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Makerspaces in the Library: Science in a Student's Hands

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Makerspaces supply a venue for students to construct a variety of real-world products at the collegiate level using science and technology standards. The maker movement is sweeping the science learning community by storm in the library setting with remarkable success. The maker movement provides an opportunity to transform the library into a learning environment that empowers learners as they research, draft, create, collaborate and problem solve. This article examines how science educators, administrators and librarians collaborate to create makerspaces with which students design projects, products and engage in activities to ignite science learning.

For America's future leaders to compete in a global market, science, math and technology skills are imperative. To instruct students in the sciences, educators and librarians are now partnering to support STEM or STEAM activities, or science, technology, engineering, art and math-based research, curriculum, and projects. STEM stands for science, technology, engineering, and math. Science, technology, engineering and math represent the different areas of STEM education. A common definition is:

> STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy. (Tsupros, Kohler, & Hallinen, 2009).

A variation of STEM is STEAM, which includes an 'A' for art and design." (National Science Teachers Association, 2015). "STEAM = Science & Technology interpreted through Engineering & the Arts, all based in Mathematical elements" (STEAM Education, 2015). The goal of STEM/STEAM is to motivate student learning using hands-on science and math skills, as well as to encourage higher order reasoning and problem-solving skills. One current successful approach to STEM/STEAM is occurring in academic libraries: makerspaces. Although the subject of makerspaces in K-12 libraries is a popular topic of national attention, makerspaces in college academic libraries provide a significant bridge from the university curriculum to the workplace.

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approach. In a historical context, "makerspaces first appeared around 2005 as part of the popular DIY (Do it Yourself) movement" (Fisher, 2012). In fact, Dale Dougherty, publisher of Make magazine, is the one who gave the movement its name in 2005" (Jeffries, 2013). The purpose of the makerspace is to create a comfortable environment for users to experiment, create and learn within a controlled setting. How do makerspaces facilitate science education? Makerspaces enable students and faculty to apply scientific principles and meet curricular science through the design, creation and building of products. Makerspaces may include 3D printers to produce three dimensional products such as toys and robots, tools for welding or building, software for the production of music as well as craft and art supplies (Fernandez, 2014).

Libraries are ever-changing hubs, resolutely benefitting the communities and schools that support them. Librarians, keeping in tune with the constant changes around them, realize that the optimum way to continue support for their stakeholders is to look toward the future. It is important to realize that "for 65% of scientists with advanced degrees, their interest in science started before middle school" (Institute of Museum and Library Services, 2014, para.1).

In order to instruct and expose more children more deeply to the sciences, educators and librarians alike have come together to support the influence of STEM activities, or science, technology, engineering, and math-based research, curriculum, and projects. Government agencies, like the National Aeronautics and Space Administration (NASA) or the National Science Foundation (NSF), are helping fund STEM development through youth and community projects aimed at STEM innovation (Hopwood, 2012). However, it is the librarian's job, as the intellectual leader of the community in a neutral setting, to promote science literacy, research, creativity, ingenuity, and scientific thinking. Of particular significance, for librarians, regardless of their educational backgrounds, is to realize their impact on the academic community and the opportunity they have to teach their patrons about STEM subjects.

Lippincott, Vedantham & Duckett describe examples of librarians collaborating with teaching faculty to supplement class learning in several case studies of academic libraries in the North Carolina State University library system such as the James B. Hunt Jr. Library and the D.H. Hill Library. In the instance of the James B. Hunt Library Makerspace that opened in 2013, the library makerspace became a campus center of creativity and area for faculty partnership. NCSU's College of Engineering used the popular James B. Hunt Library Makerspace for class assignments, course projects and co-curricular activities. In addition, Hunt library faculty and staff reached out to Nicholas Taylor in the North Carolina State University Department of Communication to facilitate course work in humanities and social sciences curriculum areas not just the typical math and engineering STEM/STEAM areas. Students' projects and course assignments were used to prototype tools such as 3D printing and circuit boards. (Lippincott, Vedantham & Duckett, 2014). Other makerspaces protypicals may include the University of Toronto. Matt Ratto at The University of Toronto, Department of Faculty of Information, "focuses on how hands-on activities with technology can help learners think critically about the relationships between digital technologies and social issues." (Ratto, 2011). Matt Ratto, an Associate Professor in the Department of at the University of Toronto in the Critical Making Lab "coined the term 'critical making" in 2007 to describe work that combines humanities insights and engineering practices, and has published extensively on this concept" (Critical Thinking Lab, 2017). Ratto's critical making work at the University of Toronto provided inspiration to NCSU librarian Brendan O'Connell and Taylor who co-designed an assignment for the undergraduate COM 250: Communication and Technology course in which students engaged in critical making using circuit boards with ideas discussed in their course (Lippincott, Vedantham & Duckett, 2014).

