Makerspace Task Force Report

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by
HS/HSL Makerspace Task Force,
Health Sciences and Human Services Library,
University of Maryland, Baltimore.

Aphrodite Bodycomb, MBA, Co-chair
Everly Brown, MLIS
Bohyun Kim, MSLIS, MA, Co-chair
Thom Pinho, Instructional Technology Specialist
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Executive Summary

The leadership of the Health Sciences and Human Services Library (HS/HSL) has decided to explore the concept of a makerspace. The recent growth and rapid adoption of makerspaces and 3D printing technology in health sciences will impact the tools that our future students, researchers, and faculty will expect to have access to. The mission of this Task Force was to determine what role a makerspace could serve in an academic health sciences library and if the University of Maryland, Baltimore’s HS/HSL could benefit from one.

Based on the environmental scan, which involved the literature review of current makerspaces in educational institutions and site visits to local makerspaces, we believe that a makerspace within the HS/HSL will greatly benefit UMB students, researchers, and faculty. It will provide an open space that will allow them to explore and utilize new technology that has a significant impact on hands-on learning, classroom instruction, cutting-edge research, and innovative patient care in health sciences. This Task Force recommends the creation of a makerspace in HS/HSL which would include 3D printers, 3D scanners, and computers with the appropriate software for modeling and visualizing 3D objects as detailed in the recommendations section of this paper. The makerspace would also organize workshops and programs to promote technological experimentation and idea prototyping to the UMB community.

To fund the creation of the makerspace, the Task Force has identified two potential grant opportunities that would help cover some costs associated with creating the space if applied for and awarded. Other potential sources of funding include soliciting donor funds for technology or stakeholder contributions. In order to best support the needs of students, researchers, and faculty, the Task Force also recommends that this project be pursued as soon as the funds are available.
1. Why Do We Want a Makerspace at UMB HS/HSL?

A. What is a Makerspace?

‘Makerspace’ refers to a community-operated workspace where people with common interests, often in computers, machining, technology, science, digital art or electronic art, can meet, socialize and collaborate. (Henry 2012) A makerspace is often used interchangeably with similar terms such as hackerspace or fab lab. But they are not synonyms. Colegrove (2013) describes a fab lab, a hackerspace, and a co-working space as follows.

“A ‘fab lab’ is workshop designed around personal manufacture of physical items—typically equipped with computer controlled equipment such as laser cutters, multiple axis Computer Numerical Controlled (CNC) milling machines, and 3D printers. A ‘hackerspace’ is more focused on computers and technology, attracting computer programmers and web designers. Co-working space is a shared working environment offering much of the benefit of the social and collaborative aspects of the informal hackerspace, while maintaining a focus on work that appeals to independent contractors and professionals rather than hobbyists.” (Colegrove 2013) (Emphasis by the Task Force.)

According to Colegrove, a makerspace encompasses a continuum of activity that includes “co-working,” “hackerspace,” and “fab lab,” all of which focus on making rather than consuming. The goal of a makerspace is to foster and facilitate creativity and innovation by providing a playful and informal learning environment for hands-on experimentation and learning-by-doing experience.

B. Why Makerspace at an Academic Library?

Since 2012, an increasing number of academic and public libraries have created and opened a makerspace for their patrons. According to Doorley and Witthoft (2012), an academic library is a great place for a makerspace due to its kinship with interdisciplinary research and collaboration.

“The library is in a unique position to be able to leverage the wealth of learning and opportunities for knowledge creation that access to such technology can provide in a way that most individual departments are not. Because the library exists for everyone in the academic community, we are well equipped to provide open support for all. By its very nature the library is an active interdisciplinary hub, where communities of practice cross paths regularly; rather than relegated to isolated departmental “silos” on campus, library technology explicitly enables learning and knowledge creation across disciplines. Science, Technology, Engineering & Math projects can be augmented
by insights from the Arts and Humanities, and vice-versa. Regardless of academic
discipline, “imagination begets fabrication, fabrication begets imagination.” (Doorley &
Witthoft 2012) (Emphasis by the Task Force.)

While makerspaces provide many other tools and resources for making activities, the most
prominently featured technology at library makerspaces is 3D printing. Having been invented in
the 80s, 3D printing technology is not necessarily new. But the recent advent of 3D printers on
the market with a much lower price tag has made a 3D printer far more accessible to the public.
Currently, those who most frequently use a makerspace at an academic library, particularly its
3D printing facility, are students in science, engineering, and arts. For this reason, most
makerspaces at academic libraries are found at science and engineering libraries, large
university libraries, and art institutes.

As we will discuss shortly in the next section, the Maker Movement, makerspaces, 3D modeling
and 3D printing technology have been revolutionizing healthcare. Furthermore, as shown in the
case of Baltimore’s Maker Camp for K-12 students in Digital Harbor Foundation
(http://www.digitalharbor.org/makercamp/), an increasing number of K-12 schools are opening
up makerspaces to introduce children to active learning, collaboration, and 3D printing and
modeling technology. University of Maryland, Baltimore will see more future students who are
familiar with and expect a makerspace with 3D printers on the UMB campus. Johns Hopkins
University, Maryland Institute College of Art, Community College of Baltimore County, and
Towson University already provide makerspaces with 3D printers to accommodate such
growing expectations from their students and they are all located in the Greater Baltimore
area.

C. The Impact of the Maker Movement and 3D Printing on Healthcare and
Beyond

The Do-It-Yourself spirit of the Maker Movement, particularly the 3D printing technology, has
not only drawn huge interest from healthcare professionals but also resulted in some significant
clinical applications. Prince (2014) describes well how revolutionary the impact of 3D printing
has been in the medical field.

“One of the most revolutionary areas where 3D printing has come into play has been in
the medical field, from the most obvious areas such as printing scaffolds for cells to cling
to and establish themselves and customizing prosthetics to the startling—printing, using
living cells as the medium. While 3D printing is still very far away from being able to
print organs, it is possible to print artificial scaffolds in the shape of an organ with living
cells. Dr. Anthony Atala at Wake Forest’s Regenerative Medicine department has
printed a kidney-shaped scaffolding, and his department has worked with the military to
print skin cells directly onto burns to speed healing. In another instance of 3D printing used in medicine, additive manufacturing saved the life of an infant. In February 2012, physicians at the University of Michigan implanted a 3D printed splint into the trachea of an infant whose collapsed bronchus was blocking airflow to his lungs. The splint was made of a biopolymer called polycaprolactone and was created directly from a CT scan of the infant’s trachea/bronchus. The splint gave the bronchus support for proper growth and, over the course of three years will be absorbed by the boy’s body. This procedure was experimental and was able to progress only because of impending threat to the baby’s life.” (Prince 2014)

The great impact of the Maker Movement and the 3D printing on healthcare is now hard to miss as it is being reported on a daily basis by the news media.

