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Maker Services in Academic Libraries: A Review of Case Studies

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ABSTRACT

Makerspaces and maker-centered learning have surged in popularity in higher education and particularly academic libraries in recent years, following trends that initially emerged in primary and secondary education and public libraries. As academic libraries develop services around maker activities and technologies, many case studies have emerged to share examples, best practices, and lessons learned from these endeavours. The purpose of this literature review is to summarise the information from the available case studies to answer the following research questions: How are academic libraries implementing makerspaces? What can we learn from case studies of academic library makerspaces? What are the prevailing gaps in the published literature on academic library makerspaces? The results of this review of case studies will be a guide for library staff who wish to implement makerspaces in their libraries, and will also serve to identify avenues for future research and scholarship on creative spaces in academic libraries.

KEYWORDS

Makerspaces; 3D printing; case studies

Introduction

As more higher education professionals follow the lead of primary and secondary educators and public libraries, we see increased efforts emerging in academic libraries to provide maker services. "Maker services" are defined here as spaces in the library that specifically promote and encourage creation, including 3 D printing and scanning services, mobile makerspaces, and dedicated makerspaces with a wide variety of tools and technologies. With the rise of such services in academic libraries, many academic library professionals have published case studies to share examples, best practices, and lessons learned from their endeavours. The purpose of this literature review is to summarise the information from the available case studies to answer the following research questions: How are academic libraries implementing makerspaces? What can we learn from case studies of academic library makerspaces? What are the prevailing gaps in the published

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literature on academic library makerspaces? The synthesised information shows not only a chronological trend towards more student-centered, hands-on, and inclusive spaces, but also several overarching themes, including the justification of maker services in academic libraries; building services around needs; developing a community of practice; supporting maker services through instruction; and the challenges of academic library makerspaces. The conclusions of this review reveal several guidelines that can inform the creation of academic library maker services in the future.

Background

Experiential learning has long been acknowledged as an effective form of scholarship in higher education (Ambrose & Poklop, 2015). Makerspaces and other creative, collaborative workspaces are the latest form of experiential learning that is becoming increasingly popular in many colleges and universities. According to the NMC Horizon Report: 2018 Higher Education Edition, "The embedding of maker culture in higher education has made students active contributors to the knowledge ecosystem. They learn by experiencing, doing, and creating, demonstrating newly acquired skills in more concrete and creative ways." (Becker et al., 2018). The Maker Literacies project, an initiative started at the University of Texas Arlington, seeks to develop national standards for incorporating maker literacies into undergraduate coursework (Wallace, Trkay, Peery, Chivers, & Radniecki, 2018). Some of the proposed maker literacies from this project include teamwork, knowledge and time management, understanding the legal and socio-economic issues surrounding making, and transferring skills learned into real-world situations.

Several studies have examined how maker activities affect student learning, both in primary and secondary classrooms and higher education. Agency by Design, an ongoing research initiative that aims to explore the pedagogical implications of learning through making, has found that making empowers students and leads to a shift in the way they see the world (Clapp, Ross, Ryan, & Tishman, 2017). Students learn to see the designed world around them as pliable, as open to redesign and change. Self-agency and self-competence are interdisciplinary skills that can help students in all aspects of their academic and personal lives. Saorin et al. (2017) conducted a study of 44 engineering students, and concluded that the implementation of 3D technology in the classroom significantly improved students' creative competence. Nagel, Ludwig, and Lewis (2017) conducted a study of learning outcomes for undergraduate students in an interdisciplinary makerspace technologies course. Results showed that the course increased learning and engagement and improved students' interpersonal communication, prototyping, and

critical thinking skills. Wilczynski, Wigner, Lande, and Jordan (2017) examined how maker activities in engineering students contributed to skill competencies in line with ABET's engineering accreditation standards. The study found that maker activities had learning outcomes in line with ABET standards for engineering education. In addition to learning specific skills in electrical and manufacturing engineering, students learned to apply knowledge to real-world situations, engage in lifelong learning, and work on multidisciplinary teams. These research projects demonstrate the wide-ranging, multidisciplinary skills that students can develop through maker learning opportunities.

In many cases, academic libraries are taking the lead in championing experiential learning through maker services. And as Burke and Kroski (2018) explain, "[Makerspaces] are as much about the tools and equipment found therein as they are about the spirit of creativity and pursuit of knowledge that encompasses them" (1). Academic library maker services can take many forms, and there is no one model to follow for establishing creative spaces and services in libraries. These services could take the form of a single 3D printer, a dedicated space with high-end fabrication tools, a small corner of the library set aside for Legos and paper crafting, or a mobile cart that is brought out whenever making activities take place. Regardless of what form maker services take, the development of community, transdisciplinary collaborations, and the fostering of inspiration and ideas are all commonly cited benefits of creative activities in libraries. As Mathuews and Harper (2018) explain, "[T]he real value of the library makerspace lies in the creative and collaborative activity that grows and subsequently shares knowledge creation and innovation" (359). University libraries are increasingly incorporating makerspaces into their service models to leverage and solidify the library's position on campus as a place for collaboration, learning, and inspiration.

