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Galina Letnikova

CUNY LaGuardia Community College

Na Xu

CUNY La Guardia Community College

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Academic Library Innovation through 3D Printing Services

About the authors - Galina Letnikova, Associate Professor and Coordinator of Library Instruction at LaGuardia Community College Media Resources Center
Na Xu, Assistant Professor at Natural Sciences Department at LaGuardia Community College, CUNY

Abstract

Purpose – One of the most innovative library services recently introduced by public and academic libraries, the technology of 3D printing, has the potential to be used in multiple educational settings. The goal of the project described in this article was to examine how this novel library digital service motivates students' learning, and to investigate managerial issues related to the introduction of 3D printing services at a medium-size urban community college library with restricted funding.

Design/Methodology/Approach - Since fall 2014, the LaGuardia Library Media Resources Center has been offering a portable consumer-end 3D printer for classroom use. This paper provides historical context for the implementation of 3D printing as a service offered by librarians and discusses how the community college library managed 3D printing services to support class curriculum. At the end of the three-semester-long project students were asked to volunteer to take a survey conducted by the librarian and the class instructor.

Findings - The results of the student survey demonstrated that library 3D printing services significantly promoted students' motivation to learn. The conceptual model of a makerspace should be an essential part of the 21st century academic library. To help make that possible this paper examines certain challenges and limitations faced by librarians when introducing 3D printing, including dedicated space management, professional education, and personnel availability.

Originality/Value - During the project described students were able to use library services to print out and study complex engineering and biology models in 3D. The proper planning and management of this innovative service allows academic librarians to enhance class curriculum by providing the means of transforming theory into physical reality.

Keywords - Library innovation, Management of change, 3D printing, Academic library, STEM education, Library instruction

Paper type – Case study

I. Introduction

Libraries have always been at the edge of new technologies. Starting from ancient times and the invention of the printing press, library patrons turned to librarians for instructions on how to access and acquire new knowledge and expertise, how to use and troubleshoot innovative tools and techniques. The appearance of 3D printers wasn't an exception. This major innovation has been applied in many industries, such as engineering, manufacturing, art, and medicine, and it quickly became popular among librarians. The public libraries, being places of community engagement, started helping their users to develop novel 3D printing skills. In 2012 the Fayetteville Free Library in New York State became the first public library in the United States to open a so called "FFL Fab Lab" which consisted of a group of machines working together and/or individually, supported by appropriate computer programming, and used for three dimensional objects production. After the official unveiling of the "FFL Fab Lab" in June 2012 (Fisher, 2012), other public libraries in the United States started opening similar spaces. The Chattanooga Library in Tennessee transformed an entire floor of its main building into a public laboratory. Their lab included laser cutters, 3D printers, and other machinery meant to support "the production, connection, and sharing of knowledge by offering access to tools and instruction" [1]. Only one month later the Westport Library of Connecticut hosted the opening of its "MakerSpace," a place where library users were able not only to explore 3D printing technology, but to learn how to design and print their own creations. Librarians at Westport Library "MakerSpace" organize community demonstrations and workshops teaching their patrons how to use the 3D printer with its special software. The Westport librarians consider that

facilitating the new knowledge creation by their patrons is one of the essential and fundamental parts of any library's mission (Enis, 2014).

Following the trend, academic librarians began rethinking library services and initiating special physical spaces for design assignments and manufacturing activities of the students. With the proper planning and management these spaces should become the centers for advance coursework and independent study. Dr. Maura Smale, Chief Librarian at the New York City College of Technology started a blog conversation titled "Making Things in Academic Libraries" (Smale, 2012) at the website of the Association of College and Research Libraries (ACRL) discussing conceptual and managerial issues of this innovative library services. The blog conversation drew attention of academic librarians from all kinds of colleges and universities. Dr. Smale raised the following questions: how would a makerspace look in an academic library; what would students be able to achieve in the makerspace; how could librarians serve students' needs; what new skills would librarians have to learn; what about extra budget for the hardware, software, and workforce (Smale, 2012). Despite the apparent complexity of these novel questions, academic librarians participating in the blog discussion unanimously agreed that the working model of a makerspace should be an essential part of the 21st century academic library; though it was not clear how this concept could be incorporated into the everyday life and library functions. "How can academic librarians, (while) our contact with students often limited to a few minutes at the Reference Desk or an hour or so in the classroom, become involved at the making, producer level with students?" Smale (2012) asked in her blog post.