- A surgeon in Maryland performed a total knee replacement surgery using 3D printing technology to cast an implant and manufacture the jigs — plastic cutting guides — that direct incisions. ([http://www.baltimoresun.com/health/maryland-health/bs-hs-3d-knee-replacement-20140720,0,7636638.story#ixzz386uPlbRx](http://www.baltimoresun.com/health/maryland-health/bs-hs-3d-knee-replacement-20140720,0,7636638.story#ixzz386uPlbRx))
- Pharmacists are exploring a way to use 3D printing to produce medicine at a much more customized and affordable manner. ([http://www.theguardian.com/science/2012/jul/21/chempunter-that-prints-out-drugs](http://www.theguardian.com/science/2012/jul/21/chempunter-that-prints-out-drugs))
- Scientists can now bio-print human tissues using a high-tech 3D printer and are attempting to 3D print even a human organ itself. ([http://www.theguardian.com/science/2014/jul/04/3d-printed-organs-step-closer](http://www.theguardian.com/science/2014/jul/04/3d-printed-organs-step-closer))
- A man in Massachusetts created a prosthetic hand for his son who was born without fingers using a 3D printer at only a fraction of the cost for a commercial prosthetic hand. ([http://www.huffingtonpost.com/2013/11/04/dad-prints-prosthetic-hand-leon-mccarthy_n_4214217.html](http://www.huffingtonpost.com/2013/11/04/dad-prints-prosthetic-hand-leon-mccarthy_n_4214217.html))
- A Baltimore-based startup company, Verve, launched a Kickstarter campaign for their 3D printed device for posture and pain relief (called ARC) and raised over $7,000 in less than 24 hours. The company includes UMB faculty member, Dr. Gene Shirokobrod in School of Medicine. ([http://stocks.moneyshow.com/intershow.moneyshow/news/read/27146844/baltimore_startup%E2%80%99s_kickstarter_raises_$7000+_in_less_than_24_hours](http://stocks.moneyshow.com/intershow.moneyshow/news/read/27146844/baltimore_startup%E2%80%99s_kickstarter_raises_$7000+_in_less_than_24_hours))

As a new and affordable means of production, the Maker Movement and 3D printing are democratizing manufacturing. This has the remarkable effect of catalyzing innovation and
fostering entrepreneurship, which is vital to continuous economic growth. Recently, the White House held its very first White House Maker Faire, where over a hundred people exhibited the items that they created using technologies such as 3D printers, laser cutters, easy-to-use design software, and desktop machine tools. The White House stated that the rise of the Maker Movement represents a huge opportunity for the nation and it will create the foundation for new products and processes that can help to revitalize American manufacturing in the same way that the Internet and cloud computing have lowered the barriers to entry for digital startups (http://www.whitehouse.gov/maker-faire#section-about). On the same day, the National Institutes of Health launched the 3D Print Exchange (http://3dprint.nih.gov/) so that researchers can share 3D print files, thereby acknowledging the important role of 3D modeling and printing technology in biomedical and scientific research. The National Aeronautics and Space Administration also released 3D files, which the public can use to create models of satellites, probes, planetary formations and even asteroids with a 3D printer (http://nasa3d.arc.nasa.gov/models/printable). The Maker Movement and 3D printing are no longer a novelty but a mainstream phenomenon.

D. Benefits of the HS/HSL Makerspace for UMB Faculty, Researchers, and Students

The increasing number of innovative applications and inventions created with 3D printing in healthcare and health sciences means that faculty, researchers, and students in health sciences will greatly benefit from being exposed to and becoming familiar with 3D modeling and 3D printing technology.

Some of those benefits for UMB faculty and researchers include:

- Create instructional tools such as 3D models of molecules or human anatomy that students can touch and handle in order to improve classroom instruction and expedite a student’s learning process.
- Strengthen a grant proposal for research funding by including the HS/HSL makerspace facility, equipment, service, and staff-expertise.
- Create a simple custom research tool that is costly or not available in the market to facilitate the research process.
- Quickly prototype a physical model of a medical or healthcare-related invention to test out the feasibility of further entrepreneurial pursuit, commercialization, and mass production.
- 3D scan and 3D print the exact bone structure of a specific patient to perform the best surgery.
- Utilize 3D scanning and 3D printing technology for personalized and innovative patient care.
The HS/HSL makerspace also benefits UMB students by enabling them to:

- Explore novel technology that has a significant impact on health sciences while benefiting from the open exchange of ideas and collaboration during the process with other students.
- Be ahead of the curve and become more competitive in their study, research, and the future job market from the learning opportunities and resources for 3D modeling and the 3D printing technology along with the required equipment and software.
- Engage in hands-on learning activities with 3D printing in a safe and fun space.
- Rapidly prototype ideas and concepts for study, research, experimentation, and innovation.

Six out of seven schools in UMB belong to the discipline of health sciences. But there is currently no open-access facility for 3D printing and 3D modeling on the UMB campus. From the meeting between the Task Force and several stakeholders on campus, we also know that there are UMB faculty members who are deeply interested in 3D modeling/printing and a makerspace within HS/HSL. Those people have not yet been connected with one another due to the lack of a common gathering space with the necessary equipment and learning opportunities for their making activities. A makerspace at HS/HSL has a strong potential for increasing experiential teaching and learning opportunities, interdisciplinary interaction, cross-pollination of ideas, and collaboration on campus by gathering creative individuals already pursuing innovative projects at an active and collaborative hands-on learning environment, where students, faculty, and researchers can tap into their own creativity and imagination in their areas of specialization. These possibilities may also result in catalyzing innovation and collaboration with an initiative on the UMB campus, such as the UMB BioPark, in the future.

