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Case Study

Tinkering with Teachers: The Case for 3D Printing in the Education Library

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Abstract

Opportunities to utilize 3D printing in the K-12 classroom are growing every day. This paper describes the process of implementing a 3D printing service in the Education Library of The University of Florida, Gainesville, a large, doctoral-degree granting, research university. Included are examples of lesson plans featuring 3D printing, creation of 3D models, how to find existing models, and examples of how to integrate 3D printing into the K-12 curriculum. The author addresses the benefits and challenges of this process for library staff and patrons as well as potential uses for the future.

Introduction

The Education Library at the University of Florida, Gainesville was given the generous opportunity to purchase a 3D printer utilizing a grant from the Science Library on campus. Much of the ground work was laid by librarians at the Science Library and therefore only minor tweaks were needed to get the project rolling at the Education Library.

The relatively low cost of purchasing and operating a 3D printer makes it more affordable than ever before to use in a classroom setting. In 1995 a "very low cost" rapid prototyping printer (the original name for 3D printers) was approximately $20,000, (Hull et al., 1995). In comparison, the one used in our library cost around $3,000 when purchased two years ago and today that same model is priced at around $2,000. Making 3D printing available in the Education Library allows future teachers and others in education-related fields to become familiar with the technology so they can use it for lesson planning and other educational endeavors.

We had numerous questions going into this project: where would we put it, how would students know it was available, how would we teach faculty, staff, as well as library employees to use it, how much time would it take away from our other responsibilities, what policies do we need to create? Most importantly, how would students in the College of Education make the best use of this new resource?

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Literature Review

While we did not locate any peer-reviewed articles specifically discussing 3D printing in a stand-alone Education Library, there are many articles that discuss 3D printing in academic libraries in general, in K-12 settings, and in public libraries. This literature review discusses 3D printing as it relates to academic libraries and the K-12 environment.

The 2015 *NMC Horizon Report* K-12 includes a section on 3D printing which outlines the applicability of 3D printing to teaching and learning in K-12 education. NMC estimates that 3D printing will be standard in schools within the next two to three years. From a high school in Maine using 3D printing to create art pieces based on a graphic novel to a school in Taipei that uses 3D printing to teach students engineering skills, the use of 3D printing is growing in K-12 education. However, for 3D printing to continue to grow in this environment, "adequate training is needed to ensure teachers and students have the digital competency needed to turn their ideas into reality" (NMC Horizon Report, 2015, p. 41).

Ambitions are high for 3D printing in the K-12 classroom. MakerBot Academy has a proposal to put a MakerBot 3D printer in every school in America and provide related educational content (MakerBot Academy). In addition, "the Chinese government has created new policy that will install a 3D printer in nearly 400,000 schools over the next two years" (NMC Horizon Report, 2015, p. 41).

In 2012, the first University Library to offer 3D printing was the DeLaMare Science & Engineering Library at the University of Nevada-Reno (Free, 2012). However, SPEC Kit 348 states "the ARL survey results…make clear that the broad appeal of these technologies extends beyond technology-focused universities" (Association of Research Libraries, 2015).

One researcher noted that "an anticipated problem with expanding 3D printing technology to disciplines other than engineering was the students in those disciplines may not have the CAD [computer aided design] expertise to create a digital model from scratch in software" (Pryor, 2014). The Education Library has addressed this issue by directing students to 3D Printing LibGuides with information on using existing 3D models, creating 3D models, and by offering workshops that provide an introduction 3D printing technologies.

Some University Libraries have purchased 3D printers for the specific purpose of making them available to academic units not typically thought of. The Dalhousie Libraries in Canada purchased 3D printing technologies "to encourage the use of these technologies by academic units not traditionally associated with them, such as Biology, Chemistry, Physics, Mathematics, History, and Theatre" (Groenendyk and Gallant, 2012).

The use of 3D printing in the K-12 environment is still new but teachers are already developing ideas and beginning to implement them. An elementary school in Tennessee purchased a 3D printer and challenged the kindergarten and first grade students to design a new piece of playground equipment. At the end of the project, the playground equipment was installed in their playground. The authors noted that the project could have been improved by including preservice teachers who were knowledgeable about 3D printing: "Preservice teachers could be prepared for this type of project by replicating the process in the college classroom.

They would understand and be able to implement the project in many settings, but having the experience and knowledge would prepare them for the classroom" (Wendt & Wendt, 35).

At a middle school in North Carolina, students in Art class are learning to use Tinkercad and Thingiverse to design and download 3D models such as "key chains, nametags, and other designs such as small houses" and in the future they will "create Chinese calligraphy seals in an Asian art lesson, as well as stop-motion puppets" (Moorefield, 2014). Meanwhile, a middle and high school Librarian in North Carolina is teaming up with another Art teacher for a steampunk sculpture project (Moorefield, 2014).