Some of the answers to Dr. Smale's questions were found by the members of the Libraries' Emerging Technologies Team at the DeLaMare Science & Engineering Library of the University of Nevada at Reno. This Team, led by the Head of the Library, Dr. Patrick (Tod)

Colegrove, certainly had confidence in 3D printing and the opportunities it would bring to the academic libraries (Colegrove, 2014). After deciding to adopt the public libraries' "MakerSpace" model, the DeLaMare Science & Engineering Library acquired two 3D printers and one 3D scanner with the supporting software. Librarians at the University of Nevada believed that the strategic move to the new library services would support knowledge creation across departmental boundaries, and would shift library services "from an emphasis on housing and archiving print resources to one of directly supporting knowledge production" in response to the "higher education ... major paradigm shift, moving from teaching to learning as its primary focus" (Colegrove, 2014). According to Colegrove (2014) the library was "actively building an environment that nurtures creativity while stimulating and supporting learning and innovation across the university landscape". Rapidly, other academic libraries in the United States followed the University of Nevada example in their aspiration to become a place where students and faculty from all disciplines could gather, explore 3D printing, and create three dimensional objects. Librarians from the University of Alabama Libraries crafted their own "model for managing 3D printing services in academic libraries" (Scalfani and Sahib, 2013). In fall 2012 they opened a "3D Printing Studio" consisting of one 3D printer, materials and accessories, and multiple computer workstations with software necessary for digital modeling and file conversion. The librarians at the University of Alabama planned for three primary goals: operation should be highly visible with minimal access restrictions; users must receive ample operating and safety training; users should be able to experiment in the Studio (Scalfani and Sahib, 2013). They situated the Studio in the University Rodgers Library for Science and Engineering, and made it accessible to all university members. The librarians provided support by offering workshops, course training, and personal consultations. "In just two months, approximately 50 users have

been trained through a combination of six workshop” (Scalfani and Sahib, 2013). After few months of the Studio operation librarians analyzed and evaluated their experience, they surveyed operational procedures, and assessed the approximate service costs. Scalfani and Sahib (2013) compared their academic library 3D printing “authorized user model” with a public library “Makerspace” model and concluded that “both models have common goals of facilitating learning, research, and creation through experimentation.” However, Scalfani and Sahib (2013) wrote, an academic library “authorized user model” has a “formal approach and promotes users to create and explore research independently; after training... through mentorship, scholarly/open web resources, and peer collaboration.” Public library “Makerspace”, on the other hand, offers “an informal learning environment where users are physically brought together in a highly collaborative setting to create and explore research as a team” (Scalfani and Sahib, 2013).

There were limited number of the publications discussing the planning and management of 3D printing services in an academic library setting when the Library Technology Team at the LaGuardia Community College Library Media Resources Center acquired one consumer-end 3D printer (Makerbot Replicator 2) and smaller related devices in fall 2014. The Library has been under renovation since 2013 and the physical space that could be dedicated to a 3D printing studio was an issue. The Team decided to create a portable “Makerspace” that could be moved from classroom to classroom. The initial introduction of the new Library 3D printer to the college faculty took place during a college-wide conference “Opening sessions” in September 2014, and this new library service immediately garnered teaching faculty interest and enthusiasm. The faculty members from Mathematics, Engineering and Computer Science Department (MEC) were the first who decided to create a special class assignment for MEC and Engineering Design course requiring students to use the library 3D printer. With the assumption

that engineering major students should develop skills in design analysis and documentation, the new 3D printing assignment asked students to research different types of truss structure, to download from an open source a file related to an engineering concept learned in class, and to 3D print it in the college library. At the end of the semester, the students were expected to make an oral presentation of their experience with the 3D printing process. That was the first LaGuardia Community College Library experience in helping students with a 3D printing assignment. The librarians realized that the new 3D printing service would help to develop the students' creativity, assisting them in visualizing difficult concepts, and enhancing large class learning by involving all students in design activities. Though, at this point LaGuardia librarians didn't have 3D printing services policies in place, the technical knowledge of the engineering faculty facilitated the process. Students came to the library in groups of four or five, well prepared for the assignment by the teaching faculty. The students possessed general knowledge of the 3D printing process and the software that it used, as well as having the appropriate downloaded files with them. The library 3D printer was situated in a small room where students were able to print truss structures under the general supervision of the library's technical assistance staff.

