional accreditation review perspective.

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HIGHER EDUCATION ACADEMIC MAKERSPACES AND ACCREDITATION

Higher education accrediting associations help ensure the quality of academic programs by establishing criteria and periodically reviewing each institution's ability to meet those standards. Within the United States, institutions of higher education are reviewed by regional accrediting organizations such as the New England Association of Schools and Colleges (NEASC) and the Western Association of Schools and Colleges. Specific programs and academic disciplines are also reviewed by external evaluators against standards established by program accreditors. For example, the Accreditation Council for Business Schools and Programs reviews business programs while the Accreditation Board for Engineering and Technology (ABET) is the accrediting organization for engineering programs. Regional accreditation ensures that the college or university as a whole meets institutional standards, and program accreditation ensures that departments meet discipline-based standards.

Program accreditation standards place additional emphasis on the curriculum within each academic discipline, though both levels of accreditation address common elements that contribute to the teaching and learning environments. For example, both regional and program accreditors evaluate the financial, resource, and planning aspects of institutions and programs.

More specifically, institutions accredited by NEASC (per NEASC Standard 3–Organization and Governance) must provide evidence that "the institution creates and sustains an environment that encourages teaching, learning, service, scholarship, and where appropriate, research and creative activity" (New England Association of Schools and Colleges, n.d., Standard Three ¶ 1). Similarly, programs evaluated using the ABET standards must document (per General Criterion 7–Facilities) that "modern tools, equipment, computing resources, and laboratories appropriate to the program [are] available, accessible, and systematically maintained and upgraded to enable students to attain the student outcomes and to support program needs. Students must be provided appropriate guidance regarding the use of the tools, equipment, computing resources, and laboratories available to the program" (ABET, n.d., General Criterion 7 ¶ 1).

Higher education academic makerspaces can play an important role in substantiating the ability of an institution or program to meet such standards. The existence of a higher education academic makerspace within a particular department on campus, especially when the facility is open to the entire university community, illustrates the concept of continuous improvement as a mechanism to improve learning and promote creativity. Examples of the impact of higher education academic makerspaces on campus include case studies that detail cross-departmental initiatives to develop multidisciplinary academic courses and the development of summer product design programs, community outreach programs for high school students, and an institution-wide mechanism for learning basic fabrication skills (Ali et al. 2016).

In each case, these developments were created by the students, faculty, and staff associated with each campus makerspace. The fact that these programs, and usually these spaces, did not exist during previous accreditation reviews is evidence of the institutional and programmatic commitment to improving student learning. The investment of space and resources (including staffing and financial support) in higher education academic makerspaces also represents increased levels of fiscal, administrative, and planning support for student learning, areas specifically addressed in accreditation standards and criteria.

It is essential to note that engineering programs have a long tradition of hands-on learning, including open access for exploration both associated with and independent of coursework at a limited number of select universities. However, the concept of higher education academic makerspaces as spaces that support a number of factors in both engineering education and personal development, including design thinking, project-based learning, independent exploration, collaborative problem solving, and entrepreneurial endeavor, is relatively new.

As previously noted, the term "higher education academic makerspace" refers to the facility, staff, resources, and associated community that support creating, learning, and fabricating in a higher education setting. Included in this list is the respective community of users in each space who use the facility for their own projects and assist others in using these resources. With this expanded understanding of what constitutes a higher education academic makerspace, it is clear that the existence of such a space addresses programmatic criteria (such as ABET's General Criterion 7–Facilities) focused on student access to modern tools, resources, and computational resources as well as those criteria that monitor institutional support for learning. For example, ABET's General Criterion 8 on Institutional Support requires that resources be available to "acquire, maintain, and operate infrastructures, facilities, and equipment appropriate for the program, and to provide an environment in which student outcomes can be attained" (ABET, n.d., General Criterion 8 ¶ 2). Here, too, the existence of a fully functioning higher education academic makerspace accessible to students, faculty, and staff in an accredited program provides significant evidence aligned with this criterion.

Determinations of accreditation are based on a collection of evidence provided by the evaluated institution that details how the accreditation standards are met. This evidence must include assessment methodologies, results, and implemented improvements for each accreditation standard. The presence of a higher education academic makerspace provides a rich pool of quantitative and qualitative data that can be used to demonstrate compliance with accreditation criteria.

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Documenting student experiences is common practice for most higher education academic makerspaces. These experiences are frequently archived as videos, photographs, and articles that are accessible through a space's web portal. Many makerspaces even offer live video streaming of their activity space. Video data can provide insight into how a space is used, what hours are busiest, etc. These records help others learn what can be accomplished in the facility, including new members who are exploring the space, administrators who are evaluating the impact of the space, and potential contributors who are considering investing in the space. These records are also a valuable accreditation resource as they provide (readymade) narratives that can be grouped to demonstrate institutional or programmatic accomplishments related to specific accreditation standards.