At NCSU, the James B. Hunt Library as well as D.H. Hill Library and other branch libraries, the librarian oftentimes becomes an "integral part of the course project, consulting frequently with the professor and her students as they moved from design ideas into content development and, ultimately, implementing their vision in the exhibit experience" (Lippincott, Vedantham & Duckett 2014).

> This project would never have happened were it not a) for Hunt Library and for the technology, and the possibilities opened up by the space, and b) for Jason [the librarian] who not only facilitated my relationship with the library — because I had no connection to Hunt prior to my connection with this project — but really did so much of the groundwork with making the room happen, making the technology happen, helping me and my students understand how to use the technology that we had access to make this happen. (Lippincott, Vedantham & Duckett 2014).

Library involvement in promoting STEM or STEAM awareness at any level helps show "how essential libraries are in the digital age" (Duff, 2012, p 24). Farkas (2015) asserts that the primary mission of educators and librarians is to promote a culture that values creation and "making" as a lifelong learning quest. In her opinion, inspiring students to pursue new proficiencies with STEM or STEAM-related subjects and their emergent career fields will be "part of the solution to a major national problem (Farkas, 2015, p. 27.)

Libraries are uniquely positioned to work with faculty on curricular change. Students associate libraries with research paper assistance and think of libraries as a place to borrow books, videos, laptops, and so on. Adding in expertise with media creation positions libraries to take advantage of constructivist trends in teaching and learning. (Lippincott, Vedantham & Duckett, 2014). One faculty member at The University of Pennsylvania Libraries' David B. Weigle Information Commons (WIC) stated after her experiences at the WIC, "the skills the students learn at the WIC help them for other classes. They develop a rapport with the staff and are encouraged to think outside of the box." (Lippincott, Vedantham & Duckett, 2014).

The Value of Makerspaces in the Library

Having long been the center of information and knowledge, the library is an ideal destination for projects to blossom (Preddy 2013). Librarians continually search for ways to engage students in thinking, creating, sharing, and growing; therefore, the partnership of the science educator and librarian to encourage these skills is quite powerful. A makerspace is an ideal place to incorporate more STEM activities into a fun and inspiring environment beyond the constraints of a traditional classroom setting.

Because academic libraries already nurture critical thinking and learning, they are a perfect environment for makerspaces:

> Librarians can help faculty develop new assignment types that both connect to the disciplinary content and encourage students to experiment with new media. In many cases, faculty are open to thinking about such assignments if they are not solely responsible for the technical aspects of its implementation and the associated risks (Lippincott, Vedantham, & Duckett, 2014).

For example, the librarian, as an information specialist, possesses the knowledge and expertise to guide budding scientists to the right DIY instructions and information through library sources such as virtual databases, informative websites and credible journals. However, collaborating with trained STEM/STEAM educators, technology faculty and library staff may provide new opportunities by combining their shared skillset and expertise. Science educators and librarians can create a partnership to develop spaces for probable heightened collaboration, enhanced mutual respect and the achievement of common professional goals (Augustin, 2014). For example, Luz Rivas (2014), an electrical engineer and educator, created a makerspace for young women in her community where they are able to create real products, like toys, video games, and electronic garments. She believes that the makerspace is helping the young women gain scientific skill and confidence, which could lead them to a better future career. Although Rivas' research addressed young women, in today's increasingly computerized, scientific environment, this could be true for either gender in gaining scientific skill and confidence.