For these reasons, the Task Force believes that there is a clear need for bringing these technologies closer to UMB students, faculty, and staff and for making them easily accessible by creating a makerspace equipped with necessary tools, resources, and educational training opportunities. As an established traffic hub for students, faculty, staff on campus, the HS/HSL is well positioned to meet this need on the UMB campus. Creating a makerspace at HS/HSL also supports the HS/HSL’s mission of supporting discovery and learning by keeping the UMB students, faculty, and researchers up-to-date with fast-changing technology developments that have a significant impact on their fields.
2. Environmental Scan

As a preparatory step for writing a recommendation to create a makerspace in the HS/HSL, the Makerspace Task Force have reviewed approximately thirty makerspaces at academic libraries, public libraries, and also those located in Baltimore area. In addition to collecting information about these makerspaces from the library and information science literature and each makerspace website, the Task Force also visited four local makerspaces - Digital Media Center (DMC) at Johns Hopkins University (JHU), Digital Fabrication Studio at Maryland Institute College of Art (MICA), FabLab at Community College of Baltimore County (CCBC), and Baltimore Underground Science Space (BUGSS). (The photos taken at these visits can be viewed at the HS/HSL Makerspace Task Force website at http://hshsl-umaryland.beta.libguides.com/c.php?g=108113.)

A. Makerspaces in Academic Libraries

For this report, thirteen academic libraries that offer either a makerspace or 3D printing service have been reviewed. None of these libraries provides extensive information about the background of their makerspaces or 3D printing facility, how they came to exist, how they align with the library’s mission, and what purpose it serves for their user population on their websites. Some of these libraries’ makerspaces and 3D printing facilities have limited information about even their operation, services, and policies. Not much literature exists in library and information science that discusses creating and managing makerspaces for libraries in detail. This is perhaps understandable considering that 3D printing facilities and makerspaces are still quite new to libraries. The DeLaMare Science and Engineering Library at the University of Nevada at Reno was the first among the academic libraries in the US to offer 3D printing and scanning as a library service to all students in the summer of 2012. The Fayetteville Free Library in New York State created the first makerspace in a public library in the US in 2011.

Our environmental scan identified only two academic health sciences libraries that experimented with 3D printing: (i) University of Virginia Claude Moore Health Sciences Library and (ii) University of Michigan Taubman Health Sciences Library. Claude Moore Library purchased a 3D printer, but it was never put on the floor. Instead, the individuals who learned about it through the library’s marketing efforts have contacted the library to use the 3D printer. There was no further information that could be found about 3D printing on their website. University of Michigan Taubman Health Sciences Library refers their library patrons who are interested in 3D printing to the large makerspace facility in their main university library. Their library is currently under construction for the coming year and has no walk-in patrons. While there are not many academic health sciences libraries that provide a makerspace or even just a 3D printer currently, this may quickly change since 3D printing has been almost reshaping
biosciences. (SciBytes 2014) We believe that this is an opportunity for HS/HSL to be a pioneer in creating and experimenting with a makerspace at the academic health sciences library setting. Below is the summary of the key findings from our environmental scan of makerspaces at academic libraries.

*(For more detailed information about each academic library makerspace reviewed, please see Appendix 1.)*

- **Vision:** None of the reviewed academic libraries provides much information about the background of their makerspace or the 3D printing facility, how they came to exist, how they align with the library’s mission, or what purpose it serves in their user population in a public manner. This may be because the makerspace or the 3D printing service they offer is an experimental project on a small scale.

- **Role:** 3D printing service at an academic library benefits the whole university campus by allowing universal access to a new technology suitable for rapid prototyping for the whole campus, thereby benefiting even those institutions that already have some 3D printing facilities in specific schools or laboratories. A 3D printing service can help students’ independent study, research, and course projects. For example, the teaching faculty can use the 3D printing service to create lab equipment and instructional models. As 3D printing technology becomes more widely adopted in industries, the knowledge of 3D modeling and 3D printing may also provide tangible benefit for students in the job market. University of Alabama Rogers Science and Engineering Library regards creating more 3D modeling users through education and training as one of the explicit goals of their 3D Printing Studio.

- **Staffing:** University of Nevada, Reno, DeLaMare Library, North Carolina State University Libraries, and University of Michigan Library hire students who are familiar with 3D modeling and 3D printing to work at the library makerspace. Other libraries are allocating part of the work time of existing librarians and staff to the management and operation of their 3D printing service. The service hours tend to be much shorter than the library’s open hours, and some places require users to make an appointment in advance.

- **Service:** Except University of Alabama, all other academic libraries that offer 3D printing provide a mediated service, which means that only the library personnel can handle the 3D printing equipment. Library patrons submit a .stl (stereolithography) file for 3D printing and pick up the finished product later on after paying a nominal fee for the cost of the material. The turnaround time for the 3D printing service is 2-3 days on average.
By contrast, University of Alabama runs its 3D printing studio as an open-access model after a required workshop and individual consultation.

- **Programming**: Beyond delivering a 3D model from a file submitted by a library patron, there is a varying degree of the support by library staff for patrons who are not already familiar with 3D modeling. Most libraries offer help with the 3D printer setting. Many libraries also provide a list of helpful resources and tools for learning 3D modeling. But only some libraries appear to offer workshops or in-depth consultation on 3D modeling. Groenendy and Gallant at Dallhousie University Libraries noted that simply providing 3D printing and scanning technology without instruction will impede effective use of these technologies due to the lack of experience of students and faculty and argued for the need for demonstrations and various instructional seminars. (Groenendy and Gallant 2013)

- **Space**: Little information was found about the makerspaces at academic libraries on their websites. This is likely to be due to the fact that most of these makerspaces are simply a place for a mediated 3D printing service. Since library patrons do not actually operate a 3D printer in this service model, 3D printers are often invisible to library patrons and put out for a show rather than being used as an active learning equipment. (Makerspaces that do not belong to a library but located at academic institutions such as MICA, CCBC, or Johns Hopkins, on the other hand, are exceptions to this. Those space include multiple computers with a suite of 3D modeling software, work tables, lockers, and the wall space for tools. The Task Force included these spaces in the next section, “Local Makerspaces.”)

- **Equipment**: 3D printing is the major focus of the makerspaces at academic libraries. As a matter of fact, only two of the academic libraries – NCSU and University of Michigan – offer equipment beyond 3D printing with plastic such as a laser cutter or a 3D printer that works with resin or epoxy. DeLaMare Science and Engineering Library recently also added a laser cutter to its equipment list.

- **Operation Policies**: Not all libraries have detailed policies, but most of them specify the costs for 3D printing and provide FAQs about 3D modeling/printing. University of Alabama Rogers Library has a detailed operation manual that is used for training for both library patrons and staff. University of Michigan Library provides a large number of video tutorials on YouTube as well as an online self-test to familiarize library patrons with operating its 3D printers available for check-out.