Literature review method

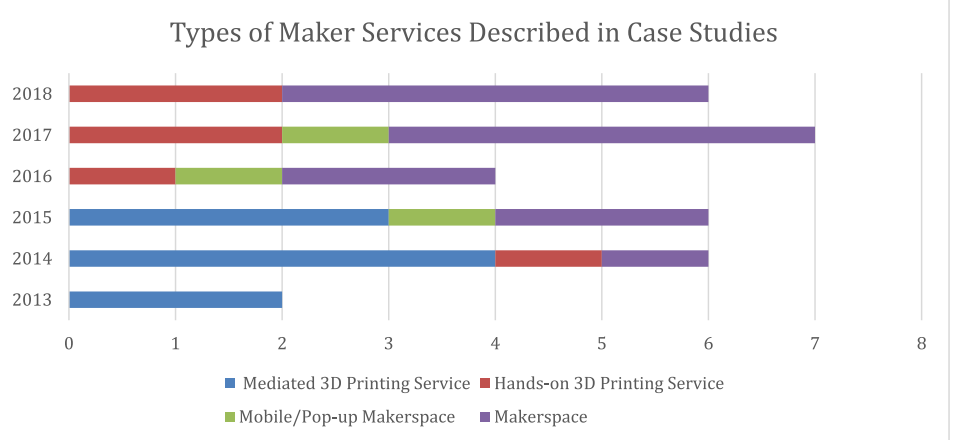
To meet the criteria of this literature review, the main focus of papers needed to be either a case study of a single academic library creative space or a study that amalgamated information from multiple academic library creative spaces. For the purposes of this review, a "case study" is defined as an article specifically describing an academic library makerspace or maker service, usually to share best practices, lessons learned, and recommendations for others doing the same. The majority of papers analysed in this review were found between January and April 2019 through searches using Library and Information Science Abstracts, ERIC, Web of Science, and Google Scholar. Results were limited to a chronological period of 2012 to

present. Searches were conducted using various combinations of the following terms: "3D printing", "(maker* OR mak*) AND space*", "creative spaces", "higher education", "academic libraries". The snowball method was used to follow relevant citations or subject headings found in the pool of papers from the initial searches. Searching and snowballing was repeated until a saturation point was reached where no new papers were found through searches or citation chaining. 48 papers were found during the searching process. These initial papers were analysed based on title and abstract to weed out those which did not meet the above criteria. Finally, the 30 remaining papers (a total of 31 case studies, as one paper included 2 case studies) were analysed to determine overarching themes and prevailing lessons that could be applicable to a wide range of academic libraries. The review was not limited by geographic area, but 26 of the 31 case studies came from the United States, with 3 from Canada, and 1 each from Singapore and Nigeria.

An evolution of trends

When we examine the case studies from a chronological perspective, a pattern emerges that shows a progression of increasing variety in maker equipment offerings and, simultaneously, an increasing level of user autonomy and interaction with the equipment. From 2013 to 2016, the majority of case studies focussed on 3D printing or 3D scanning as emerging services in academic libraries (Bharti, Gonzalez, & Buhler, 2015; Gonzalez & Bennett, 2014; Groenendyk & Gallant, 2013; Knies, Lynn, & Angel, 2017; Lenton & Dineen, 2016; Messner, 2015; Moorefield-Lang, 2014; Nowlan, 2015; Reuscher, 2014; Ryan & Tandy Grubbs, 2014; Scalfani & Sahib, 2013). Within the movement to establish 3D printing as a library service, we also see an evolution in the level of user interaction with the technology. Many 3D printing efforts began as staff-mediated services, where users simply submit files and staff handle the printing. Gradually, libraries began overcoming fears of safety and security and opening up technology directly to users through hands-on 3D printing services. From 2014 to 2018, we see an increase of case studies that describe either mobile/pop-up makerspaces (Lotts, 2017; Moorefield-Lang, 2015; Purpur, Radniecki, Colegrove, & Klenke, 2016) or more permanent makerspaces that hold a variety of equipment and allow users to interact directly with the technology (Carr, Gits, Ledbetter, Townsel, & Young, 2016; Davis, 2018; Guevara, 2018; Harris & Cooper, 2015; Horbal & Tobery, 2018; Lee, 2017; Moorefield-Lang, 2014; Nichols, Melo, & Dewland, 2017; Okpala, 2016; Passehl-Stoddart, Velte, Henrich, & Gaines, 2018; Schuck, Wainscott, Church-Duran, & Del Bosque, 2017; Sin Guek, 2015). Table 1 illustrates these trends, showing the number

Table 1. Types of maker services described in case studies.



of case studies per year from 2013 to 2018 that describe each type of maker service. [Table 1 near here.]

