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A Classification System for Higher Education Makerspaces

Dr. Vincent Wilczynski, Yale University

Vincent Wilczynski is the Deputy Dean of the Yale School of Engineering and Applied Science and the James S. Tyler Director of the Yale Center for Engineering Innovation & Design. As the Deputy Dean, he helps plan and implement all academic initiatives at the School. In addition, he manages the School's teaching and research resources and facilities. As the James S. Tyler Director of the Center for Engineering Innovation & Design he leads the School's efforts to promote collaboration, creativity, design and manufacturing activities at Yale's academic makerspace. His professional interests in Mechanical Engineering are in the areas of data acquisition/analysis and mechanical design. He is the Co-Chair of the Executive Advisory Board of the FIRST Foundation and is a Fellow of the American Society of Mechanical Engineering. Previously, he was the Dean of Engineering at the U.S. Coast Guard Academy and has had fellowships at the MIT Charles Stark Draper Laboratory, the Harvard School of Public Health and with the American Council on Education. He has also served as the Vice President of Public Awareness for the American Society of Mechanical Engineers and was the 2001 Baccalaureate College Professor of the Year by the Carnegie Foundation, the only national award that recognizes outstanding college teaching.

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Abstract

Makerspaces exist in a variety of forms on college campuses. The terms “academic makerspaces” and “higher education makerspaces” are used interchangeably to distinguish these spaces and their users from those that exist in industry, K-12 schools, and within communities as non-profit and for-profit entities. Over the last decade, many forms of higher education makerspaces were established for a variety of purposes. It is proposed that standardized nomenclature be developed to structure discussions about and comparisons between higher education makerspaces. This paper proposes a classification system for higher education makerspaces and applies the proposed classifications to existing spaces. The classification system indicates the purpose of the space and includes indices for the space’s accessibility, population, size, and staffing. While noting that interpretation differences can result from system-wide generalizations, the concepts of categories and classes are routinely applied in nearly all fields to assimilate data and make comparisons. The higher education makerspace community is now large enough to benefit from an enterprise-wide classification system. It is suggested that such a classification system will be helpful to improve current spaces and guide the development of future spaces.

Introduction

Makerspaces on college campuses have become common over the last five years as physical locations and social networks to support curricular, extracurricular, and independent activities to design, fabricate, assemble, and test individual components and engineered systems. In addition to fostering collaboration and community, academic makerspaces create environments where users learn from one another and freely share their knowledge. Beyond being locations to work in, makerspaces help students learn theory and practice skills in training sessions, workshops, and formal academic classes. The history, value, and impact of makerspaces on university campuses, often referred to as higher education makerspaces (as well as academic makerspaces), has been previously reviewed and documented.[1,2,3]

The rapid growth of makerspaces within higher education is significant. While originating in engineering programs, often as extensions of the infrastructure needed to support open-ended problem solving in keystone and capstone courses, higher education makerspaces are also being created to support student learning in other disciplines.[4] The concept of learning by creating in the physical and digital space has also been adopted by liberal arts programs to promote critical and innovative thinking.[5] In a related development, the American Library Association identified makerspaces as an important trend in the evolution of libraries, including university libraries, as a method to explore innovations that propel scientific learning and discovery.[6] The range and types of activities in higher education makerspaces is large. For example, some higher education makerspaces are open to the entire university community, regardless of each user’s academic discipline, while others are restricted to students in specific courses.[7]

Higher education makerspaces have proliferated on college campuses over the last five years. Yet, establishing the number of higher education makerspaces is difficult due to the lack of universal methodology to identify, categorize, or catalog such spaces. It is estimated that there are more than 150 higher education makerspaces in the U.S., with additional facilities continuously being planned and developed.[8,9]

Equally important as the number of higher education institutions with existing makerspaces is the trajectory of makerspaces on college campuses. In 2014, an annual publication of trends and technologies that drive change in higher education identified makerspaces as a notable development based on the large number of institutions that were developing these spaces to integrate creativity with hands-on learning opportunities.[10]

Subsequent versions of this report in 2015 and 2016 elevated the status of makerspaces as a leading trend and as "important developments in educational technology for higher education." [11,12] The trend is expected to continue for two to three years as institutions build new facilities and repurpose existing spaces to help students develop skillsets with "real, applicable value in a rapidly advancing world." [11] These reports associate the growth in the number of spaces with an increased awareness of and value in hands-on design and fabrication activities that encourage creativity and open-ended problem solving. It is noted that the analysis presented in these reports is not restricted to engineering programs, but rather is a broad review of national trends on university campuses. The reports cite examples of makerspaces to support students majoring in journalism, digital media, art, and design. In all applications, makerspaces provide a way for students from across the university to gather as a community and become engaged in learning.

