Chapter 20

Makerspaces Empowering Graduate Student Research

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Why Make Such a Big Deal about Makerspaces?

We live in a world our forebears would have found difficult to conceptualize. Frankly, we live in a world most of us would have been hard-pressed to imagine just a few years ago. Amid the accelerating pace of change, there are persistent, comforting familiarities that thankfully don't seem to be endangered: baby animals continue to be adorable, Earth's obliquity remains around 23.4 degrees, and if one makes too much noise in a quiet area of an academic library, a librarian will still walk over to restore scholarly quietude. But in other areas of some academic libraries, one might find a librarian leading a training session on how to safely operate a compound miter saw or mentoring students on the differences in 3-D modeling strategies between video games and 3-D printing outputs. Power tools and virtual reality experiences might seem to be an incongruous pairing in any collection, especially when juxtaposed against the trope of libraries as austere temples of books; it might appear as though one has finally lost one's grip and fallen through the looking glass.

Nonetheless, libraries worldwide are embracing maker culture with astonishing enthusiasm, investing in digital fabrication technologies and redefining the types of inquiry libraries support. The written word is a uniquely powerful method of communicating thoughts across time and space, though text is but one of many valid vehicles for meaningful learning. "When learning is conceived as a holistic adaptive process, it provides conceptual bridges across life situations such as school and work, portraying learning as a continuous, lifelong process … [of] creativity, problem solving, decision making, and scientific research."[1] By providing a platform for students to autodidactically work through the complications of associating theoretical knowledge with practical experiences, libraries situate themselves at critical junctions in learners' processes of self-actualization. The nature of such spaces in higher education libraries presents the opportunity to leverage talented and diverse graduate students who will both improve the quality of the space itself and gain valuable professional skills while practicing the application of their studies in a unique setting. This affords the applicable challenges of the "real world" while maintaining the relative safety of the iterative design process in an educational institution.

Beyond simply being labs and workshops where objects are produced, makerspaces embody a visceral public interest in communal knowledge sharing and a palpable desire to form relationships with the objects in our lives that passive consumerism could never satiate. Makerspaces are popping up in an inspiring array of settings: elementary schools, top-tier universities, rural public libraries, corporate incubators, community centers, private clubs, renovated school buses, and so on. While makerspaces took root independently of libraries, and many makerspaces are thriving today without any library affiliation, numerous librarians are nurturing a florescence of heretofore latent public passion for this type of facility in their local library. Soon, patrons may commonly expect their library to operate a makerspace, perhaps especially within academia.

Until 2011, facilitating the fabrication of physical objects within a library had been rather novel,[2] though the flurry of library-based maker activity in the wake of the Fayetteville Free Library's Fabulous Laboratory is a testament to the fact that the maker movement shares a natural resonance with the traditional mission of libraries,[3] and all indicators point to an increasingly intertwined concept of libraries and makerspaces. Indeed, the core values of the American Library Association (ALA) are remarkably similar to the founding principles of the Higher Education Makerspace Initiative (HEMI):[4]

ALA Core Values	HEMI Founding Principles
• Extending and expanding library services in America and around the world • All types of libraries—academic, public, school, and special • All librarians, library staff, trustees, and other individuals and groups working to improve library services • Member service • An open, inclusive, and collaborative environment • Ethics, professionalism, and integrity • Excellence and innovation • Intellectual freedom • Social responsibility and the public good	• There is no one best way for all academic makerspaces to work. • Thoughtful metrics, data, assessment practice, and sharing/dissemination are key to: (i) creating safe and effective makerspaces, and (ii) upgrading and continually improving makerspaces and makerspace best practices. • Student-centric culture and community, and student involvement/autonomy are the key foundations of success. • Safety and personal responsibility are key foundations of academic makerspace success and are complemented by regulatory and legal issues. • Recognizing and minimizing boundaries and barriers to entry are key to successful academic makerspaces. • Outreach and inclusivity are key to successful academic makerspaces.

Though the conceptualization of makerspaces is a relatively recent phenomenon, there is nothing particularly new about the presence of digital fabrication equipment on college campuses; in fact, the earliest computer numerical control (CNC) system was developed at Massachusetts Institute of Technology (MIT) in the boom decade following the second world war (see figure 20.1).[5] University research labs have been intimately involved with the development of CNC systems since inception,[6] though access to such technologies was strictly controlled,[7] with relevant labs available only to select graduate students, and even then generally only as assistants on larger research projects. Recent technological developments and patent expirations into the public domain have made technologies such as 3-D printing vastly more affordable,[8] though they are still rather beyond the range of what most people can afford to purchase for intermittent use.