- **Cost recovery**: All academic libraries reviewed are charging fees to recover the cost for the material except the University of Alabama. University of Alabama Rogers Science
and Engineering Library is offering the 3D printing service for free during its piloting phase. The University of Michigan Library leaves it to patrons to purchase the plastic directly from the manufacturer of the Cube 3D printer.

- **Usage Pattern:** Southern Illinois University Lovejoy Library noted that while the demand is relatively small, the rate of repeat user was high and this is likely to be due to the fact that many users do not know how to create a 3D model or do not have access to software that allows them to do it. (Pryor, 2014)

**B. Local Makerspaces**

The Baltimore Area is a growing hub for makerspaces partly due to the large number of local universities and a wealth of technology and arts programs. These programs created an atmosphere conducive to creating and expanding makerspaces. The innovations in 3D printing/modeling technology have transferred easily into many academic programs. Somewhat of a newer phenomenon to academia and STEM is the growing desire of innovators and researchers to use this technology for the quick prototyping of their ideas and inventions. Previously, 3D printing technology was cost-prohibitive and consequently only available to large companies, government agencies, and the military. Recent innovations in this area, however, have made 3D printing more affordable. The expiration of a 3D patent further opened up competition in the market and enabled 3D printing to expand at a more rapid pace to the non-commercial environment. ([http://www.extremetech.com/extreme/175562-major-patent-expiration-could-spark-a-second-3d-printing-revolution](http://www.extremetech.com/extreme/175562-major-patent-expiration-could-spark-a-second-3d-printing-revolution)) Local Makerspaces are growing fast, and a recent article described 3D printing as the next Industrial Revolution anticipating rapid growth over the next three years. (Hiavin 2014)

Below is a summary of the key findings from the environmental scan of several local makerspaces in Baltimore. The local makerspaces reviewed include five at academic institutions and several independent membership-based makerspaces such as Baltimore Node, Baltimore Hackerspace, and Baltimore Underground Science Space (BUGSS). Among these, the Task Force visited four local makerspaces: DMC at JHU, FabLab at CCBC, Digital Fabrication Studio at MICA, and Baltimore Underground Science Space (BUGSS). It is to be noted that the four local makerspaces at JHU, CCBC, MICA, and Towson did not belong to a library. The photos of these places and the list of the questions asked during the visits can be found in the HS/HSL Task Force website. ([http://hshsl-umaryland.beta.libguides.com/c.php?g=108113](http://hshsl-umaryland.beta.libguides.com/c.php?g=108113))

*(For more detailed information about each local makerspace reviewed, please see Appendix 2.)*
• **Vision**: These spaces generally serve to promote science and creativity. The general theme that carries over from one makerspace to another is the desire for individual freedom to create without limitations and promoting future innovative discoveries.

• **Role**: Makerspaces allow their members to quickly prototype ideas or manufacture items using equipment that are not usually available at someone’s home. For example, people can make wooden boxes using a laser cutter or 3D print a plastic iPhone case using a 3D printer at these makerspaces. Makerspaces at academic institutions not only enable students to create models for their academic projects but also function as a space where they can have fun and also engage in creative activities. BUGGS has the unique mission of making biotechnology accessible to the public by educating them and providing a biology lab facility and equipment.

• **Staffing**: Makerspaces at academic institutions such as DMC at JHU and Digital Fabrication Studio at MICA were staffed during all open hours and had several staff members for on-site help as well as group workshops and training by appointment. Other local makerspaces were open to their members during set hours, and as a membership-based organization, they did not staff the space full time but relied on an environment that encouraged members to help each other out.

• **Service**: Makerspaces at academic institutions offer some equipment for check-out (digital cameras, kits, etc.) or use (a plotter, computers with 3D modeling software, a 3D printer, a laser cutter, etc.) as well as group workshops, events, and on-site help and some training by the staff. Membership-based makerspaces mostly made their equipment and workspaces available to their members and also ran some workshops and talks on an ongoing basis.

• **Programming**: Workshops and gatherings appeared to be consistently well attended at each location, even more so than the use of the equipment at least in their beginning phases. Many makerspaces brought in 3D printing technology, and since it is still somewhat of a newer offering, those makerspaces have supplied training, tutorials, and workshops to bridge the knowledge gap in users who are new to the 3D printer. The programming themes varied, but they were all innovative and progressive topics. Programming ranged from workshops that teach building and creating objects including items such as 3D origami and jewelry (DMC). Other examples included programming on creating medical devices and working with the FDA and “Building a Gene” (BUGSS). Most makerspaces offered or required training on the use of the equipment including a 3D printer, safety equipment, a laser cutter, and provided other workshops such as how to use software to design a 3D model and how to print a 3D object. Programming which
educates on the use of new technologies, along with offering topics that inspire creativity and innovation, stood out as a very important factor in developing and sustaining a successful makerspace.

- **Space**: Local makerspaces varied in sizes but ranged from 1,500 square ft. to 3,500 square ft. and were often broken into different work areas. For example, 3D printers were kept separately from a milling machine, a laser cutter, or other workshop space. Computers were often separated from the printing or the other workspace. Both the MICA and the DMC JHU staff commented that the most heavily used and populated space is the area where computer workstations are because most students spend a lot of time designing a model on a computer before printing it out or laser-cutting material.

- **Equipment**: There was a wide range of equipment available at each space. Spaces associated with the arts or digital media - such as MICA and JHU - had larger and higher-end devices, tools, and other drilling and building types of equipment. Unlike other makerspaces, BUGGS offered the biology lab facility and equipment because it focuses on biohacking activities such as gene sequencing or working with cells.

- **Operation Policies**: Most spaces required safety training for users. They also had set hours during which the space was open for use. Two makerspaces - MICA and JHU - had Lynda.com on the makerspace computers. Lynda.com is an educational resource which offers a wide array of online tutorials about 3D modeling and other makerspace-related devices, tools, and activities for self-directed learning. At academic makerspaces, in-person training is also provided by the staff in the form of workshops and on-site help. Membership-based public makerspaces appear to provide much less staff help and instead emphasize members helping one another while they are using the space.