Involving the library in promoting STEM proficiency is an extremely important key to reaching a wide variety of people of all ages and backgrounds. Library programs can benefit STEM learners by offering everyone "learning opportunities that spark curiosity and build interest in STEM subjects" (Institute of Museum and Library Services, 2014, para. 2). Unfortunately, research has shown that the STEAM workforce is lacking in female and minority employees. The Institute of Museum and Library Services (2014) reports that "women hold only 23% of STEM jobs." (Institute of Museum and Library Services, 2014, para. 1). One reason for injecting an art aspect into the STEM program to form STEAM is because art projects based on math and science principles tend to encourage participation from girls who are perhaps intimidated or overwhelmed by the math and science subjects alone (Koester, 2013). Encouraging female and minority participation is another positive aspect of involving the library in this national push towards STEM subject mastery. Since the majority of librarians are female, they can act as positive mentors when modeling STEM and STEAM activities and projects in the library. Koester (2013) emphasizes, "That's the power of STEAM: To bring together all the facets of the things we find interesting in the world in a way that's tactile and packs educational punch." (Koester, 2013, p. 22). In the case studies of North Carolina State University and The University of Pennsylvania Libraries' David B. Weigle Information Commons (WIC), it was suggested that academic libraries can stimulate curriculum connections by directly linking these students, staff and faculty with library spaces and technologies. (Lippincott, Vedantham, & Duckett, 2014).

Partnership Spaces

Makerspaces not only allow students to form cooperative teams but allow for educators to plan, collaborate and execute hands-on projects to meet academic standards and curricula. The learning process within the making environment is conveniently supported by local, state and national standards for inspiration, production, thinking, contributing and inquiry are met through makerspace activities (Preddy, 2014). In the K-12 school setting, there has been a popular trend for STEM because the objective of recently implemented Common Core Standards is to ensure that our college graduates are able to compete effectively in a global market. Common Core Standards came into existence because many industry employers lamented that college graduates are extremely unprepared for the demands of the workplace. In turn, colleges and universities have noted that the high school graduates lack the necessary skills to succeed in the academic environment. Therefore, the concept of the makerspace reinforces the concept of problem based learning in the university setting. Not only do makerspaces extend the precepts of Common Core and STEM, but they also support National Science Education Standards and creative thinking. Because library faculty may teach in a K-12 setting rather than just a university setting and many times interact with students of all ages, Common Core precepts were included. Why is Common Core relevant in the academic setting? Common Core's mission is to prepare K-12 students to be college and career ready as well as to solve problems collaboratively within a given context. Makerspaces enable students to exchange ideas and solve problems within the scientific framework. Makerspaces not only provide physical areas for the university curriculum to transform into learning for business and industry needs but they also promote cross-discipline communication among students by offering collaborative opportunities and conduit between the university setting and the community.

The curriculum is, in fact, a primary factor to consider for developing a makerspace. Makerspace projects are enjoyable for students but it must support academic objectives. It is crucial that the educator be involved with the planning and utilization of tools and activities in the makerspace to ensure that science and technology curricular needs are met. For example, engineering or architecture professors may ask students to create building models using AutoCAD and 3D printers housed in the library makerspace.

Through the achievement of academic standards, makerspaces fit the needs of science education by capturing the interests of today's inquisitive and curious learner. Makerspaces allow the free flow exchange of ideas by accepting changing opinions, reasoning and answers encountered in the school media space and through personal experience; when school libraries, science curriculum, and maker mentality work together, it is ultimately students who benefit in this innovative model for education (Gustafson, 2013). In the end, the learning space should be reflective of the goals of the educators yet easily adaptable to the physical constraints of the actual environments.