It is expected that the number of higher education makerspaces will continue to increase. This growth will result from the influence of other trends in higher education. Factors such as an increased appreciation for hands-on learning, the incorporation of creativity into fundamental courses, and the integration of problem-based learning in engineering courses will continue to propel the advancement of makerspaces on college campuses.[13,14] Growth has also been prompted by increased levels of attention on the curricular contributions of such spaces to develop design skills and fulfill accreditation standards.[15] Applying the concepts of making to entrepreneurial activities is another development that prompted the creation of academic makerspaces.[16,17,18,19]

A defining attribute of makerspaces is the resulting community where members work collectively and collaboratively. Makerspace members willingly share their knowledge and best practices with others. Anderson uses the phrase "open-innovation communities" to describe the comradery and cooperation that exist within makerspaces.[20] This collaborative spirit exists across higher education makerspaces, with organizations recently founded to identify and share best practices in academic making.[9,21,22]

Higher education makerspaces are quite varied. Each makerspace exists for a specific purpose, whether that be to support the work of individuals, co-curricular activities, or curricular-based instruction. Much more than a static facility, makerspaces are defined by the community of users that form the making culture of each makerspace. In addition to facilities and tools, makerspaces also offer instruction, training, and oversight. Some spaces are student-managed while others are entities much like libraries with designated professional management and support staff. The size of the makerspace and the collection of equipment varies from site to site, ranging from a few tools in a 100-square foot room to the latest digital fabrication equipment in a multi-floor, 10,000 square foot facility.

Given such disparities, it is not practical to simply compare features, attributes, and best practices from one makerspace to another if the spaces are dissimilar in size, function, or levels of support. It is proposed that a classification system based on standardized nomenclature be developed to structure discussions about and comparisons between higher education makerspaces. The classification system would succinctly indicate the purpose of the space and include indices that reflect the space's accessibility, population, physical size, and levels of staffing. By establishing a makerspace classification system, similar spaces could be more easily compared. Also, the collective practices, standards and equipment within each category of space would produce meaningful metrics to compare each space to the norm of a classification group.

Identifying and Sharing Best Practices in Higher Education Making

Understanding the origins of making helps explain the adoption of this form of learning in higher education. Dougherty identifies the year 2000 as the start of the "maker movement" (an ecosystem of individuals and organizations that adopted making as a means for creating and learning).[23] Since 2000, the maker movement has migrated into higher education, with the lessons learned from the non-academic makerspace ecosystem guiding the development of higher education makerspaces. Before this time, engineering labs and machine shops provided some of the functions common to modern makerspaces, but did not provide the broad range of bundled services afforded by makerspaces. The creation of Fab Lab at MIT in 2002 marked the entry of large-scale university programs into the makerspace network.

Identifying and sharing best practices in higher education makerspaces is becoming more common within engineering education and professional societies. In 2014, a single paper at the annual meeting of the American Association for Engineering Education included the key term "makerspace." This keyword was included in 22 papers of the 2015 ASEE Annual Conference Proceedings and 49 papers in the 2016 ASEE Annual Conference Proceedings. Ranging in coverage, the papers identified unique attributes of higher education makerspaces, established comparison metrics, and examined staffing models.[24,25,26]

Gathering knowledge and distributing best practices across the higher education makerspace community was the focus of the first International Symposium on Academic Makerspaces (ISAM) held at the Massachusetts Institute of Technology (Cambridge, MA) in November 2016. The conference proceedings totaled 264 pages and addressed culture and community, programming, outreach, safety, staffing, management, metrics of effectiveness, entrepreneurship, and campus collaborations.[27] The Make-Schools Higher Education Alliance is another example of an organization created to identify and share best practices at higher education makerspaces.[9]