One ambitious educator references Star Trek when explaining 3D printing saying, "if students aboard the starship Enterprise were studying the organelles of a cell during a biology lesson, they might use the "replicator" to actually build a large model of a cell in three dimensions…Turns out the replicator-otherwise known as a 3D printer-is already here" (Horejsi, 10). He goes on to predict additional uses saying that, "digital textbooks, with some tweaks, could be linked to a 3D printer so that topics covered literally materialize off the screen," (Horejsi, 10).

What is 3D Printing?

3D printing is an example of additive manufacturing, where objects are created by laying down layer upon layer of filament until an object is formed on the x, y, and z axes. 3D models are created using CAD (computer aided design) software programs such as Tinkercad. 3D models can also be created by using scanners to scan an object that can be downloaded as a 3D model. An app called 123D Catch can be downloaded free to your smart phone and can create a 3D model after taking a series of photos in small increments around the object. There is also a product called iSense which can be attached to an iPad and create a 3D design by walking around the object you wish to capture.

Setting up the printer

We knew from another campus library primarily serving the sciences that the printer needed placement where it would not be physically disturbed. From early use at the Science Library we knew that even a strong breeze coming through a nearby door could affect the printing. We purchased a MakerBot Replicator 2 and had a clear plexiglass container built to house the printer to protect it from environmental disturbances.

At first, the printer was placed on the Circulation Desk but after several failed prints we became concerned that perhaps it was too draughty there and placed it on a table behind the Circulation Desk. It was a little better but there were still some errors in the prints so a clear plexiglass shield was built to protect the printer from breezes either from the front door or people walking briskly by the machine. Once we put the plexiglass shield in place the prints were error free.

Leveling the build plate, the part of the printer where the print is actually built, can be one of the hardest parts of getting the 3D printer set up. This ensures that the extruder is extruding the filament at the same distance at all levels during the build. The extruder for the MakerBot travels to the four corners of the build plate thick piece of paper to slide in between

the build plate and tip of the extruder nozzle. All four corners should feel like there is a just enough room to slide the paper in between without being too loose or too tight.

Organizing all of the tools required for 3D printing can be a challenge as well. We decided to purchase an Airwolf 3D Printer Cart, but we are still using a book cart to store our extra filament. The advantage to having the printer on a cart, is that we can wheel it to the library classroom for demonstrations during our 3D printing workshops. Our future goals are to create an enclosed room that will include storage space for filament, tools, and a place to store finished prints waiting to be picked up. The 3D printer and filament cart currently sit behind the Circulation Desk.

Useful tools to have on hand include: pliers and tweezers for pulling off supports, small and large plastic baggies for putting finished prints in along with the patrons name, a ruler, flash drives, SD cards, a scale to measure how much filament is left on the roll, a small level to aid in leveling the build plate, a scraper to help get the print off the build plate, and scissors.

Figure 1
3D Printing Tools

Figure 2
MakerBot Replicator 2 with plexiglass case

Figure 3
MakerBot on AirWolf 3D Printer Cart.

Figure 4
Filament rolls stored in plastic baggies with a silicone gel pack inside to keep the filament fresh.

Temperature

Manufacturers suggest filament temperature setting depending on the type of materials and the color of the filament. We found that suggested temperatures do not always print the best and a system of trial-and-error helped us determine the ideal temperature setting to use. For our MakerBot Replicator 2 using PLA filament, we found that the ideal temperature setting is 225 degrees Celsius for white filament, 220 degrees Celsius for color filament (black, white, red, green, blue, etc.), and 210 degrees Celsius for glow-in-the-dark, natural, and wood filament.

Safety

The extruder and nozzle of 3D printers generate high temperatures and should never be touched before cooling down. Once the equipment begins printing, the extruder can move rapidly in several directions inside the build area so it is best to make sure the print is complete before removing the printed object. PLA plastic while not toxic, does produce an odor and may

bother people in the vicinity of the area so it is recommended to keep the printer in a well-ventilated area.

Filament

There are many types of materials that can be used for 3D printing. Due to cost, the most commonly used material in libraries is plastic filament. There are two types of plastic that can be used in 3D printing; ABS (acrylonitrile butadiene styrene) and PLA (polylactic acid). ABS plastic is the type used in LEGOs®. It is a more durable material but the downside is that the fumes or odors produced when melting the plastic can be toxic. We use PLA filament, which represents a lesser health and safety risk than ABS (University of Florida, Environmental Health & Safety, 2016).

With either type of plastic filament it is important to have your 3D printer in a well-ventilated area to mitigate any fumes from the melting plastic. The University of Florida's 3D Printer Policy requires that there be no more than "one printer per standard office and no more than two printers for a standard classroom or workroom" (University of Florida, Environmental Health & Safety, 2016).

