# Work in Progress: Designing a University 3D Printer Open Lab 3D Model

**Hector Erick Lugo Nevarez, University of Texas, El Paso**

Mr. Hector Lugo works as a Student Technology Success Coordinator at The University of Texas at El Paso. He holds a B.S. in Electrical Engineering. He is currently enrolled as a Master of Science with a Major in Electrical Engineering. His motivation and passion pushes him into research in wireless communication, especially in Bluetooth Low Energy and Near Field Communication as well as building projects and fostering innovation with faculty and staff members. As part of the Learning Environments division, the idea to develop, oversee and assess engaging students to expand their knowledge and creativity by innovating new technologies application for Engineering Education is currently under way to engage the university and the community. Concluding, Mr. Lugo's ambition is to encourage students to focus in science, technology and engineer abilities in order to expand their professional potential.

**Mr. Mike Thomas Pitcher, University of Texas, El Paso**

Mike Pitcher is the Director of Academic Technologies at the University of Texas at El Paso. He has had experience in learning in both a traditional university program as well as the new online learning model, which he utilizes in his current position consulting with faculty about the design of new learning experiences. His experience in technology and teaching started in 1993 as a student lab technician and has continued to expand and grow over the years, both technically as well as pedagogically. Currently he works in one of the most technically outstanding buildings in the region where he provides support to students, faculty, and staff in implementing technology inside and outside the classroom, researching new engineering education strategies as well as the technologies to support the 21st century classroom (online and face to face). He also has assisted both the campus as well as the local community in developing technology programs that highlight student skills development in ways that engage and attract individuals towards STEAM and STEM fields by showcasing how those skills impact the current project in real-world ways that people can understand and be involved in. As part of a university that is focused on supporting the 21st century student demographic he continues to innovate and research on how we can design new methods of learning to educate both our students and communities on how STEM and STEAM make up a large part of that vision and our future.

**Prof. Oscar Antonio Perez, University of Texas, El Paso**

Prof. Oscar Perez received his B.S. and Masters in Electrical Engineering from the University of Texas at El Paso with a special focus on data communications. Awarded the Woody Everett award from the American Society for engineering education August 2011 for the research on the impact of mobile devices in the classroom. He is currently pursuing a PhD in Electrical and Computer Engineering. Prof. Perez has been teaching the Basic Engineering (BE) – BE 1301 course for over 8 years. Lead the design for the development of the new Basic Engineering course (now UNIV 1301) for engineering at UTEP: Engineering, Science and University Colleges. Developed over 5 new courses, including UTEP technology & society core curriculum classes specifically for incoming freshman with a STEM background. Prof. Perez was awarded the 2014 "University of Texas at El Paso award for Outstanding Teaching". Prof. Perez has over thirteen years of professional experience working as an Electrical and Computer Engineer providing technical support to faculty and students utilizing UGLC classrooms and auditoriums. Mr. Perez is committed to the highest level of service to provide an exceptional experience to all of the UGLC guests. Mr. Perez strongly believes that by providing exceptional customer service that UGLC patrons will return to make use of the various services the university offers. Mr. Perez enjoys working on the professional development of the students' employees at the UGLC. He shares with his student employees his practical experience in using electrical engineering concepts and computer technologies to help in everyday real-world applications. Mr. Perez has worked with the UTeach program at UTEP since its creation to streamline the transition process for engineering students from local area high schools to college by equipping their teachers with teaching strategies and technologies each summer. Oscar enjoys

teamwork, believes in education as a process for achieving life-long learning rather than as a purely academic pursuit. He currently works on maintaining, upgrading and designing the classroom of the future. Mr. Perez is inspired because he enjoys working with people and technology in the same environment.