Figure 20.1

Ivan Sutherland demonstrating his Sketchpad program on the TX-2 at MIT, one of the earliest ancestors of computer-aided design (CAD) programs (Photo Courtesy of Gwen Bell/Computer History Museum).

Just as academic libraries have existed to provide access to expensive media such as research journals, primary source collections, and other traditional information media for centuries, providing access to institutionally affordable equipment for capturing, analyzing, and processing information has been a natural evolution for libraries in the age of the computer. The snazzy branding of many makerspaces may rub some traditionalists the wrong way, though the core principles of the contemporary maker community are right in line with long-established library values: democratized access and opportunities to build relevant literacies. In the context of a makerspace, this access and learning often center around digital fabrication technologies, offering learners the ability to process virtual objects into tangible materials and analyze physical specimens as data.

Much of the current makerspace buzz among librarians focuses on the approachability of makerspace technologies to young students and the powerful experiential learning that takes place when one moves beyond the theoretical with iterative design.[9] Unlike graduate students, K–12 students and undergraduates have had virtually zero access to digital fabrication technologies until very recently. The evolution of libraries to incorporate makerspaces is nonetheless extremely relevant to graduate students, as the barriers to equipment access in the library makerspace are generally universally removed, not departmentally controlled. This radically opens the possibilities for autodidactic and extracurricular learning for all graduate students, from all disciplines, regardless of the ostensible curricular relevance or departmental research agenda. Whether the informal learning is under the guise of a stress-relieving hobby, an entrepreneurial effort, or extracurricular research, the freedom to experiment in this manner can be an especially potent catalyst for graduate student learning.

Academic Library Makerspaces Are an Invaluable Campus Resource

Of course, library makerspaces can also support and complement departmental labs, which is especially relevant for those at universities where budgets would be less able to support each department with digital fabrication equipment for their graduate students. Libraries might well be considered a valuable location for campus makerspace investment rather than multiple departments purchasing the same equipment. In order to gain legitimate traction in this regard, it is critically important that the library makerspace be earnestly supported in both capital, to purchase quality equipment, and staffing, to adequately maintain the equipment and meet the needs of the campus community interested in learning to use it.

One of the more common misconceptions about digital fabrication technologies, often perpetuated by much of the marketing surrounding 3-D printers, is that the machines involved do all the work and all the operator needs to do is load a file and push a button. Obviously, this isn't really true of any technology, but promises of simplicity are a persistent sales pitch. All too often, departmental pilot initiatives to select, purchase, and maintain digital fabrication equipment are added responsibilities for already busy faculty. For the majority of researchers, interest in a promising new technology is utilitarian, rather than a research interest in specific CNC systems themselves. Learning to troubleshoot issues and discern cause and effect between design file preparation, settings in the toolpath generator, and physical output are new competencies for most people and can be frustrating to learn on one's own. The communal learning culture of the makerspace can be an important hub for sharing best practices with those interested in learning to use and maintain digital fabrication equipment already in departmental labs, presenting library makerspace staff with opportunities for relevant liaison services.

Much More Than Machines: Makerspaces Are Humans Helping Humans

Library investment in staff training is essential in establishing the knowledge base. Onboarding new employees ought to be planned well in advance of cyclical times of need within the academic year to allow for adequate training and on-the-clock practice time. The more technologies the makerspace provides access to, the more time is required for trainees to become sufficiently familiar with the software and equipment that they are able to provide effective guidance.

Employees who have been directly involved in making things themselves with each piece of equipment will be more attuned to the nuances of process and thus able to offer more appropriate advice to learners at various stages of that workflow. This experiential learning and knowledge-sharing cycle is empowering for the employee and inspiring for the learner, and it tends toward the completion of projects that are more successful than they would have been were the library staff not involved. By achieving consistent output results and reliable design consultations, academic library makerspaces can become a central resource for those interested in acquiring maker skill sets, offering expertise to the campus community in these literacies and significantly easing barriers to entry for experimentation with digital fabrication.