It is also common for higher education academic makerspaces to collect a large amount of quantitative data, in part motivated by an inherent need to monitor and enforce safe operating practices. For example, most spaces have databases identifying the individuals who are authorized to use the space, with that information often including the name, gender, status (student, faculty, staff), and departmental affiliation of each user who has been trained and provided access to work in the space. Similar records frequently exist that record the enrollment in makerspace courses and programs (such as evening workshops). In addition, most spaces host academic groups, such as design-affiliated student associations, for meetings and work sessions, often logging these activities into a master planning schedule. Collectively, these records form a valuable database of information that can be applied as evidence of alignment with accreditation standards.

For example, such quantitative data is important evidence in documenting an institution's commitment to creating multidisciplinary education facilities that accommodate a variety of learning styles. Higher education academic makerspaces favor a form of active learning focused on both individual drive and community-based problem solving. User demographics and frequency-of-use data provide valuable documentation of an institution's commitment to fostering personal discovery, professional development, and lifelong learning—attributes frequently evaluated by institutional and program accreditation organizations.

Both forms of accreditation also review curriculum-related aspects of students' education, typically by allowing each institution or program to establish discipline-specific educational outcomes and measurement mechanisms to evaluate individual attainment of these outcomes, which often include academic and disciplinary knowledge, skills, and competencies. Higher education academic makerspaces provide venues in which to increase knowledge, skills, and competencies, with this topic explored in more detail in the following section.

SPACES AND LEARNING

Makerspaces are academically interesting in two ways: (1) enhancing teaching objectives and (2) enhancing student outcomes. It is worth noting that while these two concepts are similar, they are not identical in terms of modern accreditation standards. Teaching objectives can be seen as a measure of how specific skills are passed on from teachers to students. For example, if students leave a fluid dynamics course with a mathematical understanding of fluid flows and qualities, then the teaching objectives are met. In contrast, student outcomes in engineering, as defined by ABET (n.d.), include more nebulous and difficult-to-measure qualities such as the development of lifelong learning skills and effective communication skills or the ability to function on multidisciplinary teams and use modern engineering tools necessary for engineering practice. These broader student outcomes encompass experiences and learning that occur throughout a program of study rather than merely within one class. Makerspaces can play a role in both of these areas. Teaching objectives can be met via project-based assignments completed in a makerspace. Student outcomes can be enhanced by providing a community of practice where students can learn from peers, engage in self-directed learning, and be exposed to mind-sets that foster the more nebulous qualities, such as those of a lifelong learner and effective communicator. Makerspaces and their influence on both student outcomes and teaching objectives are explored below within the context of accreditation.

To understand how makerspaces could help universities reach accreditation goals, it is worth exploring what sorts of skills makers are learning within makerspaces and how this skill acquisition could be of use in academic engineering programs. Looking at makers outside of engineering students can offer insight into what sorts of skills are learned within makerspaces without the risk of observing what engineering students may be learning from classes and then applying within makerspaces. In a multiyear qualitative study of 36 young makers and 40 adult makers who presented their work at Maker Faires, it was found that makers outside of academia were learning strategies and skills applicable to both ABET general student outcomes criteria as well as discipline-specific criteria. The makers interviewed described examples that showed they were engaging with many ABET accreditation areas. Half described developing lifelong learning strategies; 75 percent showed competent communications skills when describing technical artifacts; 43 percent described the application of science, engineering, and math knowledge to their creations; and 38 percent described how they designed systems with constraints. The makers also showed discipline-specific skill development related to electrical and computer engineering (57 percent), mechanical engineering (28 percent), and manufacturing engineering (49 percent) (Wigner, Lande, and Jordan 2016). Further, the makers interviewed identified the core components necessary for learning new skills, including access to a space with the needed tools, access to online materials (YouTube, how-to blogs, etc.), and access to a community to provide mentorship and peer learning opportunities.

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The development of both engineering-specific skills and more broadly applicable student outcomes noted in the above study is not an isolated case. A 2014 National Academies-commissioned literature review of maker-related research found that the broader impacts of making, as claimed by the literature reviewed, were greater contextualization of STEM concepts and practices, deeper understanding of scientific concepts, and development of fabrication skills and innovative combinations of disciplinary skills (Vossoughi and Bevan 2014). This study also offered two areas of caution germane to the discussion of makerspaces and accreditation. First is the risk of focusing overly narrowly on STEM when making is often practiced in a more holistic, interdisciplinary manner. Second, the study warned against the fetishizing of tools. Tools themselves do not enhance education, but rather the community of makers who uses tools in specific contexts does. In essence, the tools don't make makers; makers make themselves. In addition, a 2017 meta-study of 43 (mostly qualitative) peer-reviewed articles on making showed that participants gained technical skill and knowledge along with increased self-efficacy (a vital part of lifelong learning) and noted making's positive effect on student engagement (Papavlasopoulou, Giannakos, and Jaccheri 2017). In all but one of the studies reviewed, making was integrated into the curriculum. Many of the studies showed making integrated into the classroom with positive results.