Passehl-Stoddart et al. (2018) point out the ideological struggle between mediated 3D print services and the more open and hands-on model of most makerspaces. The Making, Innovating, and Learning Laboratory (MILL) at the University of Idaho Library was created to counter the barriers to emerging technology that many students encountered on campus through mediated 3D printing services. "In contrast, the MILL promotes an environment of inclusive peer learning, provides open and equitable access to technology, and facilitates a low-risk creative space where students can explore and learn together" (137). From 2016 to present day, we see an increasing number of libraries including hands-on and student-led makerspaces, often branching out to include a variety of technology and emphasising partnerships with faculty, campus units, and sometimes the wider community. The chronological trend of case studies shows academic library makerspace missions that increasingly invite patrons to interact directly with technology, mirroring trends in the library community at large to remove barriers to use and to provide inclusive spaces and services.

Justifying maker services in the library

Libraries as neutral, Central space

Many case studies include a discussion of the justification for the campus library as the ideal place on campus for innovative, creative spaces and services. One almost universal sentiment in these justifications emphasises the neutrality of the campus library, casting it as the perfect place to democratise access to technology and create interdisciplinary collaborations.

Nichols et al. (2017), point out that the library finds its niche by occupying "a neutral and central space" on campus (365). Purpur et al. (2016) label the library as "the heart of the university", arguing that libraries have the unique ability to have the largest possible impact, utilising relationships with students, faculty, and staff, and pulling in new makerspace users with pre-existing networks. Harris and Cooper (2015) argue that makerspaces fit within the library's traditional role "as a shared place with shared resources" (7), and also allow users a space to be creative outside of curricular activities.

Often, the case studies present the contrast between the library's openness and neutrality to other maker services on campus that are restricted to specific majors or classes (Lenton & Dineen, 2016; Schuck et al., 2017). Okpala (2016) explains, "Every other department in a university may have their laboratories, but a makerspace brings people from all fields together, and the library being the heartbeat of the University can only serve as a central place for all" (577). Gonzalez and Bennett (2014) echo this sentiment, saying, "Specialized printers restricted to specific groups have their role on campus but also underscore the value in supplying a universal and basic service by the libraries" (para. 11). The authors explain that maker technology in campus libraries acts as an equaliser, allowing students of all majors an opportunity to gain experience with the equipment, techniques, and concepts. Students can then take this introductory knowledge gained at the campus library and pursue advanced projects in more specialised labs on campus.

Alignment with library mission

Another justification cited in case studies is the alignment between the values of the maker movement and the missions of libraries. Brown and Vecchione (2014) explain that library missions have evolved in modern times to support digital fluency and expose patrons to emerging technologies. Thus, the authors argue, "providing campus-wide access to a 3D printer fits perfectly with this aim by bringing students, faculty, and staff together to investigate a new technology" (para. 1). Purpur et al. (2016) and Ryan and Tandy Grubbs (2014) bring forth similar points, presenting 3D printing and other maker technologies as perfectly aligned with the missions and goals of academic libraries.

The benefits of Maker-Centered learning

The benefits of maker-centered learning are repeatedly outlined in the case studies as further justification for providing makerspaces in libraries. Cited

benefits of maker-centered learning for college students include the ability to prototype, failure positivity, problem-solving skills, creative thinking skills, innovativeness, and communication, to name a few. Brown and Vecchione (2014) argue that:

> The digital fluency skills students acquire in the 3D design and printing process translate beyond 3D printing. Working through the process gives users an opportunity to work on their problem solving skills in a supportive environment where a "failure" isn't seen as a roadblock, but as a speedbump. The reward being a sense of satisfaction in going from idea to tangible object (para. 5).

Lee (2017) pushes this argument further, stating that students enter college with a lack of abstract thinking skills due to an education system that focuses on memorisation and test-taking. The author argues that makerspaces can provide the "metaphorical jump start" that many college students need to help them begin thinking creatively and independently. Citing research from the corporate world showing that employers are in need of innovative, creative problem solvers, Schuck et al. (2017) point out that makerspaces provide "innovative skill development" through playful learning and interdisciplinary collaborations, something students often won't find in structured college courses (520).

Building services around need

A needs analysis is often the recommended first step in defining potential users and developing a plan for creative spaces. A needs analysis will also help define the scope of the space, develop a mission and goals for the space, and tie that mission into library- or university-wide initiatives and goals. According to Webb (2018), the first and most important questions to ask are, "Does this fit our mission?", "Who benefits and how?", and "What does success look like?" (43). A full needs analysis could include surveys, interviews, and focus groups. In the place of performing a comprehensive needs analysis *before* opening a space (which can take months to complete), many spaces open smaller, low-budget "prototype" spaces. The idea here is to get the service in place at the most rudimentary level, continually gathering feedback throughout the process from users and stakeholders, and then build out the service slowly, adjusting as needed based on the feedback. Gonzalez and Bennett (2014) explained how they started a 3D printing service at the University of Florida Libraries. After initially setting up their 3D printers and doing some staff training, they brought in "beta testers", comprised of local advocates they had identified in their initial needs analysis. Due to feedback from these initial test users, library staff were able to tweak their instructional materials, policies, and procedures to better serve first-time users.