- **Funding**: Various funding models exist across different makerspaces, but there were other themes, which included student fees and membership dues with or without the startup costs funded by donations. Many spaces used cost recovery when it came to 3D printing supplies. Other spaces - DMC at JHU - charged for additional services such as printing a large poster with a plotter. Makerspaces at academic institutions received most of their funding from their schools. For example, the funding for DMC at JHU comes from student fees at JHU’s Schools of Engineering and Arts & Sciences. As such, the DMC serves primarily the students of those two JHU schools. Membership-based local makerspaces such as Baltimore Node and BUGSS are funded by their membership dues.

- **Usage Pattern**: Most local makerspaces commented that their programs are well attended and spaces were used for various reasons such as the availability of 3D
modeling and design software, using the 3D printer for a “trial run” before sending it out to a more expensive venue, checking-out of equipment, and collaboration and discussion with other people. The local makerspace staff whom we met during our site visits also emphasized the importance of building an active maker community as an even more crucial element to the success of a makerspace than providing an array of expensive higher-end equipment, tools, and devices.

C. Makerspaces in Public Libraries

Nine makerspaces in public libraries in the United States and Canada were examined. The spaces varied, but there were also recognizable commonalities. Below is the summary of the key findings from the environmental scan of makerspaces at public libraries.

(For more detailed information about each public library makerspace reviewed, please see Appendix 3.)

- **Vision:** The public libraries examined spoke in similar terms when describing their vision for the makerspace. They aim to provide a communal space that is inspirational, accessible, and collaborative; to allow people to bring their ideas into reality and share their talents. The Madison Public Library’s space, The Bubbler, was one of the more elaborate. “Whether offering the basics of animation, screen printing, music, clothing design, dance, or painting (to name a few), the Bubbler’s hands-on pop-up workshops introduces participants to a variety of local experts who share their talents and physical resources. Our deep list of partners keeps the Bubbler experience current and dynamic, offering a wide range of lectures, demonstrations, performances, and make-and-take workshops in all nine library branches and at partner locations around the city.”

- **Role:** A few of the spaces were limited to teens or children, but most were open to all ages with some separate programming for the different groups. There is a definite commitment to community service, with classes that range from practical to whimsical (bike repair vs. egg decorating). They see themselves as a way to bring people and talents together.

- **Staffing & Service:** Hours and staffing levels varied considerably. The aforementioned Bubbler is open during all regular library hours, but most were on a more limited schedule. Most of the websites did not discuss cost, though a few mentioned charging a small amount for the cost of the filament used in 3D printing. Several also spoke of users bringing in their own kits and supplies to workshops. Staffing was diverse as well. Detroit’s [HYPE Teen Center](#) provides expert instructors, but most rely upon either library
staff with “some” training or community volunteers. Two mentioned having “artists in residence.”

- **Programming:** Programming was wide-ranging and interesting and usually presented in a calendar of events. Classes were a mix of drop-in and registration-required. There were regularly recurring classes and also “open lab” hours. The Piscataway Public Library’s Make it Yourself (MiY) space offers a “Summer of MAKE” program to children for 8 weeks with 20 unique programs “experimenting with a variety of materials and across disciplines.” Here is a list of a few of the workshops that the libraries offered: drop-in animation lab, cheese making, sewing wearables, 3D cookie cutter lab, Raspberry Pi projects, audio engineering, robotics club, and making with arduino. Several of the libraries offered laser cutter and 3D printer certification classes before allowing un-mediated work with the machines, and only one library did not allow any unmediated use of their 3D printer. This stands contrasts with makerspaces at academic libraries, most of which offered the 3D printing service in the mediated manner only.

- **Space:** Most libraries did not describe their makerspace area, but photographs posted to their websites did provide some information. Large rooms with many broad tables and chairs appeared to be the norm. Cabinets and countertops ringed the walls to house the equipment and supplies. The Cleveland Public Library’s Tech Central goes a step further and offers, “a small seating and meeting space, including a SMARTBoard projector” for project design and collaborative meetings.

3. Recommendations for HS/HSL

A. Vision, Service, and Educational Training

Based upon our research about makerspaces and 3D printing technology, the Task Force recommends the creation of a makerspace at HS/HSL. We believe that the following vision and role would be suitable for the HS/HSL makerspace.

- **Vision:** Promote, support, and facilitate hands-on learning and research activities and creative experimentation, which are vital to innovation. Develop and cultivate a vibrant and inviting collaborative workspace where students, researchers, and faculty members exchange ideas and tinker with physical objects and 3D models to experience what it is like to make things, create 3D models on a computer, and print them out using a 3D printer.

- **Role:** Provide access to 3D printing/modeling technology to enable UMB students, faculty, and researchers to quickly build a prototype to test theoretical ideas and
concepts and to keep them up-to-date with technologies that drive current innovations in healthcare and biomedical research.

For the service model, our recommendation is the open studio model that allows patrons to freely access and use the makerspace and its equipment without the mediation of the staff. We are aware of the fact that most academic libraries operate on the mediated service model. But the mediated service model offers 3D printing as an on-demand service and does not provide an active hands-on learning environment. Consequently, it does not fit the vision of the HS/HSL makerspace as a vibrant collaborative workspace where students and faculty exchange ideas and tinker with things on their own. The open studio model, by contrast, provides those who have successfully completed the safety training and workshop with the full access to the makerspace. The open studio model also helps bringing in students and faculty who are not familiar with 3D modeling and printing but are eager to learn by trying out. By minimizing the barrier to accessing new technology, the open studio model allows to make a makerspace inviting to those with little experience or knowledge in the 3D modeling/printing technology as well as those who are already familiar with it.

● **Service Model:** We recommend the HS/HSL makerspace operate on the open studio model with the mandatory completion of safety training and a workshop that introduces patrons to the basics of 3D modeling and the other tools and resources available in the makerspace.

The Task Force also recommends the following for educational training and program planning for the makerspace.

● **Educational Training:** We recommend that the HS/HSL makerspace offer regular training and workshops on 3D modeling to grow more 3D modeling users on campus. The makerspace should also offer assistance and consultation by appointment for those who bring an .stl file to 3D print their models. It would be idea if online tutorials, handouts, and training manuals for first-time users are also available. But developing such instructional materials will take a significant amount of staff time at the early stage of the makerspace. For this reason, we also recommend providing other learning resources such as Lynda.com ([http://www.lynda.com/](http://www.lynda.com/)), which offers a large number of online tutorials about 3D modeling software, to facilitate self-directed learning as much as possible.