Filament comes in a variety of colors and textures. Students have the option of choosing a color such as blue, green, red, etc. or even glow-in-the-dark. Another option is to print using a standard white filament, which can then be colored using paint or enamel. One of the more exotic filaments we provide is wood. It is a combination of plastic and pine shavings that give the finished project the look of a wooden item.

Raft

A raft is the horizontal layer of filament that is printed beneath the object to provide stability and a foundation during the printing process. It is not always necessary to print a raft but the option is available to choose it or not. In the example below, a raft is being used to connect a collection of ancient horse teeth. The object(s) can be easily removed from the raft when the print is complete.

Figure 5
Raft holding horse teeth

Figure 6
Raft holding horse teeth.

Supports

For print jobs with parts that have nothing below it (like an overhang), a support can be printed that will assist that part of the print during the printing process. Imagine printing the letter "T" standing up straight. Without supports there will be nothing to hold the arm of the letter therefore supports are needed to keep it sturdy during the printing process. In some cases, the need for supports can be alleviated by laying the object down flat but that is not always possible for more complex forms.

The supports are weaker than the actual printed portion of the model and can easily be taken off once the print is complete. The supports can sometimes be taken off by hand and other times require tools such as tweezers or pliers. Once supports are removed it is sometimes necessary to use other tools such as an emery board or nail file to smooth the places where the supports were connected.

Below are examples of a triceratops made on a Fusion printer from a Thingiverse model (Triceratops) before and after supports were removed. Notice that the underside of the finished model has a rough appearance from where the supports were connected. This can be smoothed down using a nail file if desired.

Figure 7
With supports, side view.

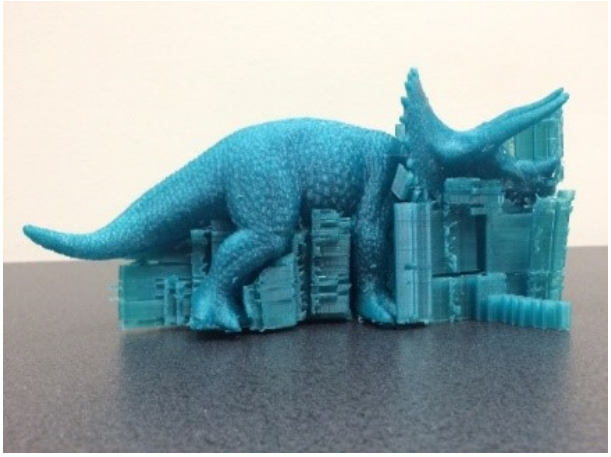


Figure 8
Supports removed, side view.

Figure 9
With supports, bottom view

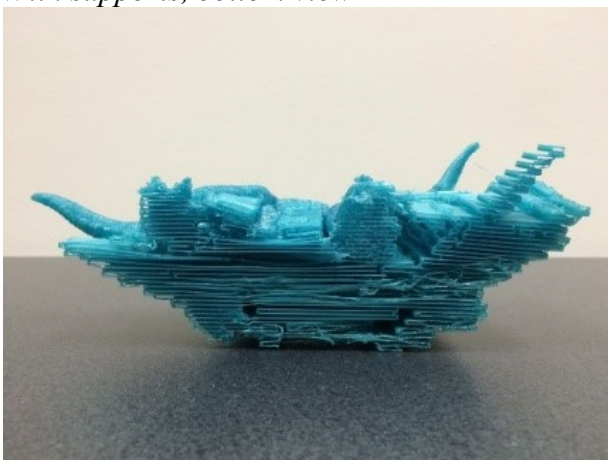
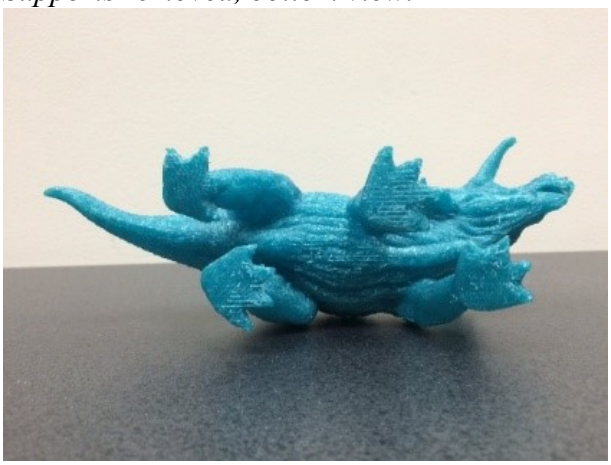


Figure 10
Supports removed, bottom view.