The Environment of a Makerspace

Kurti, et al, (2014b) shared some qualities of an ideal makerspace as it is aligned to the tastes and purposes of the population it is serving. First, the space should be inspiring. It should be open, full of light, inviting to students as well as have sufficient space for creation to occur. The furniture should be flexible and easily rearranged, and spacious. There should be sufficient access to electrical outlets, easily cleaned tables and access to a sink is also good if projects get messy. Preddy (2013) encourages seating or standing space for the patrons, as well as adequate storage space for both tools and projects that are underway. She also advocates clearly defined rules and policies, including safety and clean-up procedures.

In addition to these physical needs, the ideal makerspace should include some objects that encourage students to think about things they may never have considered. There could be regular events at which students share their own projects. Students can be encouraged to solve a problem facing their own community. These events encourage students to create their own solutions and help solve some of the world's issues (Preddy, 2013). Many makerspaces projects can be tailored to community needs to add a layer of purpose or activation of prior knowledge. Projects in the makerspace could even promote social responsibility, providing an outlet for students to create innovative solutions for projects such as home models for displaced veterans, battered wives, etc. using sustainable materials. By creating these models and then, ultimately the structures, students also learn the importance of life-long service and community involvement.

Additionally, makerspaces in academic libraries supply a bridge to real-world applications. Architectural or engineering students may be given hypothetical scenarios based on geological or climatic challenges. For example, a university may use AutoCAD and 3D printers to design homes for displaced families due to natural and man-made disasters. Engineering students may be tasked with the creation of robotics or prosthetics.

The environment of a makerspace will include a variety of tools, from simple to complex. As the students increase in skill and confidence, some intermediate tools can be introduced, budget permitting. Some of these are 3D printers and drawing programs, scanners, and simple electronics. As students become more skilled, the tools should become more complex, and should include a wider variety of electronic equipment, both to use and to disassemble, investigate, and reassemble. As the tools become more advanced, expert advice may be helpful in selecting the best devices for the students. However, some librarians have already adopted a more hands-on approach by providing instruction in various technology applications.

Implementation and Funding in the University Libraries

Once the librarian has established need, demand and environmental considerations for a makerspace, how does one begin? Commonly, limited budgets and long-term sustainability may be obstacles for enthusiastic, well-intentioned librarians. Crumpton (2015) suggests developing funding strategies in the initial planning stages to ensure long-term maintenance. "Developing a makerspace can be much the same as starting a business and creating a business plan for growth" (Crumpton, 2015, pg. 92).

Some libraries go above and beyond the simpler science or math-related readings and group experiments, and offer recurring youth programs, workshops and special events for their communities. They work with local companies and businesses to get additional funding and supplies, host sponsored workshops and guest speakers, and acquire technical volunteers for group STEM demonstrations. Communities greatly benefit when libraries offer their patrons new technology options and supply learning spaces that feature youth-centered approaches to create a foundation for the pursuit of higher education STEM opportunities and jobs. Some STEM-based recurring youth library programs encourage weekly participation and "value beyond entertainment," The Chicago Public Library has teamed up with Northwestern University's FUSE project to encourage their patrons to use kits that "explore topics like robotics, biotechnology, and app design" (Koester, 2013). Although some of these projects are very ambitious, it is understood that every library has different space, staffing, and budget issues. It is important for each library to accommodate STEM or STEAM projects in the manner that best fits their community. Koester (2013) points out, "STEAM programming can be as simple or complex, low-tech or high-tech, or cheap or lavishly funded as you like." (Koester, 2013, p. 22).

Ultimately, a preferable approach is to utilize materials that are easy accessible and affordable. Creative funding and thrift material hunting is certainly feasible. The academic librarian and science instructor may write collaborative grants as well as elicit community partnerships to reduce implementation costs. For example, many national and local businesses in the science and technology sectors donate funding or even materials such as iPads or used printers. Preddy (2013) offers some advice which could be useful, especially if the budget is small. She suggests first setting aside a percentage of the annual library budget for the space, then soliciting the help of the administration, especially after they have seen student interest and excitement in the space, and including a list of the academic standards being met within the makerspaces.