Such papers and case studies are valuable and resulted in a data base to learn from and improve local practices. Common to many papers that review makerspace issues using multiple campus models are tables, graphs and diagrams that identify program aspects (such as the unit sponsor, access, and overall size) and common attributes (such as the management structure). Detailed descriptions of each facility are often provided to identify organizational and operational elements that can be imported from one facility to another. For example, a detailed matrix of programs offered by a large (multi-thousand user), independently-staffed facility may not be appropriate for a smaller, student-managed facility. Similarly, comparing the equipment in a new grassroots-initiated space to that of an established university-funded makerspace may not be an appropriate comparison.

Informed comparisons, based on the attributes of each higher education makerspace, can lead to a better use of data and improved decision-making. It is proposed that a classification system be established for higher education makerspaces as a tool to guide comparisons and make operational/planning decisions.

Examples of Classification Systems in Higher Education

The use of classification systems within higher education and the engineering profession is common practice. At the institutional level, the Carnegie Classification of Higher Education organizes colleges and universities based on their educational and research purposes. The system identifies groups of comparable institutions and establishes a framework to compare and contrast the institutional attributes within and across classification groups. In addition to the educational and research indices that establish a basic classification level (such as “R1: Doctoral Universities with the Highest Research Activity” or “Baccalaureate Colleges - Arts & Sciences”) the Carnegie Classification system is further developed and refined using other institutional categories. These include profiles of the undergraduate and graduate instructional programs, enrollment, size, and setting. This framework efficiently models institutional characteristics, creates groups of comparable programs, and facilitates appropriate comparisons between institutions.

Characterizing institutions by size and resources is also the basis of the National Collegiate Athletic Association Divisions (I, II, III). These groupings (and the additional classifications within each division) establish a framework to help create, guide, and maintain competitive equity in college sports. The system has also been used as an aspirational model where programs establish goals and adjust institutional commitments for specific sports to align their competitiveness with schools in that division.

Within the sciences, Biological Safety Levels (BSL) identify the hazards in biological labs. Guidance associated with these levels, ranging from the lowest hazard category of BSL-1 to the most hazardous BSL-4, specifies the required safety equipment and allowable operations that can be conducted in each lab. The biological safety levels are also used to design lab spaces and structure the training and certification programs for researchers who work in the spaces. This methodology influenced the development of a hazardous classification system for tools and equipment (as well as the associated access, training, and supervision pertinent to each hazard class) in machine shops and makerspaces.[28]

Other examples of classification systems related to higher education makerspaces include the Postsecondary Facilities Inventory and Classification Manual (which establishes common practices for inventorying space at postsecondary institutions), the International Building Code Use and Occupancy Classification (that designates factory, industrial and hazardous spaces) and the North American Industry Classification System (that classifies business establishments by industry).

The use of classification systems is also common practice in engineering. The International Classification for Standards, National Electrical Code, European Commission Standards, American National Standards Institute, and the ASTM International (originally named the American Section of the International Association for Testing Materials) establish operational practices and material use guidelines. This background is presented to illustrate the wide-spread use of classification systems in higher education and engineering practice.

A Classification System for Higher Education Makerspaces

A classification system is proposed for higher education makerspaces. As with other classification systems used in higher education and engineering practice, a higher education makerspace classification system provides a systematic methodology to designate these spaces. Once classes of makerspaces are established, relevant comparisons can be made between programs within and across specific classes. The classification system also establishes standardized nomenclature to structure such comparisons.

The motivation for a higher education makerspace classification system stems from the nascent state of academic making. Institutions frequently make comparisons between higher education makerspaces to plan new spaces and improve existing spaces. But without a way to differentiate between higher education makerspaces, it is difficult to make inferences on the space, staffing, equipment, and programming aspects of these spaces. With the existence of a higher education makerspace classification system, processes such as facility planning become easier since decision making can be based on similarly classed facilities. Such comparisons occur now (in the pre-classification system era) but require individual efforts to identify and sort spaces to establish an institutional database of similar programs.