The experience of using the library 3D printer for students' assignment by LaGuardia MEC department stimulated the interest of faculty from the other college departments. In January 2015 a faculty member from the Department of Natural Sciences, contacted Library Media Resources Center about the possibility to use Library 3D printer for an introductory biology laboratory class assignment. The goal of the assignment would be to enhance students' curiosity and course material understanding, to motivate student's schoolwork, and to improve students' learning outcomes.

In this article the authors describe the collaborative efforts between biology professor and instruction librarian in incorporating 3D printing technology into biology classroom. The authors discuss how a medium-size urban community college library may extend its services helping students with their needs for the new technical skills, and how the 3D printing technology implementation in a classroom promotes students' interests in learning biotechnology and STEM disciplines. The authors expect that the use of 3D printing technology in the classroom would serve as a means to improve Science, Technology, Engineering, and Math (STEM) education and to increase retention rate of STEM majors at colleges and universities.

For the last decade 3D printing has positioned itself as a vital component in STEM education (Hughes, B. and Wilson, G., 2015; Cambron, T. and Rosen, J., 2014). Recent publications on incorporating 3D printing in academic libraries and other educational environments illustrate its cost effectiveness and informational value for higher education, especially for technology, engineering and clinical medicine classes (Costello et al., 2014; McMenamin et al., 2014; Martin et al., 2014). However, the authors didn't find a description of a real life example on how to plan and manage an academic library support for a STEM class curriculum by offering and maintaining library 3D printing services. The project described here may serve as an effective model for fellow educators and academic librarians of enhancing their teaching practices, curriculum development, and library services innovation.

II. Project overview

Traditional biology classes use a variety of teaching materials such as textbooks, PowerPoint Presentations, practice questions, videos, and complementary laboratory experience. Most materials used to illustrate the structure and function of biological molecules and

compounds present them as 2D pictures. Thus, the students have limited access to practical models and have difficulty correlating 2D pictures with the real 3D objects. The lack of association between 2D pictures and 3D structures often discourages students from further exploring important knowledge. To solve this challenge, it was hypothesized that a class assignment requiring practical 3D models printing would support students' understanding of biology molecules structure and function. The novice 3D printing service offered by LaGuardia Community College Library Media Resources Center was planned to be used by the students to fulfill this assignment. It was expected to provide students with an affordable and convenient hands-on experience in printing 3D models of biological molecules learned in class, and to help students in understanding, analyzing, and predicting how the molecules and the compounds work together carrying out specific biological functions. In the course of the three-semester-long project the authors investigated the planning process of implementing an academic library 3D printing services in an effective way, and evaluated how these services would influence students' learning motivation. The results of the project contributed to the development of the library 3D printing management policies and operating procedures. The project was approved by the LaGuardia Community College's Institutional Review Board for the Protection of Human Subjects.

III. Procedure, Assessments and Measures

The project described here lasted three semesters. The pilot stage of the project was initiated at the beginning of the six-week semester of fall 2014 (March-February 2015). The authors collaboratively created an assignment for the Principles of Biology class curriculum requiring each student in the class to choose a biological molecule structure learned in classroom