Repeated throughout the case studies is the development of maker services through an iterative process of piloting, assessing needs, and then scaling up to fit a demonstrated need. Benjes-Small, Bellamy, Resor-Whicker, and Vassady (2017) conducted a study of 25 academic library makerspaces to determine the factors that led to their success. The study revealed that many makerspaces found success in starting small, piloting limited maker programmes, and gradually scaling up based on feedback from core user groups. According to the study authors, this process "permitted further growth of their spaces to be organic and directly driven by usage and user need" (432). The BatLab Makerspace at Austin Community College Libraries was developed through a similar process of piloting, testing, and scaling up. A series of student-led, pop-up maker workshops gave the BatLab its start and allowed for low-stakes experimentation. The space will continue to grow and refine services, including workshops, a circulating collection of maker kits, and 3D printing technology, all the while collecting user input for future growth (Carr et al., 2016).

Gonzalez and Bennett (2014) describe 3D printing as a "gateway" to makerspaces with a variety of tools, giving libraries a starting point to beta test with campus partners and grow interest on campus. Several of the case studies similarly describe 3D printing as a starting point for comprehensive maker services. At Southern New Hampshire University, Harris and Cooper (2015) began with a single 3D printer, but quickly saw such enthusiasm from students and faculty that the library altered plans for a new Library Learning Commons building to include a makerspace. They plan to continue the path of piloting and scaling, "let[ting] users shape the future of the space going forward" (6). Horbal and Tobery (2018) followed a similar path, beginning with a single MakerBot Replicator 2 in the Spring of 2014 at University of Maryland's main library. A staff presentation on the 3D printer garnered interest from donors and led to a $30,000 donation, allowing them to create a dedicated makerspace in the library. However, the John & Stella Graves Makerspace still went through several more iterations, overcoming lack of space and ventilation issues before finally landing in a new 1,200 square foot space that was previously the library's graduate reading room. These examples demonstrate that it's not necessary to perform a full, comprehensive needs assessment before putting maker services in place, but the literature overwhelmingly recommends starting small, getting feedback from users throughout the process of developing the space, and gradually scaling up based on demonstrated need.

The case studies repeatedly recommend first outlining the purpose of maker services (intended audience, learning goals, etc.), and then determining what equipment, furniture, and space designs support that purpose. According to Vecchione et al. (2017):

> A makerspace is a design thinking workspace where the actual space itself is a design thinking problem. A room can have all the technology in the world, but its success also depends on the way individuals and groups are empowered, how the community interacts, and the users' radical trust in the makerspace (52).

By defining a need and which audience that need affects, we can ensure that our spaces start with a dedicated audience, and we can build out the user base from that solid groundwork.

Keeping potential users in mind for the entire planning process (and continually getting user feedback once the space is open) will ensure that the final space is filling a true need on campus. Many case studies have found that users move through tiered levels of interaction with creative spaces, starting out as passive users and moving towards becoming active leaders and sharers in the space. Harris and Cooper (2015) accommodated various levels of technical knowledge by encouraging users to move through three tiers of experience (Users, Innovators, and Makers), where each tier builds on users' knowledge and encourages higher levels of interaction with the space and other users. Similarly, Vecchione et al. (2018) describe six levels of user engagement. The first level involves a curiosity about the tools, equipment, and services, and users build all the way to the sixth level, at which they take on responsibilities in the space, often "training and mentoring a large group of users with whom they most closely identify" (57). For both of these examples, importance is placed on getting constant feedback from users and allowing users to shape the levels of engagement. By allowing users to shape the future of the service or space, the community of makers grows because users gain a sense of ownership and feel empowered to pursue projects that appeal to them. The case studies show that when the users of maker services are given autonomy appropriate to their level of knowledge, they are more likely to stay engaged and invested in the space.

Makerspace community

A vital aspect of the success of the modern maker movement is community. Many successful academic library makerspaces actively cultivate transdisciplinary communities of practice, allowing users to share knowledge and ideas in informal, low-stakes environments. Particularly in a university setting, students may not have a lot of opportunities in their courses to interact with students outside of their majors. Brown and Vecchione (2014) describe the importance to students of "a group of peers who can help them through the roadblocks towards graduation" (para. 8). To this end, the Albertsons Library strives to provide opportunities for students to make connections through maker events, clubs, and other social opportunities.

Similarly, the iSpace at the University of Arizona Tucson puts emphasis not only on space for students to use maker equipment but also on social interactions in the space. Nichols et al. (2017) explain,

> By sharing a space across disciplines, scholars find dynamic relationships that support multiple points of inquiry, expertise across design, programming, a marriage of science and arts, and a nexus of innovative and scholarly production. The UA campus is benefiting from the expertise of communities of people who can help think through ideas and prototypes in a transdisciplinary setting (366).