**Mr. Hugo Gomez, University of Texas, El Paso**

Mr. Hugo Gomez works as an Instructional Technologist at the University of Texas at El Paso, he is focused on expanding the professional and technical skill sets of our students and faculty community to better prepare them for the world of technology today and tomorrow. He works alongside a wide assortment of students, faculty and staff on campus to make sure their technology toolsets are up to date. Furthermore, Hugo provides workshops to over half of the student population at UTEP and as such, has been instrumental in providing the behind the scenes support to all these courses. Mr. Gomez also collaborates in the Learning Lab team to explore and implement new educational strategies in the classroom. Mr. Gomez has a Masters Degree in Engineering Education from The University of Texas at El Paso. He has participated in the UTEACH summer program as a Technology Instructor in which he provided workshops on website design, movie creation and computer networking. In addition, Mr. Gomez teaches UNIV1301 Foundations of Engineering, were students learn academic, personal and engineering skills, among many other abilities that help them understand their opportunities and responsibilities as engineering students.

**Mr. Pedro Arturo Espinoza, University of Texas, El Paso**

Pedro worked in the manufacturing industry as a Quality Control Engineer for some years before acquiring his current position as an Instructional Technologist at the University of Texas at El Paso (UTEP). For over ten years in this role, he has worked with a team of managers that oversee various learning environments and systems in the Academic Technologies Department at UTEP. He leads a group of more than 40 multidisciplinary student employees that help support a wide range of technologies for classrooms and other learning spaces, including videoconferencing rooms. In addition to teaching a Foundations of Engineering course, Pedro also provides technology training on Mac OS X, CISCO networking and various other technology topics. He also enjoys the role of social media coordinator for Academic Technologies to showcase the department's services and the dedicated students and staff members who work there. Pedro received his Bachelor of Science degree in Electrical Engineering and a Master of Science in Engineering with a concentration in Engineering Education from UTEP.

**Mrs. Herminia Hemmitt, University of Texas, El Paso**

Mrs. Herminia Hemmitt is part of the Learning Environments team in Academic Technologies at The University of Texas at El Paso. She is responsible for coordinating classroom technology upgrades and implementations to ensure project deadlines and anticipated goals are met. Her educational background in organizational and corporate communication is utilized in consultations with faculty and staff about their learning environments in order to correctly match them to appropriate learning spaces or adapt existing spaces to meet their pedagogical and technological needs. Her focus is on the specific user to make sure that classroom needs, technical needs, and/or event needs are met.

**Mr. Randy Hazael Anaya, University of Texas, El Paso**

Randy Anaya, Instructional Technologist at the University of Texas at El Paso. Received a BFA in Graphic Design with a minor in Multimedia design from the Universidad Autónoma de Ciudad Juarez, Mexico. Received a BA in Media Advertising at UTEP and is currently enrolled as a Master of Interdisciplinary Studies with an emphasis on the use of art and technology in teaching and learning. Randy works on research and development of applying the creative process to workshops, trainings and student engagement. Currently doing extensive research and deployment of emerging technologies to redefine the classroom, mentoring and excellence through student interaction.

# Work in progress: Design of a university open lab 3D printer model

Abstract

3D printing is progressively impacting many areas of our society. While the general public is becoming increasingly aware of the possible applications of 3D printing and companies are looking to incorporate the technology, higher education's dissemination of this technology is not progressing at the same speed between various colleges within the same university. College students do have access to this new technology but at different rates, thus creating a barrier between students and their access to this new technology.

Learning Environments is currently working on the design of a 3D printing open lab concept. This is the second year that this effort has been ongoing and several procedures have been developed based on the data collected from year one of the pilot. Currently, different systems of student 3D model submissions are continuously being tested and data collected to determine which to implement for year three of the pilot. Based on previous student feedback, this modified system should allow for supervision of the 3D printing model via a website using webcams. In addition, students should be able to print their own design using standard or alternative plastic materials with specific attributes such as flexibility, transparency, electrical conductivity or any other material that is compatible with the printer. Of utmost importance, this model has to be able to be escalated to a campus-wide system to allow access to the entire student body.