Several staffing strategies are evident in current library makerspaces; while there are notable success stories of spaces run by dedicated student volunteers, such as the Invention Studio at Georgia Tech,[10] most operational spaces rely on a small core of full-time staff with significant help from students. Student employees are far more than merely logistically necessary to provide the breadth of services and hours of access due to the obvious structural wage differentials with full-time staff and increasingly limited institutional budgets. Employing students critically reinforces a conceptual commitment to student-first services by offering more relatable assistance to the average college student than more mature library staff could provide. The additional training and support student employees receive in order to be effective library ambassadors are legitimately contextualized as an investment in the impact on retention, professional development, and workforce preparedness academic libraries can have on students prior to their graduation.[11]

Makerspace student staff are predominantly engineering students, though there is a real value in conscientious employment of students from a variety of disciplinary backgrounds. Learners from nonengineering departments might be reticent to approach engineering students for help with their projects, especially for first-time users of makerspace technologies. By diversifying the disciplinary demographics of the student staff to reflect the campus community, academic library makerspaces can cultivate a more welcoming culture to better meet students at their need. Additionally, the collegial interactions between student staff of varying majors and perspectives provide plenty of opportunities to practice interdisciplinary communication skills, a key transferrable competency. Similarly, the wealth of perspectives and skill sets contributing to the aggregate culture of the makerspace is enriched by employing a spectrum of students from freshmen to super-seniors to PhD candidates.

The prospects for mutually beneficial employment of graduate students in academic library makerspaces are difficult to overstate. In addition to all the desirables mentioned above, academic makerspaces are an emerging discipline, meaning ample opportunities abound for applied ingenuity to have a large impact. Graduate students working in academic library makerspaces are likely to find projects that provide real solutions to earnest organizational needs, building confidence in their abilities to effect positive change in the world (and bolstering their resumés) while enabling academic library makerspaces to better serve their communities. Given the right circumstances, such projects might even be able to be undertaken as part of one's thesis.

Case Study: UTA FabLab

Graduate students are a significant percentage of the frontline employees who run the day-to-day operations of the 8,000-square-foot makerspace on the first floor of the University of Texas at Arlington (UTA) Central Library, as both student assistants and shift leads. The small cadre of full-time staff makes extensive use of student service learning projects to simultaneously reinforce training and improve lab infrastructure.[12] Two student employees who displayed a great deal of initiative and phenomenal follow-through in their projects are now graduate research assistants working for the FabLab, giving them more flexibility in project scope and further contributing to the sense that this academic library makerspace is an integral part of the research conducted at an R1 university. This staffing model begins to resemble the organization of other departments on campus, normalizing makerspaces within the fabric of academia.

One of these GRAs, Tushar Saini, is a shining example of how library student employment can be a catalyst for life-changing experiences. Tushar had wanted to design aircrafts since before he started high school, following his dream 1,400 miles from home to complete his BS in aeronautical engineering at one of India's top accredited programs in the field. He moved another 8,000 miles further afield to pursue an aerospace master's degree at UTA and was about halfway through that program when he got an on-campus job as part of the first cohort of student employees in the FabLab. After gaining firsthand experience working with 3-D printers, Tushar realized his passions and skills are better suited to solving the problems of additive manufacturing,[13] switching course to the mechanical engineering program for his master's and now continuing on for his doctoral research. If he had continued with his preconceived plan, Tushar would have likely eventually gotten to use 3-D printers in his aerospace research, though the nature of the interaction would have been substantively different. Rather than concentrating on aerodynamic features of the prints, Tushar's job in this academic library makerspace challenged him to understand the technology on a much deeper level in order to guide learners though the successful iterations of their wide-ranging ideas. Along with the responsibility to ensure the machines were functional, the FabLab job offered the freedom to experiment and play without the need to justify all machine use as research. This activated different parts of the brain than would have preponderated under the temporal and monetary constraints of curricular projects, contributing to that unquantifiable matrix of experiences that culminate in someone reexamining his life-long aspiration.