Finally, Kurti, et al, (2014c) share their observations about the creation of a successful makerspace. They discuss one particular librarian who was given the challenge to transform the library into a "vibrant learning environment," a space where "every student has the ability to invent, tinker, create, and innovate" (p. 21). The initial investment was less than $1,500, with the exception of the cost of a 3D printer, and many of the tools were free. The space had fixed stations, such a 3D printer, with quick makes, as well as flexible stations, which might include more complex projects like stop-motion animation or engineering inventions. Two of the students, in particular, have emerged as the 3D printer experts, and other students come to them for advice and assistance. Because this makerspace is only a year or two old, its long-term effects cannot yet be measured. However, it is a tremendous success in student popularity. Many students have tried the simple tools and are ready for a more complex challenge, with an emphasis on robotics.

The authors recommend following these steps in order to create a successful makerspace:

- Observe the students to determine their interests.
- Review curriculum and college programs to find compatibilities and possible augmentations to offer in the makerspace.
- Consider national and global trends in technology and culture.
- Set aside space and bring in tools and parts.
- Create an environment promoting student ownership of the makerspace.
- Reinforce to students that problem solving, multiple iterations and process thinking is preferable in product creation.
- Continue assessing, redesigning, and adding new tools every semester to ensure a relevant, growing experience (Kurti et al, p. 23).

Makerspace Case Studies

Through a comparative case study, (Sheridan, et al. 2014) explore how makerspaces may function as learning environments. Sheridan conducted a cross case analysis of three makerspaces: (1) Sector67: Madison Wisconsin (2) Mount Elliott Makerspace: Detroit, Michigan (3) Makeshop, Children's Museum of Pittsburgh, Pennsylvania. The authors studied the relationship between the makers and the space itself and how each supports making in multiple disciplines. "One of the distinctive features of all of the spaces is the way diverse learning arrangements (e.g. solo exploration facilitated one-on-one or small group projects, collaborative projects, online forums, and structured classes) often informally evolved to support the projects and goals of the participants." (Sheridan, et al, p. 521). These makerspaces help to illustrate the fact that makerspaces can be a drop-in space, a dedicated space, a mobile makerspace, maker workshops or any combination.

In the experience of the authors, the learning spaces integrated into the academic library may have a positive correlation on students' learning. Beginning in 2015, in the southeastern part of the United States a class of engineering, technology and interior architecture students were the pilot class to utilize a makerspace in the library (Julian & Parrott, 2015). These students, as part of a clock creation assignment, were directed to use a space at the library created for this purpose. This makerspace was designed as a collaborative effort between the professor of engineering, technology and interior architecture along with the academic librarian.

Previously students had no common space for creating products such as those required by science, technology and interior architecture instructors. The engineering, technology and interior architecture classroom spaces, like in many college classrooms, perhaps designed decades earlier, are not always conducive to the technological functions required today for learning. They are often cramped for physical space and not updated to accommodate today's technological requirements. As mentioned in the article herein, budgets are commonly a detriment to learning spaces which frequently need expansion and upgrades in response to classroom needs; this instance was no exception. Professors are required to be creative in terms of space because of a classroom shortage and the makerspace in the library is the ideal solution to create additional space with the necessary technological necessities. Therefore, this project was born from necessity of space. The professor and academic librarian collaborated to form one of the first creative endeavors in a location which had been underutilized in the library. Creating the makerspace in the academic library was a natural trajectory due to lack of space in other campus buildings.

The exercise conducted by the authors of the study was assigned as an experiment or possible prototype for future assignments. In the makerspace, the students were asked to draw a clock in AutoCAD or Revit and create models. The students also benefitted from the use of a 3-D printer and foam cutters provided in the library. Previously, the students had to share an antiquated printer. The library's new 3-D printer helped the class to leverage time and resources. Another advantage of the makerspace being located in the academic library was the close proximity of technology support and the expertise of the academic librarians in locating resources which might support the making culture. The students were assigned to groups and given 4 weeks to complete the assignment. Upon completion, students presented their finished clocks to the class and described the process in informal presentations. Assessment was administered in the form of a written test on the technical aspects of the clock, use of materials, wood joinery and safety in addition to a participation grade for group work.