Introduction

The earliest 3D printing technology was developed in the late 1980's and was referred to as rapid prototyping technology. The idea of rapid prototyping came to be from the need for quicker and cost-efficient design testing for product development within the manufacturing industry. It wasn't until 2009, however, that 3D printers became commercially available. By 2012 several 3D printer companies began to offer their products on the market either as an open or licensed source[1].

3D printing is also commonly known as additive manufacturing. There are couple of processing methods for 3D printing, the printers that we currently are using would be Fused Deposition Material, trademarked by Stratasys (FDM); also commonly known as Fused Filament Fabcrication, by RepRap (FFF). It consists of extruding thin layers of melted material, mostly plastic, onto a level building plate, across the length and width of the space (x and y axis). As the thin layer is introduced through both axes, it will rise to the predetermined height selected and then repeat and start again to introduce the next layer of material across both axes.

3D printing in higher education has been available for quite some time. However, access has been limited to students at colleges across our campus. As an example to illustrate this point, only mechanical engineering students are allowed to use 3D printers located only within the college of engineering. In addition, these printers may only be available to specific classes or research groups and during very limited scheduled times. Even those students that have the opportunity to use the printers may be restricted to using them once per semester. If printers are to go offline due to failure or for maintenance, this schedule is further restricted. After a semester of collecting feedback from students at The University of Texas at El Paso the following was found: print queues are usually long, there is no chance for trial and error, it takes time to print the models successfully and requires constant or full-time supervision. These long queues negatively impact completion of prototypes and class projects by assigned strict deadlines. Designing a higher education open 3D lab for use by students, faculty and staff on a campus-wide level, presents many challenges due to the fact that there are hundreds of variables that could potentially hinder the lab's usefulness for so many users.

There is a growing demand for teaching concepts enhanced by the use of 3D printing. There are some schools that have bought several printers and new methodologies and pedagogies are being incorporated to address the unique application of 3D printing in the classroom. In general, instructors lecture on certain concepts and theories and a 3D printer is used to create final a model that is used to further aid in the explanation of the material covered[2]. The goal of this research is to pilot a campus-wide 3D printing system along with the space where students will be able to work on 3D designs and projects and have the opportunity to supervise the printing of their own prototypes. An additional goal is to provide instructors with a vehicle that will allow them to assign and/or demonstrate more in-depth details of the material being covered with the expectation that the implementation of this technology and associated pedagogies may lead students to real-world solutions. Students that have registered into our pilot program have the opportunity to design, innovate and create 3D models that could aid them in their degree, courses and/or personal skills without being required to belong to a specific degree.

## Materials and Methods

The paper will be divided into two segments. The first part will address the pedagogies incorporated with 3D printing, which demands the creation of such a system. The second part will discuss the set up of the structure for a small- or large-scale deployment of a 3D printing open lab within campus to meet the identified needs.

Three of the authors of this paper teach an undergraduate engineering introductory course at The University of Texas at El Paso. The curriculum for this course includes engineering design concepts and projects and subsequently a 3D design capstone project was added to the curriculum. In 2013, the department (name removed) invested in a Makerbot Replicator 2$^{nd}$ Generation 3D printer, with a build volume of 28.5 L x 15.3 W x 15.5 H cm. As a final project, the students in each of the three classes were grouped in teams of no more than five students. Each team had to create a 3D design of a bridge and the final part of the assignment was to 3D print this bridge. The design had to meet specific criteria such as exact dimensions on width, length and height, and had to support an object of at least five pounds without breaking[3]. A total of 15 bridges were printed. The success of this assignment was such that other engineering instructors wanted to incorporate this 3D design project into their own courses. With the success of the first year and the addition of other instructors to the program, this pilot doubled its size within a semester. The original three instructors continued the program a second year with similar success. As such, the department of Learning Environments at The University of Texas at El Paso decided to backup the pilot and expand it by providing four extra printers for the 2016 spring semester.