and print it out in 3D. The teaching biology instructor provided the students with a general overview of the 3D printing technology and introduced them to the assignment. The students were asked to use an open source of the National Institute of Health [2] to download the chosen file of a molecule on a flash drive, to bring the flash drive with the downloaded file to the library, and to print it out individually on the library 3D printer. A short report and reflection about the experience with 3D printing was also expected. Shortly, it became clear that, despite the classroom introduction to the 3D printing process, students were unable to choose and download 3D files in a proper software format. Each time when a student came to the library to fulfill the assignment a library staff's help was required to instruct and supervise students while downloading a file and using the library 3D printer. The value of the printer and the complexity to operate the system dictated close interaction between librarians and students. As a result, approximately twenty hours of working time were spent by library faculty and staff helping seventeen biology class students with one 3D printing assignment. The authors analyzed the experience of the pilot study and decided to make a few modifications to the 3D printing assignment. During the next twelve-week semester of spring 2015 (March – June 2015) the class was divided into groups of four-five students asking them to finish the assignment as a team. This change helped librarians to reduce workload when assisting students with the assignment. Instead of seventeen individual 3D printing sessions of approximately sixty-eighty minutes each, librarians spent a total of approximately seven hours helping four groups of students. The students were yet trained by their biology instructor in a regular classroom on how to explore the National Institute of Health website, how to find and download files for 3D printing. Each group of students was required to download one common 3D model file for a molecule they were interested in as a team homework. Each group had to schedule an appointment with the library to

print out one 3D model of a chosen molecule. However, the students still came to the library mostly unprepared struggling with downloading a proper format of a molecule model for 3D printing. This part of the assignment was mostly done by the students during 3D printing library session with the help of the library personnel. At the end of the semester, students were required to showcase their printed 3D models explaining the biological background of it, and to reflect on what they had learned about the 3D printing technology. In addition, students were asked to volunteer in a survey consisted of eleven questions (Appendix A). The evaluation of the results of this survey helped the authors to further revise and improve the 3D printing assignment. For the next twelve-week semester of fall 2015 (September – December 2015) it was decided to include a one-hour library instruction session in the class curriculum in order to introduce students to the 3D printing technology and to explain the 3D printing assignment in details. At this time the authors, also, invited a library intern to help with the project. The one-hour library instruction session was held in a dedicated library computer lab. The teaching librarian brought a portable 3D printer to illustrate its function in real time. During the library session the librarian, the intern, and the class instructor helped students with accessing the National Institute of Health 3D models and downloading a chosen model in a proper format. At the end of the session, the students were able to schedule library 3D printing appointments. At the end of the semester, a second survey was conducted to assess the revised assignment's teaching and learning outcomes.

Two surveys, one taken at the end of spring 2015 semester, and another taken at the end of fall 2015 semester, were analyzed and compared. In order to assess survey results the authors assigned points to the students' responses: 0 points if a student strongly disagrees with a statement, 1 point if a student disagrees with a statement, 2 points if a student agrees with a

statement, and 3 points if a student strongly agrees with a statement. Survey results were analyzed statistically using the formula syntax of the TTEST function in Microsoft Excel.

IV. Survey results

This was a qualitative study surveying library 3D printing experience of the students from LaGuardia Community College entry level biology classes, and the learning outcomes of the biology class 3D printing assignment. The survey consisted of eleven questions and was collegially developed by the biology class instructor and the instruction librarian (Appendix A). A total of twenty six students were enrolled in the study. The survey results clearly illustrated that the requirements, learning outcomes, and the level of the library involvement with the biology class 3D printing assignment significantly improved from spring 2015 to fall 2015 semester (Figure 1).

The survey questions aimed to assess several aspects of the project. First, the authors analyzed the clarity of the assignment and the ease of choosing a biological molecule for the 3D printing. The results of the first survey indicated an average score of 2.3 points for the clarity of the assignment and 1.5 points for the ease of choosing a 3D model. At the beginning stage of the project the biology instructor was given a brief classroom introduction to the 3D printing technology and asked students to research and download a 3D model as a homework. Though students understood the assignment in general, they had difficulties downloading the 3D files on their flash drives. The teaching librarian and the library technician had to spend time explaining and assisting each individual group of students with a 3D model download and format. To solve this problem, it was decided to schedule a one-hour library instruction session as a part of the biology class curriculum. At the second stage of the project, the library instruction session was

held in the library classroom equipped with computers and Internet access. The teaching librarian brought a movable working 3D printer to illustrate its function. The students received detailed hands-on instructions on how to navigate online resources, and how to research and identify a 3D model suitable to print. The class instructor explained the goals and the structure of the assignment. Under the close supervision of the teaching librarian, the class instructor, and the library intern the students were able to work in groups and download 3D printable models of biological molecules. As a result, the students could easily understand the procedure and the evaluation criteria for the 3D printing assignment. The average score of the second, fall 2015, survey results increased from 2.3 to 2.7 points for the clarity of the assignment, and from 1.5 to 2.5 points for the ease of choosing a 3D model (Figure 1).