The use of the makerspace in the library became an actual extension of the classroom in which didactic knowledge transformed into three dimensional products. The space for students to move about and tinker with the product allowed for increased engagement between students who might not normally interact. Although in the infancy stages, the use of the makerspace for the project shows immense promise to grow and correlate to other disciplines. As a result of this pilot project, the professor and librarian observed the students' increased understanding of the importance of shared space in the collaborative classroom as well as team cooperation in terms of time management, accomplishment of goals and content comprehension. These items were observed in student focus groups, class discussion and reflections. Additionally, the professor noted a 10 percent increase in the written post-test scores for this project. Based on this limited measurement, the professors anticipate increased test scores as the makerspace gains funding, participation and growth.

Implications and Reflections

The authors felt that this "accidental makerspace" collaboration was a success. Based on the positive feedback and assessment scores from this initial exercise in clock making, the authors suggest that the makerspace in the academic library could be the hallmark of physical space in which future engineers, architects and technology professionals gain necessary hands-on experience. The professors and academic librarian are in the planning process for additional projects to be completed in the makerspace such as prototypicals for building models or electronic circuitry before more expensive materials are utilized or purchased as part of the design process. Further, the academic librarian and professors are researching grants and enlisting the support of local businesses to build the makerspace. For future collaborative assignments, the authors plan to modify the assessment by weighting the assignment more heavily in the group dynamic. Because collaboration in the workplace is so critical in today's global market and because strong professional dispositions are heavily emphasized in college accreditation standards, it makes sense to also assess students' abilities to work within a team.

Additionally, the professors and recruit industry for material resources. The professors are also investigating the uses of scraps that industry would typically discard as a use for the makerspace. For example, some businesses discard sheet metal, plastic resins, ceramic tile or glass; students may take this scrap material and use it to create items in the makerspace.

In terms of implications for academic librarians, makerspaces have the potential to increase library visits, and possibly circulation, due to increased use. Increased usage data, which could be important in future fund-raising endeavors and provide valuable data for approaching industry for funding as well as material resources.

Conclusion

In conclusion, makerspaces are immensely exciting for both college science educators and academic librarians because they powerfully allow students to step away from the classroom and actually apply scientific principles as well as information knowledge. Makerspaces are engaging for all of those involved-- especially students. There is no limit to the types of workshops one could create in the makerspace environment to fit curriculum needs. Because the academic library is a venue where students assemble to collaborate and learn, it is an ideal area for a makerspace to thrive. Moreover, learners delight in the hands-on application of emerging technologies and a comfortable familiarity with the type of experimentation that leads to a finished project. Any dedicated educator can create a makerspace, regardless of budget, as long as there is vision and willingness to try.

Makerspaces are a means to engage students from multiple disciplines. "The Committee on Equal Opportunities in Science and Engineering recommends that National Science Foundation implement a coordinated initiative that would create centers, dedicated to transforming U.S. educational institutions into inclusive STEM institutions." (CEOSE, 2012, p. 21). Makerspaces in the academic library assist in achieving this goal; they elevate STEM learning at the collegiate level and provide a coordinated initiative and dedicated space to address emerging challenges and opportunities. They also help to stimulate participation in STEM as it relates to university long-term academic goals.

References

Augustin, S. (2014). Designing for Collaboration and Collaborating for Design. Interior Design Educator's Council, *Journal of Interior Design*, 39 (1), ix–xviii.

Committee on Equal Opportunities in Science and Engineering (CEOSE). (2012). Biennial Report to Congress 2011-2012.

Critical Thinking Lab. (2017). http://criticalmaking.com/matt-ratto/.

Crumpton, M. (2015). Fines, fees and funding: makerspaces standing apart. *The Bottom Line,* 28 (3), pp 90-94.

Duff, Marina Leigh. (2012). 10 steps to creating a cutting-edge STEM school library. (feature: Hot Spot: STEM) (Science, technology, engineering, and mathematics). *Young Adult Library Services, 10*(2), 24-28.