Particularly in the neutral space provided by the campus library, maker services can serve as incubators for interdisciplinary collaborations that may never have happened elsewhere on campus.

Supporting services with instruction

But how do we create an infrastructure that supports users and gives them the resources they need to ascend through the levels of knowledge and engagement? The case studies overwhelmingly recommend developing instructional plans to support library creative spaces. By actively participating in the campus instructional climate, librarians can not only ensure that the library's creative spaces are being utilised, but they can maximise the benefits of maker-centered learning for library patrons. A 2017 survey by Benjes-Small, McGlynn Bellamy, Resor-Whicker, & Vassady showed that partnering with faculty in various ways, including incorporating maker topics into curricula, was something many makerspaces believed contributed to their success. Speaking of 3D printing services specifically, Wagner et al. (2018) point out that just having the equipment available at the library is not enough. If instruction, training, and guidance is lacking, the expensive machinery will not be utilised to its full potential. After incorporating 3D printing projects into Occupational Therapy and Physical Therapy courses at Touro College, the authors reported numerous benefits, including creating visibility for the library, increasing traffic to their 3D printing area, and shifting campus-wide perceptions of the library as "central to learning". Radniecki and Klenke (2017) repeated the sentiments that it is not enough to just provide equipment; users need a path to develop skills beyond the initial excitement of experiencing new equipment. Examples of how library creative spaces are providing instruction includes workshops, one-on-one consultations, online tutorials (LibGuides, Lynda.com, etc.), and partnering with faculty to incorporate maker projects into coursework.

Many case studies describe developing strong partnerships with faculty (Benjes-Small et al., 2017; Crum, Hillock, Johnson, & Schmand, 2017; Gonzalez & Bennett, 2014; Lee, 2017; Wagner et al., 2018), a strategy that fulfils several purposes. First, as Messner (2015) explains, academic partners

often become "regular baseline users" of maker services, ensuring that the equipment will be used. According to Messner, "We avoid the question a reviewer might otherwise ask, 'What is a library going to do with this machinery?' To turn a phrase, if we have it, we know they will come, because it is being written into their curricula and research agendas" (25). Nowlan (2015) explains another purpose of faculty partnerships. The University of Regina Library presented sessions through the University's Centre for Teaching and Learning on 3D printing, modelling, and design in order to promote the library's 3D printing services to faculty. Because of this outreach, library staff were able to bring Computer Science and Engineering faculty to the library to conduct workshops. This allowed the library to hold more in-depth workshops for students that might have fallen outside of the expertise of library staff.

Curriculum integration

Faculty partnerships also allow for the incorporation of maker topics into the curriculum, which in many cases solidifies the mission of the library as central to learning and ensures a wide impact for library maker services. More and more, university libraries are realising their niche as facilitators of this type of cross-disciplinary experiential learning. Several case studies cite specific implementations of maker topics in the curriculum. Bharti et al. (2015), in a case study of Marston Science Library at the University of Florida, give several examples of incorporating library 3D printing technology in academic research and teaching in Biology, Computational Microbiology, and Engineering. At Stetson University Library in Florida, Ryan and Tandy Grubbs (2014) collaborated with faculty from chemistry to create tangible molecular models as three-dimensional teaching aids (12).

Challenges of academic library makerspaces

Staffing

The levels of service and instruction that take place within library maker services will hinge strongly on the staffing model of the space. Davis (2018) found that the learning curve for staff and the staff time required for machine repair were widely cited by New England CRLs as one of the biggest challenges in creating makerspaces. Horbal and Tobery (2018) also found difficulty with staffing as demand increased for the University of Maryland's John & Stella Graves Makerspace. With just two staff members running the space, one of which found their time split between roles, the makerspaces organisers struggled with keeping up with the increasing demand of staffing the space. The pair finally solved these issues by

inheriting a swipe-card access system upon moving their space, allowing trained users to access the space on their own.

Benjes-Small et al. (2017) interviewed makerspace organisers on the factors that contributed to their success, and found that sustainable staffing models were key to preventing burnout in makerspace staff. This involved hiring knowledgeable and motivated student support staff to supplement full-time staff, as well as establishing limits of what full-time staff can and cannot accommodate in the space. Messner (2015) advocates for employing student workers from across the university, enhancing library services with students' technology skills while providing students with highly employable skills for their future job searches (23). Scalfani & Sahib also looked to student workers to fill the staffing gap at University of Alabama (UA) Libraries' 3D Printing Studio.