Submitting a 3D Printing Job

At this time, our faculty, students, staff, and the general public submit their 3D print jobs in person at the library by bringing a .stl (stereolithographic or Standard Tessellation Language) file on a flash drive to the service desk. If the job is deemed simple, it can be accepted immediately. If it is complex or raises questions we set an appointment with the student to examine the design file more closely to increase the odds of a successful printing.

Students must sign an agreement (Appendix A) stating that they agree to adhere to the University's Computer Use Policy and copyright regulations. The student is given a cost estimate and payment is made by major credit card or debit card online. Prints that fail because of a student error are not reimbursed. However, students whose prints fail due to machine or library staff error will receive a voucher for future printing.

Students are given an estimate, but not a guarantee, of when their printed object may be ready and are sent an email when the job has finished and ready for retrieval. Priority is given to University students, faculty, and staff, and printing jobs for a class assignment.

Printing Cost

The initial cost of printing a 3D object at the Library was set at $0.06/gram + $0.02/minute as determined by Makerware, with a $3.00 minimum charge. After the libraries on campus purchased additional 3D printers that printed at varying speeds this was changed to a flat rate of $0.15/gram. Several small objects can be batched together to meet the $3.00 minimum requirement. Most items under 1.5" x 1.5" are $3.00. An object around 6.5" x 3.5" costs around $20.00.

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Making the Case for 3D Printing in the Education Library

What makes 3D printing educational objects special is the ability to customize the 3D print models to adjust to any specific curriculum needs. Prefabricated objects can often be expensive, may not fit the exact needs of the lesson, and may include a kit with objects that aren't needed. Whereas, 3D printed objects, created and designed by the instructor, will be a perfect fit. 3D models can also be modified to fit a school's limited budget.

Using CAD software, such as TinkerCAD or AutoDesk, objects can be customized. The teacher can create objects that cause students to think and provide an opportunity to excite students in their learning.

There are several websites that include lesson plans using 3D printing. Thingiverse has a website of 3D models related to Education in its Curriculum collection (Thingiverse Curriculum). Their website features lesson plans for teachers using 3D printing in content areas of math, science, social studies, fine arts, and maps. Many of these lesson plans include instructions for use in a variety of classroom settings and information on Common Core and other related standards.

Other websites that have lesson plans and/or have tied-in 3D printing to the Common Core Standards include PaleoTEACH, MorphoSource, and the Smithsonian. PaleoTEACH exists to provide "high quality 3D models of fossils to a K12 audience and a set of lessons in connection with 3D models," (PaleoTEACH).

MorphoSource is a collection of 3D morphological datasets which is not specific to K-12 but does include some lesson plans, available in the Project section of the website, on topics such as human evolution, horse evolution, megalodons, and a lesson on base-ten conversions using scans of fossilized mammalian teeth (MorphoSource).

The Smithsonian has a website devoted to 3D printing that includes a link especially for educators (Smithsonian). This website includes 3D models of scanned artifacts from the Smithsonian collection such as the life mask of Abraham Lincoln which includes a free eBook that can be downloaded on iPad, iPhone, and MAC, discussing Lincoln in more detail (The Mind behind the Mask).

Summary

The Education Library began offering 3D Printing on January 2nd, 2015. In the first six months of printing we executed 116 print jobs, using nearly 11 kilograms of filament, and 770 hours of printer time. The average printed object weighed 94 grams and cost $13.63.

Table 1
Summary of 3D Printer Usage for the first six months

# Prints	116
# Grams	10,955.9
Average grams/print	94 (@ 0.2 pounds)
# of minutes printed	46,241 minutes (770 hours: 41 minutes)
Patron consult time	1,131 minutes (18 hours: 51 minutes)
Consult time/print	9.75 minutes
Average cost/print	$13.63
Average print time/request	398 minutes (6 hours: 38 minutes)

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Conclusion

With opportunities for 3D printing in the K-12 classroom continuing to grow, we predict that the demand for the printer will also continue to grow. Based on initial demand and successful integration we plan to continue offering 3D printing and enhance it by acquiring complementary equipment such as portable 3D scanners for use with iPads, developing a repository of lesson plans, and marketing to our primary library constituents: education faculty, students, and staff. In addition, the library is planning to host a series of workshops to introduce education faculty, students, and staff to 3D printing concepts.

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Appendix

User Agreement

"I acknowledge that my item(s) adhere to copyright restrictions and to UF's computer use policies. I understand that the Libraries reserve the right to decline a print request that does not comply.

I understand that I will not be reimbursed for jobs that failed on my part, but I will receive a voucher for jobs that fail on the library's part.

I understand that the Libraries cannot guarantee a print time, however staff may be able to provide an estimate based upon the print queue length.

I understand that priority is given to UF students, faculty, and staff, and also to class assignments.

I understand that items printed that are not picked up within 14 days become the property of the Libraries. Items must be picked up by the individual who printed them."