● **Makerspace Programming Committee:** The Task Force also recommends the creation of a standing committee for the HS/HSL makerspace programming. This committee will plan and organize interesting talks, presentations, making activities, and workshops by inviting UMB students and faculty and other local makers and scientists. In the
beginning stage, it is hard to determine the level of interest or demand for the makerspace on campus. Active programming will be a key to generate the necessary buzz - a mix of inspiration and excitement - that would be crucial to establishing and cultivating the new HS/HSL makerspace as an active peer-to-peer learning and collaboration space and to growing a community of makers on the UMB campus. *(For more ideas about potential programming ideas for the HS/HSL makerspace, see Section 3-D: Promotion and Programming.)*

**B. 3D Printers, Other Equipment, and Resources**

We recommend the following items in each category as an appropriate set of equipment, tools, and resources for the HS/HSL makerspace in its beginning stage. As the makerspace evolves and the HS/HSL staff gain more understanding about the users’ needs and demand, more items should be added for it to better serve the UMB community.

*(Please see Appendix 4 for the list of items listed below and more comparable items under each category along with their prices, features, and other factors.)*

**Hardware**

- **3D Printers**
  - Replicator 2x: The Replicator 2x from MakerBot boasts among the finest print resolution (only 11 microns on the xy axis - extremely fine) with a layer height of 2.5 microns - while having a substantial print volume of over 9x6x6 inches.
  - Cube: The Cube by 3d systems offers a measured balance between speed and performance with the added advantage of the ‘cartridge’ load system, which virtually eliminates print head maintenance issues. University of Michigan Libraries have a dozen of these and check them out to patrons, who buy the printing materials directly from the company.

- **Computers**
  - In addition to two dedicated printing workstations with capable 3D graphics rendering hardware, the space should also offer a bank of computer workstations equipped with 3D modeling software as well as other experimental software tools [e.g. data visualization tools, animation suites, programming packages.] This resource serves not only the purpose of allowing patrons a chance to create or modify their models but also provides a viable venue for training.

- **Finishing Tools**
  - The makerspace needs to provide some manual finishing tools such as fine chisel blades and micro-files to allow for the separation of finished prints from support structures and the smoothing of rough draft-quality prints. Proper finishing tools
would elevate the novelty aspect of the prints to something useful and utilitarian.

- **Supplemental Hardware**
  - Button maker
  - Sheet/Vinyl cutter
  - Plotter
    (We suggest relocating the one that is currently in use for the library staff in the makerspace to make it available to students.)
  - Electronics explorations tools
  - Oculus Rift for visualization

**Software**

- Rhino5 from Rhinoceros: A 30-user lab license include Rhino for modeling, Flamingo for lighting visualization, Penguin for photo-realistic on-screen rendering models, and Bongo for animation of models. (Cost: $2700)
- Google SketchUp Pro: The licensing fee for a lab is $15 per seat for one year or $30 per seat for three years.

**Additional Consumables**

- Plastic spools (ABS and PLA) for 3D printing
- Photopolymer materials for SLA printing
- Solvent for dissolvable substrate materials

**Other**

- The will be a need for solvent storage and the availability to store tanks in which to submerge models in said solvents for the purpose of removing support media. (Solvents used will be food-grade and citrus-based in the case of PLA printing.)

**C. Location and Space Planning**

The Task Force identified four potential spaces in the library for the makerspace. They are listed below in the descending order of our preference. We outline the pros and the cons of each option as the location of the HS/HSL makerspace.

Our top choice for locating the makerspace is at the back of the HS/HSL first floor. This area works well with the library’s plan to make the first floor a more active and lively environment where people freely congregate and collaborate. There are several ways we could build out a makerspace here. A variety of portable and flexible wall types are available to frame out the space without completely enclosing it. We may also leave the area completely open while signifying with visual cues and signs that the area within the four columns is for making activities. Or we can combine these two approaches creatively to make the space as welcoming and inviting as possible.
The Westport Public Library makerspace in Connecticut used this model, thereby creating a light framework in the middle of their stacks. The makerspace at New York Hall of Science took a similar approach. (See Figures. 1-6. Below.) Also see the photos of four local makerspaces that the Task Force visited - DMC at JHU, Digital Fabrication Studio at MICA, FabLab at CCBC, and BUGSS in the Makerspace Task Force website at [http://hshsl.umaryland.beta.libguides.com/c.php?g=108113](http://hshsl.umaryland.beta.libguides.com/c.php?g=108113).

We need to find a way to secure equipment and supplies if we adopt the open design for the makerspace. We could also build an enclosed space with glass walls and a secure door equipped with a UMB Card reader. However, this second option would be much more expensive and time-consuming. We believe that the flexible model will keep the makerspace inviting, open, and visible.

**Back of the First Floor**

- **Pros** - This attractive area would have high visibility in an already popular space in the library. It would provide us with a large area to work with and has good ambiance and lighting. There are computers and power outlets available in and near this space. It is also close to the HS/HSL Computing and Technology Services (CATS) and Services staff area and next door to the Family Conference Room, which could provide a complementary space for programming events associated with the makerspace.

- **Cons** - The renovation of this space could be quite expensive and time consuming if we choose heavy construction over a lightweight flexible wall system. If we do go with an open design model, we would need to find a way to secure the equipment. Additionally, we would lose an already popular study area with students.

*Figure 1. and 2. Makerspace at Westport Public Library*
Figure 3, 4, 5, 6. Makerspace at New York Hall of Science

Second Floor, Room 201C

- **Pros** - This room would not need many modifications to make it ready to use as a makerspace, and therefore the start-up cost would be low. A glass door might be re-purposed from the Circulation conference room to improve the visibility of the makerspace. The current door already has a cypher lock for security. Additionally, this room is next door to the Presentation Practice Studio and an open space where we already have computers available. One idea that we brainstormed for promoting this space is to hang a large poster over the circulation desk to signify that there is a makerspace in this location.

- **Cons** - The drawback to Room 201C is that it is fairly hidden away and would not be highly visible.

Tower Lounge

- **Pros** - This is a bright and attractive large space at the front of the library that would be very visible, at least from outside the library.
**Cons** - The area has a prism structure in the middle and it is a circular space, making it functional as a makerspace somewhat challenging, although not impossible. There is also no easy way to secure the room, and the access to this area is currently not monitored by the security personnel. There are no computers in this area currently but there are network outlets. Additionally, repurposing this space as a makerspace would mean taking away a space that is popular for socializing and eating.

**Circulation Desk**

**Pros** - This area is also very visible as it is the first place people pass after going through the security gates of the HS/HSL building.