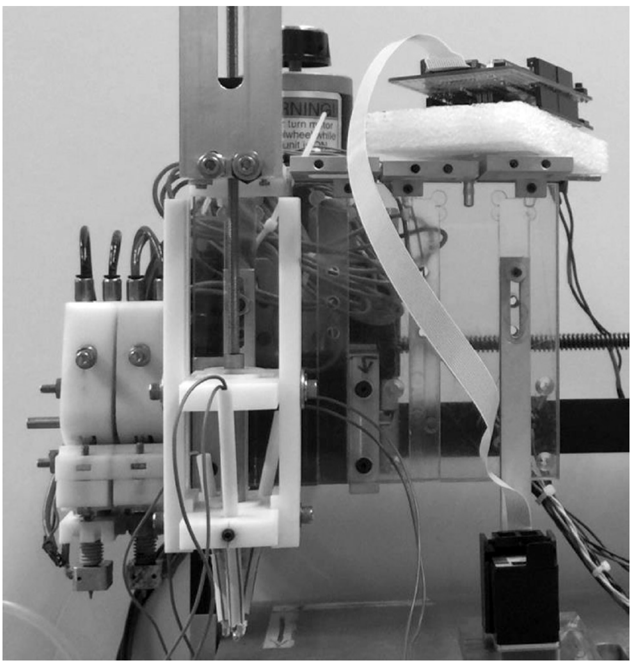

Figure 20.2
This custom multi-modality bioprinter was developed and built in a departmental lab accessible by a select few graduate students. The ivory-colored components were printed in the UTA FabLab (photo credit: Prashanth Ravi).

That said, academic library makerspaces will ultimately prove their worth by demonstrably facilitating graduate student research. One of the major projects the UTA FabLab GRAs (Tushar Saini and Jonathan Le) have worked on has involved adopting, adapting, and writing code in a collaborative process of designing programmatic workflow management and data collection solutions, collectively dubbed the "FabApp."[14] These efforts have been at least somewhat relevant to each of the graduate students' formal research interests and have definitely provided incentive to grow their skill sets in very practical fields, including supervisory experience of other employees working on FabApp modules and other programming projects. Together, they have admirably satisfied the primary library goal of streamlining the data collection process using minimally obtrusive methods, while abiding by university privacy protocols and assuaging librarians' concern for anonymity in academic freedom of inquiry.

Since the FabApp went live in April 2016, the UTA FabLab has facilitated over 14,000 3-D prints, a quarter of which were made by graduate students, likewise graduate students make up one quarter of total student enrollment. The more intriguing figure emerging from this data is that graduate students are significantly more likely to use the UTA FabLab's digital fabrication tools for research than nonacademic uses. Undergraduates, meanwhile, are about equally likely to make 3-D prints for fun as they are for class, even with ongoing library initiatives integrating making and the FabLab into undergraduate curriculum for several classes each semester.[15]

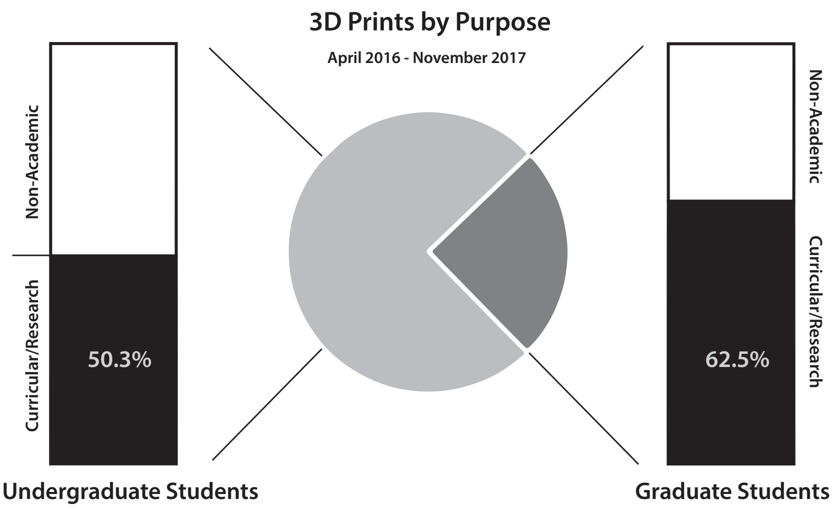

Figure 20.3

Visualizing proportional purposes of 3-D prints made by students at the UTA FabLab between April 13, 2016, and June 12, 2017. FabApp collects data about the curricular or nonacademic nature of each print job, and all personally identifiable information is hashed to protect freedom of academic inquiry.

Looking Forward

As we progress into a future where digital fabrication equipment is increasingly ubiquitous, serving the research needs of graduate students will inherently involve facilitating access to CNC tools and building a culture of transdisciplinary making within academic libraries.