A good support structure is key to making a program such as this successful. Learning Environments is a department that employs both full-time staff and part-time students to research, develop, integrate and support classroom technologies. This was the perfect fit to close the gap in the pilot design. The students that work in the lab develop their technical and personal skills by providing support to faculty using technology in the classroom. Students that showed an interest in learning and fixing 3D printers were granted the chance to manage and supervise the Makerbot Replicator 2 (The first printer in the Pilot). Having students be responsible for printers presents its challenges. Without careful supervision and little experience on such technology, parts can be easily damaged or lost when fixing printers or maintaining them on a regular basis, especially when students can only work 19 hours per week, as per state policy.

A second printer was ordered at the beginning of 2015, a Makerbot Replicator Desktop 5$^{th}$ generation with a build volume of 25.2 L x 19.9 W x 15.0 H cm. This second printer showcased a new self-leveling feature, which reduced the amount of maintenance needed. Yet the print head extruder could still be easily damaged or not positioned correctly. After printing many hours, hundreds of 3D models and analyzing each of the components of the printer, it was clear that the deficiencies for the second printer were based on its extruder design. The location of strong magnets caused the metal pieces to misalign and the extruder head to clog often if it is not calibrated correctly as well as constant stuck filament between the extruder and nozzle tip.

The need to increase the number of printers resulted from an increase in classes wanting to participate during the third year of the 3D printing in the classroom program. This required supporting approximately 150 students and 29 student bridge designs. Having only one fully functional printer to complete all the loads became unreasonable as each successful print model could require approximately four to five hours to print. This workload gave us the experience to generate requirements moving forward with the pilot. The requirements were the following. The 3D print system must: 1) be able to produce a high volume of 3D printed models, 2) provide a streamlined process for student project submission and 3) train students on 3D design using simple tools.

A proposal was submitted in order to purchase multiple printers to continue the pilot. Based on the research made, a couple of printers were filtered based on our necessities. After our experiences with the first two Makerbot models we concluded that the new printers must: 1) have less issues with clogging, 2) provide high quality printed models with fine layer resolution, 3) contain a heated platform for printing different types of materials and use less consumables items such as blue tape, 4) have the ability to upgrade extruders, and 5) provide auto leveling of the bed. Figure 1 below shows a list of printers that were considered based on our requirements and 3DPrinterOS[4]. 3D printing is still under development in terms of reliable slicing, method of transferring a 3D model into a file format such as gcode, thing or any other extension that is not compatible between printers[5]. Because dual upgradeable heads could damage the print, they too are also still under design and development, as is auto leveling.

While our research for printers was being completed, a new partnership was made with 3DPrinterOS. This new piece of software provided a central management portal for all design files for 3D printing via a cloud-based platform. This online printing system consisted of a network of printers (a list of compatible printers was provided), a raspberry pi with Wi-Fi enable or Ethernet port, a web cam, a 1- year unlimited license, on-site deployment, training and support. The big advantage of this solution is that the printers can be installed within a network and be managed through the Internet.

| Rating | Filament Size | Name | Price | Quality Score | Dimension | Layer Resolution | Print Speed (mm/s) | Heated Platform | Dual or Triple Upgradable Heads | Auto-leveling |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3mm | Ultimaker 2 Extended | 3,030 | 95% | 9.0"x8.8"x12" | 0.02-0.2mm | 30-300 | Yes | | No |
| 2 | 3mm | Ultimaker 2 | 2,500 | 95% | 8"x8.8"x9" | 0.02-0.2mm | 30-300 | Yes | Optional (not recommended) | No |
| 3 | 3mm | Lulzbot Taz 5 | 2,300 | 85% | 9.8"x10.8"x11.7" | 0.075-0.35mm | 200 | Yes | 2 | No |
| 4 | 3mm | AirWolf (Axiom) | 4,000 | 85% | 12.5"x8"x10" | | 250 | | | Yes |
| 5 | 1.75mm | Cubify Cubepro | 2,800 | 95% | 7.8-11.2"x10.5"x9" | 0.07-0.3mm | 15 | | 3 | Yes |
| 6 | 3mm | AirWolf (HD2x) | 4,000 | 85% | 11"x8"x12" | | 150 | | Yes | No |
| 7 | 3mm | AirWolf (3D HD) | 3,000 | 85% | 12"x8"x12" | .06mm | 150 | Yes | | No |
| 8 | 1.75mm | Makerbot | 2,900 | 85% | 5.9"x7.8"x9.9" | .1mm | Various | | | No |
| 9 | 1.75mm | Makerbot Mini Replicators | 1,400 | 80% | 4.9"x3.9"x3.9" | .2mm | Various | | | No |