**Cons** - As this is the first place patrons walk past when entering the building, it is likely for this space to become a de facto information desk with people stopping to ask all manners of directional and informational questions. If we want to create a makerspace that is completely enclosed, this location may also be difficult to seal off due to the large curved front desk.

**D. Promotion and Programming**

Based on our research and site visits to local makerspaces, we believe that active promotion and programming are key to the success of a makerspace and that they are as important as the makerspace equipment in sustaining its visibility and attraction to the target group. Staff at local makerspaces that the Task Force visited mentioned that their programs were well attended and helped others learn more about the resources available within the space. They further commented that in general, speakers were not too difficult to schedule. In fact, on more than one occasion, one of us attempted to sign up for a program offered by a local makerspace only to find out that it was already full. It is clear that programming that educates on the use of new technologies and inspires creativity and innovation is crucial to developing and sustaining a successful makerspace. *(For more detailed information about programming at makerspaces reviewed in our environmental scan, see the “Programming” parts in Section 2A, 2B, and 2C.)*

Promotional ideas for developing interest in the makerspace for UMB include:

- Conduct a student and faculty survey about what equipment and device they would be interested in trying out and using, thereby spreading words about an upcoming library makerspace.
- Create an email list of those who expresses interests in the HS/HSL makerspace and send out regular updates with upcoming programs, workshops, and other makerspace-related news.
• Hold a naming contest for the new HS/HSL makerspace itself with a prize.
• Organize a small maker faire or expo by inviting people from many local makerspaces and 3D printing equipment vendors to introduce 3D modeling and 3D printing technology to the UMB community.
• Hold an annual contest for the best 3D creation/invention by students in health sciences (or a student-faculty team in health sciences) for a prize to foster creativity and innovation. Depending on whether the library can solicit sufficient funding from a private donor, this contest may be held locally for UMB and Baltimore only or nationally. This would draw attention to UMB and HS/HSL.

Additional promotional ideas may include hosting an opening event for the makerspace and holding a series of talks at the planned makerspace location leading up to the opening event. “HS/HSL Makerspace Coming Soon” messages can also be shown on the public computer screen saver at HS/HSL and on digital displays campus-wide. Some potential speakers and program ideas include:

• Inviting speakers from existing local makerspaces to talk about the creations made in their spaces.
• Having local inventors discuss what they have created using makerspaces and 3D technologies as it relates to health sciences.
• Invite experts in various fields to present on the impact of 3D and newer technologies on health sciences.
• Invite well known innovators for inspiration and the promotion of entrepreneurship.
• Invite medical companies with 3D software to demonstrate the use of it in current products.
• Invite NIH to present on its 3D Print Exchange (http://3dprint.nih.gov/).
• Host a symposium on makerspaces and 3D innovations in health sciences.

More ideas to keep the makerspace highly visible to library patrons once the makerspace opens include:

• Place at least one 3D printer in a very visible place in the HS/HSL such as the low part of the Circulation Desk to get the maximum attention of all library visitors.
• Install a DropCam camera to allow people to view online what’s being printed every day by the 3D printer at HS/HSL in order to spark interest in the makerspace.
• Hold frequent demo sessions with a 3D printer and other equipment at various campus locations outside of HS/HSL to draw more interests in the HS/HSL makerspace.
E. Operation

The Task Force acknowledge that most of the makerspace operation and maintenance work will be the responsibility of the HS/HSL Computing and Technology Services (CATS) staff. This will require some adjustment in their current work duties. But the actual volume of work required for the makerspace operation and maintenance is hard to determine in advance. Consequently, we would like to leave some room for actual operational details. The recommendations below may well be subject to change depending on variables such as the makerspace’s location, set-up, equipment, and support staff availability. We would also like to point out that the HS/HSL makerspace itself will evolve over time and therefore the operational details should be amenable to future adjustment.

- **Staff Expertise:** While ideal, it would be unlikely for all CATS staff to become experts at 3D modeling software since mastering those is quite time-consuming and challenging. *(See Appendix 5 and 6.)* However, we recommend that all makerspace staff should be familiar with processing an .stl file through the 3D printer setting and sending the print job to the 3D printer. All makerspace staff should also be able to perform basic troubleshooting for the 3D printers. Since this is a crucial part of the required makerspace staff expertise, we strongly recommend setting aside enough time - at least two months - during which the makerspace staff can tinker with the 3D printer and perform troubleshooting while showcasing it to the library staff, before the launch of the makerspace. The Task Force also recommends that at least one or two makerspace staff members should become relatively proficient in 3D modeling software to be able to provide consultation and guide library patrons to relevant online resources such as Lynda.com for self-study. The ongoing staff training will be necessary for the staff to stay on top of fast-changing technologies in this field. The 3D modeling software on workstations at the makerspace should be also made available on the makerspace staff’s workstations so that the makerspace staff can train themselves.

- **Access Policy:** The HS/HSL makerspace should be open and accessible to all UMB students, faculty, and researchers. The Task Force recommends that users complete mandatory safety training and the introductory workshop on 3D modeling and 3D printing before being granted the full access. The makerspace should also hold open hours, during which a staff member will be available for a quick introduction to the makerspace. Outside of the open hours, depending on the way the makerspace is set up, access may be controlled with a UMB card reader that lets in only those who completed the required training and workshop. If certain equipment susceptible to possible theft can be secured, it is also a possibility to keep the entire makerspace open to library patrons. Whichever measure is taken for the security of the area, it is
important to keep in mind that those measures should not be perceived as a barrier for interested patrons to come into the makerspace out of curiosity.

- **Hours:** We recommend three types of hours: (i) Staffed open hours for walk-in visitors during which a staff member will be available at the makerspace, (ii) Unstaffed open-access hours during which the space is open but unstaffed. We recommend that the makerspace be set up in a way that will allow those who have completed the mandatory training and the introductory workshop to fully use makerspace equipment such as a 3D printer and other devices, (iii) Consultation hours available by appointment during which a staff member will provide one-on-one assistance. The further implementation details should be determined depending on the actual staffing and the set-up of the HS/HSL makerspace).