Some libraries have created a more sustainable staffing model for maker services by utilising volunteers. At the Albertsons Library MakerLab at Boise State University, staffing of the space is supplemented with help from the Creative Technologies Association (CTA), a club that includes students, staff, and faculty with technical expertise on various topics. CTA members help teach others in the MakerLab, and in exchange gain critical skills and experience for their resumes (Vecchione et al., 2018). The iSpace at the University of Arizona Tucson has a similar relationship with a student-led entrepreneurship group InnovateUA, which offers student-led workshops in the space. The library, in turn, provides several critical services to InnovateUA, including research assistance, advertising help, and access to library space (Nichols et al., 2017). Utilising student staff or volunteers not only takes pressure off of the librarians running the space, but it opens up possibilities for teamwork and group work, creating a community of knowledge within the space.

Shifting library culture

Although maker services do align in many ways with the mission of academic libraries, new and innovative services often meet with resistance. Library makerspace organisers frequently find themselves in a position of defending non-traditional library services, sometimes even to internal staff. Carr et al. (2016) found success in challenging the culture of the library as a quiet space. In the BatLab Makerspace, they invite the campus community to weekly events with the tagline, "Come join our noise!", a clever reminder that noisy fun can be a part of library activities. Horbal and Tobery (2018) invite staff to hold meetings in the library makerspace. This keeps staff up-to-date on what's happening in the space. One library decided to focus outreach efforts internally, creating pop-up maker events

aimed towards internal staff. At the University of Nevada, Reno, Purpur et al. (2016) found that refocusing outreach efforts internally "may be beneficial in addressing the many concerns raised by incorporating non-traditional makerspace services and technology into the academic library setting" (pp. 138–139). It seems that communication is key. The case studies show that when library staff are included in new services, and when their input is solicited, they will be more likely to support new, non-traditional library services.

Policies and procedures

Establishing strong policies is important to ensure that maker services function well and serve patrons effectively. Gonzalez and Bennett (2014) outlined important elements to include in university library 3D printing services, and many of these policy items would be important to consider for any type of library creative space. These include identifying costs, defining users (students, faculty, community members), defining services, and outlining policies on copyright and trademark issues. Additionally, Harris and Cooper (2015) recommend addressing any restrictions for use of the space, what hours the space will be open, and what training sessions will take place for patrons. Obviously, policies and procedures will evolve and change as spaces grow to meet their patrons' needs, so it is important to assess a space consistently and thoroughly to gauge whether it is meeting those needs.

The challenge of safety is touched on repeatedly in the case studies, and a major theme is the struggle that many library workers face between the desire to remove barriers for patrons and the concern for patron safety. Lenton and Dineen (2016) address this conundrum. "How do you provide unfettered access to technology, encouraging experimentation and hands-on, self-directed learning, while also ensuring everyone's safety and security in an unsupervised environment?" (183). Their solution involved making user training on safety and operations of machinery as accessible and easy to use as possible. Training materials included LibGuides, videos, posters, and even a small reference collection in the space with appropriate manuals and guides. Nowlan (2015) found similar success in mitigating potential safety concerns with clear signage, alerting users to the potential dangers of 3D printing.

Demonstrating impact

All library workers understand that demonstrating impact of library services is a complex and continuing challenge. Demonstrating impact is

especially integral for library maker services in order to justify these non-traditional, possibly controversial new library offerings. Collecting usage statistics is a popular way to gauge interest and need for particular services. Webb (2018) points out that beyond statistics and surveys, "assessment is an in-depth analysis of the impact and effectiveness of the services on offer" (60), and that the best way to structure assessment is around predetermined goals for the space. These goals should tie in with larger library-wide and university-wide initiatives and goals, and assessment should be an ongoing process, as illustrated in Maki's (2002) article on the assessment life cycle (as cited in Webb, 2018). Thorough policies and continual assessment of library maker spaces and services will ensure that a space stays relevant and useful to all members of the campus community.

Lotts (2017) used a combination of usage statistics, user surveys, and anecdotal documentation of patron projects to assess her pop-up makerspace. In assessing the impact of outreach efforts to local home-school students at the Abilene Christian University, Baker (2018) explained that effectiveness is not just measured by how many people attend a programme. Rather, they emphasise the "depth of outreach." This includes asking the question, "Were we inclusive?" If the answer is no, librarians must explore what groups their outreach is missing (1). Specific learning outcomes are another tool often used by academic library makerspaces to measure impact, and this holds true for maker services as well. The BatLab Makerspace at Austin Community College Libraries employs student learning outcomes, including students' use of makerspace tools to explore topics and students' ability to collaborate with peers across disciplines, as a means of measuring the BatLab's impact on learning (Carr et al., 2016).

Conclusions and opportunities for future study

As academic library makerspaces continue to grow both in number and in the variety and inclusiveness of services offered, case studies remain a valuable tool for sharing challenges, successes, and lessons learned. Through analysis of the case studies, we identified a chronological progression from 2012 to 2019 towards increasingly varied types of maker technology and an increasing emphasis on hands-on, user-led learning in academic library makerspaces. The prevailing themes in this review present several guidelines for the creation and improvement of academic library makerspaces:

- The academic library can be justified as an ideal location for maker services because of its position as a neutral, central space for interdisciplinary collaborations.