MAKING IN SPACES

While engineering departments were the pioneers in the recent expansion of high-tech higher education academic makerspaces, spaces for making things have been an integral part of university facilities for decades. Studio art spaces, for example for sculpture, contain many of the same tools as makerspaces, from 3-D printers to laser cutters and electronics stations. Much like higher education academic makerspaces, studio art spaces serve as places for students to learn and practice skills, explore creatively and freely, and collaborate with and learn from their fellows. Art and design have a long history of "critical making," which is the learning that occurs via the experience of creating and interacting with the physical through iterative processes and social feedback (Somerson and Hermano 2013). In studio spaces, instruction often takes place in the same shared workspace in which others quietly, or not so quietly, work on their own projects for different courses. The community is formed around growth in *making* art and integrates making into class and non-class time, both for assignments and for personal gratification or curiosity. However, these studio art spaces are generally walled away from the rest of the university and strictly disciplinary in nature. Engineering likewise houses computer labs dedicated to the simulation of industrial processes, circuit labs dedicated to the exploration of electronics, etc. In these spaces, both peer learning and coursework take place. Like studio art spaces, engineering labs are for insiders only, but unlike art studios, playful exploration is generally discouraged. Peer learning in makerspaces offers the possibility of increasing the diversity of work and people students encounter during their time in higher education.

Academic makerspaces can be viewed as places where interdisciplinary technology can be focused on training, work, and play. In the context of ABET accreditation for engineering programs, such a space could be one of the only areas on campus where the explicit goal of training engineers to function on multidisciplinary teams could be met. Where once a dedicated circuits lab, for example, would provide access to the tools and materials needed for students to complete their coursework and prepare for a real-world work experience, today's engineering career ecosystem is much more likely to require input from multiple disciplines in a rapidly changing technological landscape. To emulate the real environment, a sort of "circuits in context" lab is required, one where traditional parts and tools (e.g., resistors, capacitors, soldering irons) exist side by side with programmable microprocessors like the Arduino and the tools (e.g., 3-D printers, laser cutters, sewing machines, craft implements) needed to create the products the circuits might exist within. Here, students and student teams can explore not just what circuits are, but what they mean within a broader societal context—how circuits interface with people in real terms.

PLACES FOR ADDITIVE INNOVATION

In higher education academic makerspaces, students can engage in sharing practices that aid in the exploration of technical and design skills. The practices of additive innovation include (Jordan and Lande 2016)

» Being inspired by other students' creations
» Openly sharing and learning about technology through the creation of projects
» Designing and modifying versions of others' shared ideas
» Sharing ideas back with the community

This sharing environment allows students to learn, and reinforce the learning of, engineering skills through one another's creations. This sharing and remixing behavior lets students explore and create without necessarily facing the onus of being entirely original or struggling with fears that using others' concepts or ideas will be identified as cheating. Further, an emphasis on sharing through additive innovation encourages students to document and reflect on their work in the form of how-to guides. Examples of how these guides look in the Maker Movement can be found on websites like instructables.com, where thousands of individuals share their creations along with instructions on how one can create his/her own version (Instructables, n.d). Technological projects on such sites can range from simple circuits to complex electronics with multiple microcontrollers, sensors, and inputs. Unlike a simple how-to guide, however, Instructables acts as an open forum for creators—and copiers—to share their experiences and provide guidance to one another. This same creation feedback also occurs in physical makerspaces. The process of building, sharing, remixing, and peer mentoring can help create a community of practice that aids learning through playful investment, risk taking, and self-directed learning.

FUTURE FOR HIGHER EDUCATION

Higher education academic makerspaces allow for the significant growth of campus space in support of disciplinary and multidisciplinary collaboration. These curricular and extracurricular spaces are increasing in popularity and purpose. Because of the value of space on campus, explicitly connecting new types of spaces directly to the university mission is a concern. Given the wide array of faculty, students, and staff using higher education academic makerspaces, their role is becoming more institutionalized; given their connection to accreditation and direct support of academic programs such as engineering, they may already be sustainable.

The future of higher education may include the university working collaboratively across disciplines to solve larger and more complex problems to help society at large. The affordances that makerspaces can provide through community and technology may help catalyze and realize this potential role. Higher education academic makerspaces are an increasingly popular innovation in campus space planning that can help realize the balance of knowledge production that can also be applied to solve critical societal problems.

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