- **Staffing:** The makerspace must be staffed by those who are enthusiastic and knowledgeable about 3D modeling/printing technology and are capable of troubleshooting makerspace tools and equipment. It is hard to estimate the appropriate level of staffing for the makerspace without knowing much about what the responses on campus would be to this new facility. It would be ideal to keep the makerspace fully staffed. But if the demand is low, extensive staffing for the makerspace would be a waste of valuable staff time. For this reason, the Task Force recommends that the library should make an attempt to recruit students who are already experienced in 3D printing at local colleges such as MICA or CCBC to work from the afternoon to late evening as work-study students. The advantage of this approach is saving salaries for the work-study students from the library budget. Those student workers can also be paired with more experienced CATS staff members to create and develop online tutorials and handouts. However, the library may not be able to recruit qualified work-study students, which has happened in the past. In that case, it may be necessary to hire additional hourly staff and/or have short staffed open hours (e.g. 2-3 hours a day) in order to gauge actual need and demand. The level of staffing should be sustainable during the piloting phase without putting too much strain on the existing workload of the CATS staff.

**F. Budget**

The makerspace budget is largely based on the idea that initial start-up costs for the makerspace equipment, furnishing, and renovation would be funded through external grants, partnerships on campus, and donations. We estimate total start-up costs of a makerspace at HS/HSL to range between $87,500 - $157,500 depending on which location and renovation option is selected. Lowers cost models could be implemented with less desirable space selection and minimizing construction. This would not include the exhaustive list of hardware,
software or tools provided in this report in Appendix 4 but would include essential items for a start-up makerspace.

We also recommend seeking funding that will allow the makerspace to operate free of charge for the first year. This free-use period will encourage people to try out and experiment with the new 3D printing technology without cost barriers. After the first year, fees would be charged to recover the cost of the plastic filament used for 3D printing.

**Cost Estimate – Start-up costs**

Total estimated start-up costs range from $87,500 on the lower end, $112,500 at the mid-point, to a high point of $157,500.

- **Renovation of space:** Depending on option selected (modular sustainable walls versus construction). Construction would run approximately $120 - $156 per square foot for a maximum space approximately 25’ x 25’. Estimated cost of approximately $75,000. Modular demountable architectural wall would provide a progressive and inviting feel and likely further contribute to encouraging the use of the space. This option would be in a price range that half the cost of the constructed walls. The cost of movable walls for a 25’ x 25’ space would range $400-$600 per linear foot would be $30,000 not including additional cost for electrical work, electrical panel options in the walls or plumbing. Cost of remodeling the 1st floor closet which currently has water access and a drain would run about $5,000 to make it suitable for makerspace use if it was decided that a sink and dedicated water source was readily available to the space.

- **Furnishing:** Flexible tables, chairs, counter height pieces
  - Hurry Up flexible tables (20”x60”) approximately 10 @ $521 each for a total of $5,210.
  - Other counter height and equipment tables - $1,500
  - New Windsor Chairs, movable nesting - approximately 20@ $264 each-total $5,280.

- **Equipment** – 3D printers including MakerBot Replicator or other fused deposition modeling (FDM) printer and another printing option with stereolithographic 3d printer (SLA), cutters, 3D scanner, 6 computer and 6 computer monitors. Total estimated cost of listed equipment $50,000.

- **Software:** 3D modeling software and learning resource (Lynda.com) $6,500

- **Supplies:** 3D printer plastics, gloves, glue gun, apron, file, etc. $4,000

- **Tools:** Basic tools for constructing, cutting, drilling etc. $2,510.

- **Staff Training:** If work-study students can be hired to staff the makerspace, their salaries will not come from the library budget. In that case, the only known cost incurred in this area would be for staff training.
<table>
<thead>
<tr>
<th>Category</th>
<th>Estimated Cost</th>
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<td>$2,510</td>
</tr>
<tr>
<td>Staff Training</td>
<td>$2,500</td>
</tr>
</tbody>
</table>

**Potential Funding Sources**

- Gladys Brooks Foundation – provides award for libraries related to innovations.  
  (Application deadline for Jan. 2015 funding: May 31, 2015)  
  http://www.gladysbrooksfoundation.org/
- Library Donors – Foundation Funds
- Programming Awards – NNLM/SEA Can apply for awards specifically for programming, speakers and Symposiums  
  (Application deadline: March 2015)

**G. Implementation Steps**

Below are the steps for the HS/HSL makerspace implementation process. We recommend creating a more detailed timeline once the decision on the makerspace location, hardware and software to purchase, staffing, budget, and service model are determined after the review of this paper.
1. Review of the recommendations by the Task Force  
   / by Div. Heads
2. Stakeholder meeting & Student survey  
   / by Task Force or Makerspace Program committee
3. Decision on the makerspace location, hardware and software to purchase, staffing,  
   budget, and service model  
   / by Div. Heads
4. Space renovation and preparation  
   / by Admin
5. Purchase of computers, 3D printer, other equipment, software  
   / by CATS & Admin
6. Staff training/experimentation for the new software/hardware  
   (Note. Make sure to allow enough time - at least two months - for the makerspace  
   support staff to be familiar with using, supporting, and troubleshooting 3D printers and  
   other equipment and tools.)
7. Preparing equipment and computers  
   / by CATS
8. Create makerspace policies and training manuals  
   / by CATS
9. Plan for programming events for the upcoming semester  
   / by the Makerspace Programming Committee
10. Promotion  
    / by the Effective Communications Committee  
    (This may also include the naming contest for the new HS/HSL makerspace.)
11. Opening
References


Appendices

We include six appendices in this report. Appendix 1-3 provide the details of the makerspaces reviewed in our environmental scan process. Appendix 4 lists necessary 3D printers, equipment, and other tools and resources that are either recommended or comparable to those recommended, along with their prices, features, and other relevant details. Appendix 5 is a brief summary of the experience of two HS/HSL staff members who explored Google SketchUp, a free 3D modeling software. Those two staff members comprised the makerspace subcommittee and created a Google SketchUp User Guide, which is presented as Appendix 6.

Appendix 1. Environmental Scan: Academic Library Makerspaces
(See the separate document.)

Appendix 2. Environmental Scan: Local Makerspaces
(See the separate document.)

Appendix 3. Environmental Scan: Public Library Makerspaces
(See the separate document.)

Appendix 4. List of Equipment and Tools for HS/HSL Makerspace
(See the separate document.)

Appendix 5. Learning Experience of a 3D modeling software, Google SketchUp
(See the separate document.)

(See the separate document.)
Additional Resources

- The Library as Incubator Project
  http://www.libraryasincubatorproject.org/?tag=makerspace.
- Make Your own Makerspace (Webinar recording)
  http://www.demco.com/goto?webinar_14