Existing spaces also benefit from a higher education makerspace classification system as a tool to examine similar scale spaces, identify industry trends, and recognize evolving program developments. As with sporting teams, a higher education makerspace classification system can also serve as an aspirational model for institutions that want to improve their local spaces using "best in class" examples.

Forest (et. al.) illustrate some of the values of a higher education makerspace classification system by quantitatively comparing similar programs (in this case based on the university's level of research).[24] This methodology correlates the number of users with space size, supervision, accessibility, and funding. In this example, correlations between data sets (for example, users and size) identify the relationships between these factors for this collection of spaces. This information is valuable to make predictions on similarly sized spaces, but the data may have limited value for spaces having a different scale.

Categories of the Higher Education Makerspaces Classification System

A higher education classification system consisting of five unique indices is suggested. These indices were established from the intersection of topics presented in previous research of key factors affecting higher education makerspaces.[24, 25, 27] The five indices are scope, accessibility, user-base, footprint, and management/staffing. The indices reflect a spectrum of purposes and scale, and form a framework for making comparisons between programs. The classification system does not encourage programs to strive for the highest levels within each classification category but rather is a methodology to readily identify makerspace attributes using standard terminology.

The ***scope of a higher education makerspace*** category signals the degree the makerspace is established on campus. Contributions to the university mission based on education, research, and service activities classify spaces in this dimension. For example, a higher education makerspace can contribute to the education component of the university's mission by hosting credit-awarding courses within the space. The research component of the university mission may be fulfilled by dedicating a significant amount of resources to support faculty-led research projects. The service component might be met by supporting student clubs as well as ongoing programs where makerspace users design, fabricate, and implement solutions that fulfill needs at the university. Examples of higher education makerspaces that contribute to the service component of the university's mission include spaces that support Design for America chapters or offer courses that include university service components.

The scope of a higher education makerspace is classified using the following three parameters:

- S-1: Grassroots and initial efforts
- S-2: Programs that significantly support at least one university mission
- S-3: Programs that significantly support three university missions

It is proposed that all programs in the first two years of existence be designated as S-1 programs. That designation allows a simple format to identify new (and still developing) programs.

A designator (“E”) appends this classification for programs with substantial entrepreneurial activities in their makerspace. These programs would be identified as S-1-E, S-2-E, and S-3-E makerspaces. This designation is relevant as partnerships between academic makerspaces and entrepreneurial programs are becoming more common. For example, established entrepreneurial and innovation programs are adding makerspaces to their facilities. Similarly, higher education makerspaces are augmenting their programming with entrepreneurship-focused workshops, fellowships, and academic courses. The growing association between makerspaces and entrepreneurial activities at colleges and universities reflects a national trend to align these two (sometimes) independent directions to accelerate product development and create new companies.

Accessibility of a makerspace as a classification category denotes the degree that the space can be used by the university community. These range from access limited to participants in specific courses, members of the host department, or all faculty, staff, and students at the university. The accessibility of a higher education makerspace is indicated using the following parameters:

- A-1: Access limited to individuals enrolled in makerspace or departmental courses
- A-2: Access limited to individuals from the sponsoring Department
- A-3: Access limited to individuals associated with a specific School
- A-4: Access provided to the entire University community

This index includes the trailing designation “S” for spaces open only to students. For example, a space open only to students in a specific course would be designated as “A-1-S.” The trailing designation “P” denotes spaces that are also available for use by the public, with an example designation being the classification “A-4-P.”

The topic of accessibility is important to compare spaces for a variety of reasons. It is expected that the staffing needs for a space open to the entire university community are very different from programs that only serve specific courses. As such, staffing comparisons should be made for spaces with common levels of access. Similarly, the equipment in each space will be driven by the users, and outfitting comparisons are best explored with a clear understanding of the space’s accessibility.

The **number of users of a higher education makerspace** measures the potential energy, engagement, and impact of the space. As with the size category, the number of users can be measured using a variety of methods such as registered users, total visits by registered users, or the total number of visits (registered users and visitors). Establishing a common standard for counting and classifying the number of users of a higher education makerspace is essential to define comparable programs. The term “members” is often used within the higher education makerspaces community to define that group of individuals who are provided access to the facility. Typically, members require training before being granted access, with the training record then serving as a mechanism to establish the space’s membership.