Farkas, M. (2015). Making for STEM Success. *American Libraries*, *46*(5), 27.

Fernandez, P. (2014). Through the Looking glass: envisioning new library technologies the possibilities and challenges of 3D Printing. *Library Hi Tech News*, Vol. 31 Iss: 5.

Fisher, E. (2012). *Makerspaces Move into Academic Libraries,* ACRL TechConnect is a site of the Association of College and Research Libraries, a division of the American Library Association

Gerlach, J. (2012). *STEM: Defying a Simple Definition*. National Science Teacher's Association Reports.

Gustafson, E. E. (2013). Meeting Needs: Makerspaces and School Libraries. *School Library Monthly*, *29*(8), 35-36.

Institute of Museum and Library Services. (2014, June). *Talking points: Libraries and STEM.* Retrieved from: https://www.imls.gov/assets/1/AssetManager/STEM.pdf

Jeffries, A. (2013). At Maker Faire New York, the DIY movement pushes into the mainstream. https://www.theverge.com/2013/9/23/4760212/maker-faire-new-york-diy-movement-pushes-into-the-mainstream

Julian, K. & Parrott, D. (2015). Case Study.

Koester, Amy. (2013). Full STEAM ahead: Inject art into STEM with hands-on learning (science, technology, engineering, arts, and math). *School Library Journal, 59*(10), 22.

Kurti, R. S., Kurti, D. D., & Fleming, L. l. (2014). Practical Implementation of an Educational Makerspace. *Teacher Librarian*, *42*(2), 20-24.

Lippincott, J., Vedantham, A. & Duckett, K. (2014). Libraries as Enablers of Pedagogical and Curricular Change, Educause online.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards for English language arts and literacy in history/social studies, science, and technical subjects.* Washington, DC: Authors.

Preddy, L. (2013). *School library makerspaces: Grades 6-12*. Libraries Unlimited.

Ratto M. (2011). Critical Making: Conceptual and Material Studies in Technology and Social Life, *The Information Society: An International Journal*, vol. 27, no. 4 (2011): 252–260.

Rivas, L. (2014). The Maker Mom: Helping Parents Raise STEM-Loving, Maker-friendly Kids: http://www.themakermom.com/2014/08/luz-rivas-founder-of-diy-girls-its-stem-girl-friday.html

Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. *Harvard Educational Review*, *84*(4), 505-531.

STEAM Education (2015). Retrieved from: https://steamedu.com/

Tsupros, N., Kohler, R., & Hallinen, J. (2009). STEM education: A project to identify the missing components. Intermediate Unit 1: Center for STEM Education and Leonard Gelfand Center for Service Learning and Outreach, Carnegie Mellon University, Pennsylvania.