- Academic library maker services should fill a needs gap on campus. To ensure that a space fulfils a true need, libraries should start small, scaling up in stages in response to user input.
- Developing instructional materials and connecting making to the curriculum will maximise the impact of maker services.
- Student and volunteer staffing models in academic library makerspaces can help to reduce burnout amongst library staff.
- Strong policies help to ensure smooth operation of maker services and prevent safety and security issues.
- Assessing and demonstrating impact involves more than just usage statistics and must be an ongoing process.

The field of library maker services, particularly in academic libraries, is relatively new and therefore presents many opportunities for future study. This review focussed solely on the case studies; other scholarship surrounding maker services in academic libraries was outside of the scope. Therefore, recommendations are limited to the gaps in published case studies. Future case studies would contribute to the field by highlighting: connections between maker movement values and the missions/values of the library profession; how maker literacies might connect with the ACRL Framework for Information Literacy; ways to help patrons overcome potential barriers to using maker services; and ways to assess and demonstrate impact of academic library maker services.

References

Ambrose, S. A., & Poklop, L. (2015). Do Students Really Learn from Experience? *Change: The Magazine of Higher Learning*, *47*(1), 54–61. doi:10.1080/00091383.2015.996098

Baker, L. (2018, December). Extending Our Reach: Using Day Camps at Academic Library Makerspaces to Include Homeschoolers. *In the Library with the Lead Pipe*, 1–1.

Becker, S. A., Brown, M., Dahlstrom, E., Davis, A., DePaul, K., Diaz, V., & Pomerantz, J. (2018). NMC Horizon Report: 2018 Higher Education Edition. Retrieved from Educause website: https://library.educause.edu/~/media/files/library/2018/8/2018horizonreport.pdf.

Benjes-Small, C., McGlynn Bellamy, L., Resor-Whicker, J., & Vassady, L. (2017, March). Makerspace or Waste of Space: Charting a Course for Successful Academic Library Makerspaces. In D. Mueller (Ed.), *At the Helm: Leading Transformation. Proceedings of the ACRL Virtual Conference* (pp. 428–436). Baltimore, MD: Association of College and Research Libraries.

Bharti, N., Gonzalez, S., & Buhler, A. (2015, January). 3D Technology in Libraries: Applications for Teaching and Research. In S. Kataria, K. J. P. Anbu, S. Ram, & R. Gartner (Eds.), Proceedings of the 4th International Symposium on Emerging Trends and Technologies in Libraries and Information Services (ETTLIS) (pp. 161–166). Noida, India: IEEE.

Brown, D., & Vecchione, A. (2014). How to pack a room: 3D printing at Albertsons library. *Idaho Librarian*, *64*(3), 1–1.

Burke, J., & Kroski, E. (2018). *Makerspaces: A practical guide for librarians*. Lanham: Rowman & Littlefield.

Carr, A., Gits, C., Ledbetter, M. D., Townsel, M., & Young, B. (2016). Discovery & making in the library: two specialized spaces in Austin Community College Libraries. *Texas Library Journal*, *92*(3), 75–76.

Clapp, E. P., Ross, J., Ryan, J. O., & Tishman, S. (2017). *Maker-centered learning: Empowering young people to shape their worlds*. San Francisco, CA: Jossey-Bass.

Crum, J. A., Hillock, J., Johnson, B. J., & Schmand, K. L. (2017). Nau's cline library: How we launched our MakerBot Innovation Center in no time. *Computers in Libraries*, *37*(2), 4–8.

Davis, A. M. L. (2018). Current trends and goals in the development of Makerspaces at new England College and research libraries. *Information Technology and Libraries*, *37*(2), 94–117. doi:10.6017/ital.v37i2.9825

Gonzalez, S. R., & Bennett, D. B. (2014). Planning and implementing a 3d printing service in an academic library. *Issues in Science and Technology Librarianship*, *78*, 7–7.

Groenendyk, M., & Gallant, R. (2013). 3D printing and scanning at the Dalhousie University Libraries: A pilot project. *Library Hi Tech*, *31*(1), 34–41. doi:10.1108/07378831311303912

Guevara, S. (2018). Redefining library space: Impressions of Shapiro design lab. *Computers in Libraries*, *38*(7), 4–8.

Harris, J., & Cooper, C. (2015). Make room for a Makerspace. *Computers in Libraries*, *35*, 5–9.

Horbal, A., & Tobery, P. (2018). Third time's the Charm: Finding a permanent home for the University of Maryland's John & Stella Graves MakerSpace. *Against the Grain*, *30*(3), 18–23.

Knies, J. L., Lynn, V., & Angel, E. (2017). Parallel lives: Two Penn State campuses launch 3-D printing. *College & Research Libraries News*, *78*(6), 329–332.