Using that methodology (i.e. the number of individuals who have access to the space), the number of users of a higher education makerspace is classified as:

- U-1: less than 100 members

- U-2: 100-1,000 members
- U-3: 1,000-3,000 members
- U-4: greater than 3,000 members

The number of members affects many issues within a higher education makerspace. For example, relaying information, such as the availability of a new piece of equipment, is similar for all membership sizes as that information can be broadcast as an email or web-update. Establishing a training, qualification, and certification program for the new piece of equipment is an activity that may take on very different forms depending on the size of the membership. It is noted that while facilities have many members (who have access to the facility) it is likely that a subset of these members are regular (such as at least once per week) users of these spaces.

The **footprint of a higher education makerspace** is an important characteristic. Defining a standard practice for reporting the footprint of a space is essential for valid spatial groupings. It is proposed that all area within a higher education makerspace be accounted for when measuring the footprint of that space. For example, workshops, studios, meeting rooms, storage areas, support spaces, classrooms/lecture halls, and staff offices contribute to the footprint if the areas are dedicated to (and controlled by) the makerspace. Establishing common practices for measuring the size of higher education makerspaces can be elusive and perhaps will be included in a future edition of the Postsecondary Facilities Inventory and Classification Manual.

The size of an academic makerspace is classified using four levels:

- F-1: less than 1,000 square feet
- F-2: 1,000-5,000 square feet
- F-3: 5,000-20,000 square feet
- F-4: greater than 20,000 square feet

The ***management and staffing of a higher education makerspace*** is essential to the long-term viability of the space as well as its ability to create positive experiences for the space's members. The collaborative community of makerspaces (which scales with the size of the community) is integral to these facilities but the community cannot function without structure. In addition to the responsibility that members have to assist each other within the space, each makerspace needs a management and staff leadership team. The leaders develop the space's culture, ensure the makerspace fulfills its mission, and maintain/guide the programs, equipment, and processes that address/meet the users' needs.

Three forms of management and staffing exist within higher education makerspaces:

- M-1: Primarily Student managed and staffed
- M-2: Faculty/Professionally managed and professionally staffed
- M-3: Faculty/Professionally managed with a hybrid (professional and students) staff

Example of the Higher Education Makerspace Classification System

The classification system is illustrated based on examples from a paper on collaborative activities at seven makerspaces.[5] Each of the authors of the referenced paper was associated with one of the profiled makerspaces and provided the information for that makerspace. Attributes of the spaces are reproduced as Figures 1 and 2. These attributes provide insight into the personality of each space and their roles as collaboration catalysts. These attributes were combined with additional details to classify each higher education makerspace. This classification is presented in Figure 3.

	Institutional Home	Size (sq-ft)	Membership	Type
CMU IDeATe	University Libraries	10,000	1,800	Community + Project/Courses
Case Western think[box]	School of Engineering	50,000	4,150	Community
Georgia Tech Invention Studio	Student-Managed Makers Club	6,000	2,000	Community + Project/Courses
MIT Maker Lodge	Project Manus / MIT Innovation Initiative	850	1,100	Community
Stanford PRL	Dpt. of Mechanical Engineering	9,000	1,100	Community + Project/Courses
UC Berkeley Jacobs Institute	College of Engineering	24,000	2,600	Community + Project/Courses
Yale CEID	School of Engineering & Applied Science	24,000	2,000	Community + Project/Courses

Figure 1. Attributes of Seven Higher Education Makerspaces

	Staff (number of employees)					Hours
	undergrad students	grad students	academic	technician	**admin**	
CMU IDeATe	13			10		24/7
Case Western think[box]	35		1	5	2	MWF 9am-6pm TR 9am-10pm, Sat 10am-4pm, Sun 12pm-4pm
Georgia Tech Invention Studio	80			5		24/7
MIT Maker Lodge	40	1	1	1	2	24/7
Stanford PRL		18	4		2	M-F 8:30am - 11:00pm, Sat 8:30-5:30pm
UC Berkeley Jacobs Institute	11		2	11		M-F 8:00am - 11:00pm, Sat 12-6pm
Yale CEID	8		4.5			24/7 (staffed 10 am – 9 pm)