Notes

1. David A. Kolb, *Experiential Learning* (Upper Saddle River, NJ: Prentice Hall, 1984), 33–34
2. Travis Good, "Manufacturing Makerspaces," *American Libraries* 44, no. 1/2 (January/February 2013): 44–49, https://americanlibrariesmagazine.org/2013/02/06/manufacturing-makerspaces/.
3. Lauren Britton and Sue Considine, "The Makings of Maker Spaces, Part 3: A Fabulous Home for Cocreation," *Library Journal* 137, no. 16 (October 2012): 27–28, https://lj.libraryjournal.com/2012/10/featured/the-makings-of-maker-spaces-part-3-a-fabulous-home-for-cocreation/; Meredith Farkas, "Providing the Tools: Bringing Digital Creation Technologies to Libraries," In Practice, *American Libraries* 43, no. 1/2 (January/February 2012): 32, https://americanlibrariesmagazine.org/2012/01/31/providing-the-tools/.
4. American Library Association, *Core Values of Librarianship* (Chicago: American Library Association, July 26, 2006), http://www.ala.org/advocacy/intfreedom/corevalues; Higher Education Makerspace Initiative, *International Journal of Academic Makerspaces and Making (IJAMM)* submission guidelines, accessed May 1, 2018, https://hemi-makers.org/ijamm/.
5. J. Francis Reintjes. *Numerical Control* (Oxford: Oxford University Press, 1991).
6. Emanuel Sachs et al., "Three-Dimensional Printing: The Physics and Implications of Additive Manufacturing," *CIRP Annals* 42, no. 1 (1993): 257–60, https://doi.org/10.1016/S0007-8506(07)62438-X.
7. Gerald Barnett, "The Effect of University Monopoly Licensing in 3d Printing," *Research Enterprise* (blog), December 29, 2011, https://researchenterprise.org/2011/12/29/the-effect-of-university-monopoly-licensing-in-3d-printing/.
8. John Hornick and Dan Roland, "Many 3D Printing Patents Are Expiring Soon: Here's a Round Up & Overview of Them," 3D Printing Industry website, December 29, 2013, http://3dprintingindustry.com/news/many-3d-printing-patents-expiring-soon-heres-round-overview-21708/.
9. Lisa Schwartz, Daniela DiGiacomo, and Kris Gutierrez, "Diving into Practice with Children and Undergraduates: A Cultural Historical Approach to Instantiating Making and Tinkering Activity in a Designed Learning Ecology" (paper presented at the International Conference for the Learning Science, Boulder, CO, June 23–27, 2014), http://www.academia.edu/6413726/Diving_Into_Practice_with_Children_and_Undergraduates_A_Cultural_Historical_Approach_to_Instantiating_Making_and_Tinkering_Activity_in_a_Designed_Learning_Ecology.
10. Craig R. Forest et al., "The Invention Studio: A University Maker Space and Culture," *Advances in Engineering Education* 4, no. 2 (Summer 2014): 1–32, http://advances.asee.org/wp-content/uploads/vol04/issue02/papers/AEE-14-1-Forest.pdf.

11. Parts of this paragraph appeared first in Morgan Chivers, "Scaling the DIY Approach: Do-It-Together with Student Staff Service Learning" (paper presented at the International Symposium on Academic Makerspaces, Cleveland, OH, September 24–27, 2017).
12. Morgan Chivers and Katie Musick Peery, "Walking the Walk: Iterative Design in Student Staff Service Learning Projects" (paper presented at the International Symposium on Academic Makerspaces, Cleveland, OH, September 24–27, 2017).
13. Prashanth Ravi et al., "On the Capabilities of a Multi-modality 3D Bioprinter for Customized Biomedical Devices" (paper presented at American Society of Mechanical Engineers 2015 International Mechanical Engineering Congress and Exposition, Houston, TX, November 13–19, 2015), https://doi.org/10.1115/IMECE2015-52204.
14. FabApp (and its interdependent partner OctoPuppet) is available openly on the UTA FabLab GitHub for other makerspaces to use or further adapt to their own needs (Tushar Saini, "UTA FabLab," GitHub website, accessed May 1, 2018, https://github.com/UTA-FabLab).
15. For more discussion of makerspace course integration in UTA Libraries' Maker Literacies initiative, see Martin Wallace et al., "Making Maker Literacies: Integrating Academic Library Makerspaces into the Undergraduate Curriculum" (paper presented at the International Symposium on Academic Makerspaces, Cleveland, OH, September 24–27, 2017).

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