Lee, R. J. (2017). Campus-library collaboration with Makerspaces. *Public Services Quarterly*, *13*(2), 108–116. doi:10.1080/15228959.2017.1303421

Lenton, E., & Dineen, C. (2016). Set it and forget it (almost): How we make DIY 3D printing work in our library. *Public Services Quarterly*, *12*(2), 179–186. doi:10.1080/15228959.2016.1168725

Mathuews, K., & Harper, D. (2018). One size does not fit all: Maintaining relevancy in the modern makerspace movement. *College & Research Libraries News*, *79*(7), 358–359. doi:10.5860/crln.79.7.358

Messner, K. R. (2015). Library as collaboratory: Partnerships, knowledge transfer and dialogue in library-based 3D services. *Bulletin of the Association for Information Science & Technology*, *42*(1), 21–25.

Moorefield-Lang, H. M. (2014). Makers in the library: Case studies of 3D printers and maker spaces in library settings. *Library Hi Tech*, *32*(4), 583–593.

Moorefield-Lang, H. M. (2015). When makerspaces go mobile: Case studies of transportable maker locations. *Library Hi Tech*, *33*(4), 462–471. doi:10.1108/LHT-06-2015-0061

Nagel, J. K., Ludwig, P. M., & Lewis, E. J. (2017, June). Community health innovation through an interprofessional course. Paper presented at the 124th ASEE Annual Conference and Exposition, Columbus, OH.

Nichols, J., Melo, M., & Dewland, J. (2017). Unifying space and service for makers, entrepreneurs, and digital scholars. *Portal: Libraries and the Academy*, *17*(2), 363–374. doi:10.1353/pla.2017.0022

Nowlan, G. A. (2015). Developing and implementing 3D printing services in an academic library. *Library Hi Tech*, *33*(4), 472–479. doi:10.1108/LHT-05-2015-0049

Okpala, H. N. (2016). Making a Makerspace case for Academic Libraries in Nigeria. *New Library World*, *117*(9/10), 568–586. doi:10.1108/NLW-05-2016-0038

Passehl-Stoddart, E., Velte, A., Henrich, K. J., & Gaines, A. M. (2018). History in the making: Outreach and collaboration between special collections and Makerspaces. *Collaborative Librarianship*, *10*(2), 133–149.

Purpur, E., Radniecki, T., Colegrove, P. T., & Klenke, C. (2016). Refocusing mobile Makerspace outreach efforts internally as professional development. *Library Hi Tech*, *34*(1), 130–142. doi:10.1108/LHT-07-2015-0077

Radniecki, T., & Klenke, C. (2017). Academic Library Makerspaces: Supporting new literacies & skills. In D. Mueller (Ed.), *At the Helm: Leading Transformation. Proceedings of the ACRL Virtual Conference* (pp. 15–22). Baltimore, MD: Association of College and Research Libraries.

Reuscher, J. A. (2014). Three-dimensional (3-D) scanning within academic libraries. *Pennsylvania Libraries: Research & Practice*, *2*(1), 64–70. doi:10.5195/PALRAP.2014.56

Ryan, S. M., & Tandy Grubbs, W. (2014). Inspiring innovation: Collaboration in support of 3D printing as an emerging technology in academic libraries. *Florida Libraries*, *57*(2), 11–18.

Saorin, L. J., Melian-Diaz, D., Bonnet, A., Carbonell Carrera, C., Meier, C., & De La Torre-Cantero, J. (2017). Makerspace teaching-learning environment to enhance creative competence in engineering students. *Thinking Skills and Creativity*, *23*, 188–198. doi:10.1016/j.tsc.2017.01.004

Scalfani, V. F., & Sahib, J. (2013). A model for managing 3D printing services in academic libraries. *Issues in Science and Technology Librarianship*, *72*, 1–1.

Schuck, B., Wainscott, S. B., Church-Duran, J., & Del Bosque, D. (2017). Creating a virtuous circle of student engagement with the tech corner. *Journal of Library Administration*, *57*(5), 517–547.

Sin Guek, F. (2015). Makerspace at Singapore polytechnic. *Singapore Journal of Library & Information Management*, *44*, 1–10.

Wagner, J. B., Scheinfeld, L., Leeman, B., Pardini, K., Saragossi, J., & Flood, K. (2018). Three professions come together for an interdisciplinary approach to 3D printing: Occupational therapy, biomedical engineering, and medical librarianship. *Journal of the Medical Library Association*, *106*(3), 370–376. doi:10.5195/JMLA.2018.321

Wallace, M., Trkay, G., Peery, K., Chivers, M., & Radniecki, T. (2018, August 3–5). Maker *competencies and the undergraduate curriculum*. Paper presented at the 2018 International Symposium on Academic Makerspaces, Stanford, CA.

Wilczynski, V., Wigner, A., Lande, M., & Jordan, S. (2017). The value of higher education academic Makerspaces for accreditation and beyond. *Planning for Higher Education*, *46*(1), 32–40.

Webb, K. K. (2018). *Development of creative spaces in academic libraries: A decision maker's guide*. San Diego, CA: Elsevier Science & Technology.