Figure 2. Staff Size and Access at Seven Higher Education Makerspaces

	Scope	Accessibility	Users	Footprint	Management & Staff
CMU IDeATe	S-3	A-4	U-3	F-3	M-3
Case Western think[box]	S-2-E	A-4-P	U-4	F-4	M-3
Georgia Tech Invention Studio	S-3	A-4-S	U-3	F-3	M-1
MIT Maker Lodge	S-1	A-1-S	U-3	F-1	M-1
Stanford PRL	S-3	A-4-S	U-3	F-3	M-3
UC Berkeley Jacobs Institute	S-3	A-4	U-3	F-4	M-3
Yale CEID	S-3	A-4	U-3	F-3	M-3

Figure 3. Classification of Seven Higher Education Makerspaces

This example illustrates how the classification system provides an efficient framework to compare higher education makerspaces. The value of the framework is amplified by examining the details of comparable programs. For example, the staffing, and by association the funding, for a small, student-focused space would be very different from that needed for a large space that serves an entire university. Comparisons across classes can also be made, such as examining the program of each space. While it would not be expected that the programming for a small, student-focused space would be a model for programming a large space that serves an entire university, a comparison between classes may highlight aspirational components that could be added to existing spaces.

The classification system also has value as a planning tool for universities that are designing new makerspaces. That planning process may start with the definition of the new space using the proposed classification system indices. A review of best practices within existing comparable programs can then be used to establish norms for the new facility. In absence of a standardized classification framework, comparisons between existing spaces are frequently made, but each institution creates their own filter to identify comparable models. The proposed higher education makerspace classification system standardizes that approach and yields a more efficient planning process.

The value of the classification system scales with the number of institutions that are classified and the number of indices for each classification category. For example, consider the case where 150 academic makerspaces are classified and the list of indices includes, for example, topics such as equipment, budget, supported academic courses, programming, and the use of volunteers. With this expansive data set, someone planning a new space could use the classification system to establish norms for the proposed space. The process might originate with internal estimates on size and scope. The parameters for similar spaces could be used to then estimate the preferable footprint and optimum staffing models for the new facility. In another application, an existing space could use the database to find peer-spaces based on accessibility and the number of users. With that narrowed list of similar institutions, research into the programming elements of the similar spaces might be conducted to identify areas of improvement at the local facility.

Conclusions and Observations

The growth in the number and the variety of higher education makerspaces warrants a classification system to identify comparable programs. This conclusion is based on the awareness that all makerspaces are not the same and comparing aspects of these spaces is most relevant within specific classes. In the absence of a classification system, one may be tempted to consider all spaces as being similar – an approach that is incorrect and not applicable.

Best practices within higher education makerspaces are being identified and shared across the higher education community. Having a classification system makes it easier to understand the norms and standards of practice within each class of makerspaces, and eases the adoption of best practices within all classes. Regarding best practices, the classification system serves as a screen to identify practices that may be easily applied within a class of spaces (since the overall attributes are similar) and what practices need additional effort to implement. For example, the programming (courses, workshops, training, social activities, project support, and mentorship) at large makerspaces may indicate elements that can be implemented by smaller spaces while acknowledging the reduced scale of the smaller spaces prevents adopting all programming aspects of a larger facility. Similarly, assessment practices at a collection of larger makerspace may produce a series of best practices that are in fact applicable to all comparable programs within a specific class of makerspaces.

It is noted that the proposed classification system, including the presented indices, is an initial step. Additional indices can be added over time to extend the system's value in other domains. For example, adding indices for funding (including the source of operating funds as well as the annual operating budget) and equipment (such as basic, intermediate, and advanced) would enhance the classification system's ability to address budget issues. Similarly, comparing programming elements of academic makerspaces, including outreach activities for K-12 programs, would increase the classification system's ability to serve as a reference in these dimensions. Further review and field testing of this classification system will identify its strengths and deficiencies, thereby increasing its value as a tool for engineering educators and campus planners.

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