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Appendix

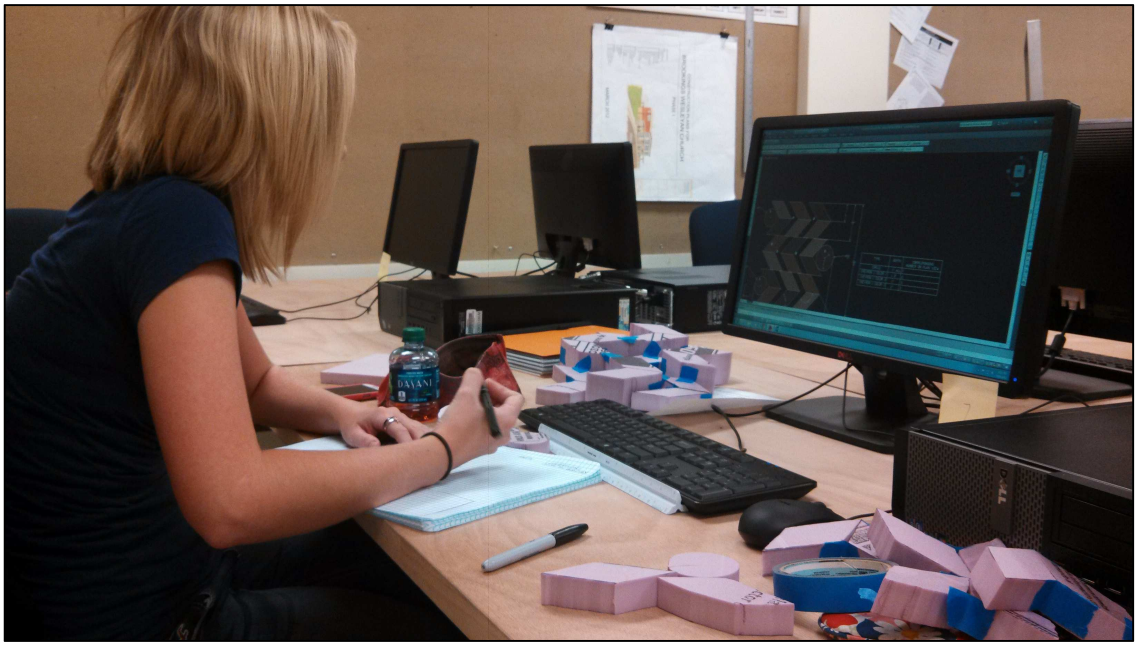

Figure 1: Student with foam model pieces and computer drawing of clock.

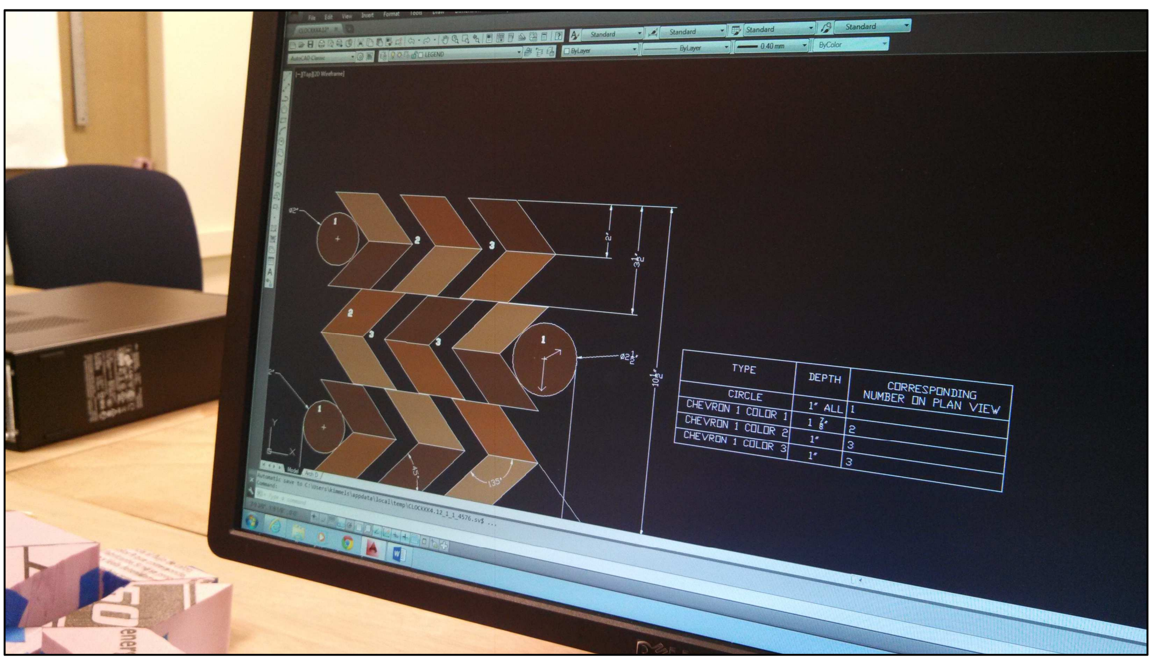

Figure 2: Student clock drawing on computer before making foam models and then wood final.

Figure 3: Students in the lab with foam models and wood.

Figure 4: Students in lab (studio) installing tables they made.