The authors also surveyed how the students evaluated the level of the help received in the library with the completion of the assignment and the ease of library 3D printing appointment scheduling. The average score for the help received in the library was constantly high: 2.3 during spring 2015 semester and 2.5 points during fall 2015 semester (between “agree” and “strongly agree”). However, at the beginning, the average score for the ease to schedule an appointment for the use of library 3D printer was 2.1 (just “agree”), which indicated the importance of improving the process. At the first stage of the project the students were required to schedule a 3D printing appointment on their own by visiting the Library Media Center desk. This wasn’t convenient for students, nor for library staff as it required an extra trip to the library and involved cancellations and appointments’ rescheduling causing miscommunication problems. At the second stage of the project, the authors asked the library intern to help library staff with 3D appointments scheduling. The library intern was introduced to the students during the library instruction session, a signup sheet (indicating the intern’s email address) was distributed to the students.

This modification improved the booking procedure which reflected in an increase to 2.7 points (average “strongly agree”) score in fall 2015 semester, compared to 2.1 points (average “agree”) in previous, spring 2015 semester (Figure 1)

To assess the learning outcomes of the 3D printing biology class assignment the authors included survey questions asking the students if they had learned new skills through this project, and whether the project helped them to understand biological molecules’ structure. The students were also asked if the 3D assignment raised their interest in biology and/or biotechnology. The total score for students’ responses to these questions was positive for both stages of the project. Figure 1 shows that the average score for learning new skills was 2.2 points in spring 2015 and 2.6 points in fall 2015. Most students also agree that through the 3D printing project they understood the biological molecule’s structure better. The average score for this category was 2.3 points in spring 2015 and 2.5 points in fall 2015. The average score for the students’ interest in biology and biotechnology increased from 2.0 points in spring 2015 to 2.6 points in fall 2015. The students’ confidence in the subject they learned increased from 2.0 points in spring 2015 to 2.7 points in fall 2015, proving that the assignment helped them to become more confident in the subject (Figure 1).

The last survey question asked students whether they would like to have a similar project in another class. In spring 2015, 58% of the students said “YES”, in fall 2015, 100% of students said “YES” clearly proving the effectiveness of the 3D printing technology for college teaching and learning enhancement (Figure 2). In summary, after analyzing and comparing the survey results the authors found increased students’ interest in learning and confidence in using library resources for their college work.

At the end of the project, students were asked to write an individual reflection on how they feel about the 3D printing assignment. The students' feedback was positive and reaffirming the survey results. Here are some quotes from the students' reflections:

“With the 3D printer we can see small sections and color it in as well to better understand what we are looking at with the hands on feel to it, something a textbook can't give us.”

“The 3D printing experience was something new that is very helpful and easy to remember and surprisingly fun.”

“By being a student here at LaGuardia Community College, this 3D printing experience is one of the best memories that I have so far.”

Y. Discussion

The increased awareness and utilization of 3D printing technology in the past years made it beneficial and necessary to introduce 3D printing to the students at an early stage of their education. Though 3D printing only recently started its way into classrooms and academic libraries, the authors are confident that in a few years, 3D printing in education will become the key element in motivating students' learning interest, helping them to understand complex topics, and will prepare students to enter their future workforce environment. That is why, it is so important for academic librarians to share their experience with 3D printing services planning and management. While the authors acknowledge the relatively small sample size, this qualitative study may serve as a model for educators to modify or build upon in a variety of classes. Academic libraries, working hand-on-hand with teaching faculty play a powerful role in connecting students with 3D printing resources. The recent American Library Association publication reports that “more than 420 public libraries now offer 3D printing services (a year

ago, the number was only at 250)” (Wapner, 2016). It is crucially important for academic librarians to join the pathway and to develop a working paradigm on how to manage this innovative library service. The project described in this publication proved the effectiveness of academic library involvement in enhancing the students’ understanding of the basic STEM subjects’ concepts, it revealed a variety of crucial issues faced by the librarians during its completion. At the present time, LaGuardia Community College Library formed a special 3D Printing Committee consisting of the chief librarian, the library media services coordinator, the library instruction coordinator, the technology and systems librarian, and the college laboratory technician. The committee is working on carefully planning and managing the new library 3D printing services. Among the issues the committee is working on are: arranging an appropriate dedicated space for 3D printers; considering library budget allocation for the 3D printing hardware, software and workforce; appointing and training librarians and technical assistants who will provide 3D printing services and instructions to the students; planning special workshops to train the library 3D printing users; keeping 3D services sustainable from technical and cost standpoints. With careful planning and management library 3D printing services will increase student’s confidence and interests in learning and will contribute to the success of the academic library mission.

Acknowledgements

The authors thank Terry Parker, the Coordinator of Media Services of the LaGuardia Community College Library Media Center and Felix Peralta, Media Services Laboratory Technician, and Seongkeun Ahn, library intern from Queens College Graduate School of Library and Information Studies for their assistance and technical support in teaching students how to use 3D printers.

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Appendix A: Students' survey questions

1. Before this class, have you ever used the 3D printer?
 Yes No
2. The Assignment was easy to understand (please circle one):
 Strongly Disagree Disagree Agree Strongly Agree
3. It was easy to choose a molecule structure file for 3-D printing on an open sources:
 Strongly Disagree Disagree Agree Strongly Agree
4. It was easy to make an appointment with LAGCC Library staff for 3-D printing session:
 Strongly Disagree Disagree Agree Strongly Agree
5. I received valuable help from LAGCC Library staff in searching and choosing a molecule structure file for 3-D printing on an open sources:
 Strongly Disagree Disagree Agree Strongly Agree
6. LAGCC Library staff helped me to understand how to work on the 3-D printer:
 Strongly Disagree Disagree Agree Strongly Agree
7. I feel that I gained new skills as far as 3-D printing as a result of this project:
 Strongly Disagree Disagree Agree Strongly Agree
8. I received a better understanding about the structure and function of molecules as a result of this project:
 Strongly Disagree Disagree Agree Strongly Agree
9. I become more interested in Biology and technology after finishing this assignment.
 Strongly Disagree Disagree Agree Strongly Agree
10. I become more confident in learning Biotechnology terms, concepts and events through this assignment.
 Strongly Disagree Disagree Agree Strongly Agree
11. Would you like to have similar project for another class, let's say - Engineering or Chemistry:
 Yes No

Figure 1. Student's survey results

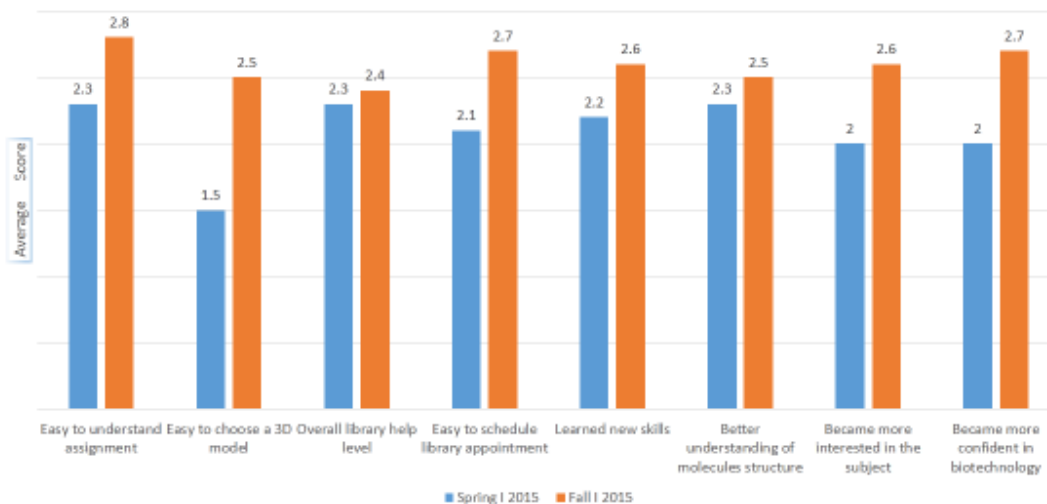


Figure 2: Student answers to the survey question "Would you like to have similar project for another class?"