Figure 1. Ranking of printers based on our requirements

There are two types of accounts for this system: user and administrator. As a user, one is able to upload .stl files (common 3D printing file extension), search for sharable and public prototypes, complete simple edits on your model, share files between registered users, fix and slice the .stl file and finally sent file to the print queue. As an administrator, one can manage the models being sent to print by selecting which ones are permitted to print and on what printer from the available ones on the network. One can also restart printing if it fails without sending it again, cancel the print, create access groups, manage the printers, generate types of reports such as the number of accounts and printers with number of prints, print errors, material used, total print time, billing and many more features.

Training workshops and technical support were integrated as part of the design of 3D open lab for the third year of the pilot program. Part-time student staff within the department with knowledge of 3D design software such as Tinkercad, Inventor Fusion, Autodesk and NX9 proactively volunteered to train other part-time students from the department in order to support student lab users. The workshops that were made available during the pilot program included: 3D computer-aided design (CAD) software (i.e. Tinkercad) and the cloud 3D printer management system 3DPrinterOS. Students that enrolled in the pilot program were given specific guidelines and after answering a small set of questions they were classified as either needing both workshops or just a quick training on the cloud management platform. After attending the required workshop, they were provided with an access code to add the printers into their account and be able to send their designs to the print queue of the printers that have been made available to them.

A very critical component to consider as part of the design of a 3D printing open lab is the material/filament. Research was also done before selecting the printers in order to maximize printer usage and diversity material selection. As students gain expertise on 3D printing, several of them started asking about different materials that can be used to create their 3D printed models. After our research on the flexibility of the printers, students can choose from different materials based on their attributes, such as Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA), High Impact Polystyrene (HIPS), Nylon, Polyethylene Terephthalate (PET), Polyvinyl Alcohol (PVA), carbon fiber, wood, bronze, copper, glowfill, conductive and magnetic filament.

## Results

The proposal was approved and four Ultimaker 2 printers, with a build volume 20.3 L x 22.3 W x 22.8 H cm, were bought, plus the unlimited license for one year. Six spools (1,000 grams) of PLA materials were purchased to ensure sufficient materials would be on hand for the demand.

Enrollment in the program far exceeded what had been projected. Advertising for the program included two video films played on two large screens for public viewing within the building and the distribution of different posters across campus. During the first eight weeks (three of those weeks were during the winter break when virtually no students are on campus), 422 people registered through Phase I. Of those, 314 people were considered enrolled after answering the survey. During Phase II, 290 were identified as students. One thing that was not considered was that during five of those eight weeks, enrollment would be competing with school activities. For example, the Thanksgiving holiday, end of term preparations, final exams and winter break. Even though the highest number of registrants came from the College of Engineering with 67% (see figure 2). There were also students from other colleges such as Liberal Arts, College of Science and a near-tie between the Colleges of Business and Education. Figure 2 clearly shows that there is an interest in 3D printing not only by the engineering department but also by students from all colleges. As of January 14, 2016 the total number of students that have attended the workshops and are certified to print within our system is 208. As of the start of the current Spring 2016 semester, during the week of January 19 through 29 (first week of classes), there was an exponential increase in the student interest for 3D printing. The total number of people registered through Phase I as of January 29 is more than 4% of the campus population totaling 715 registered students.

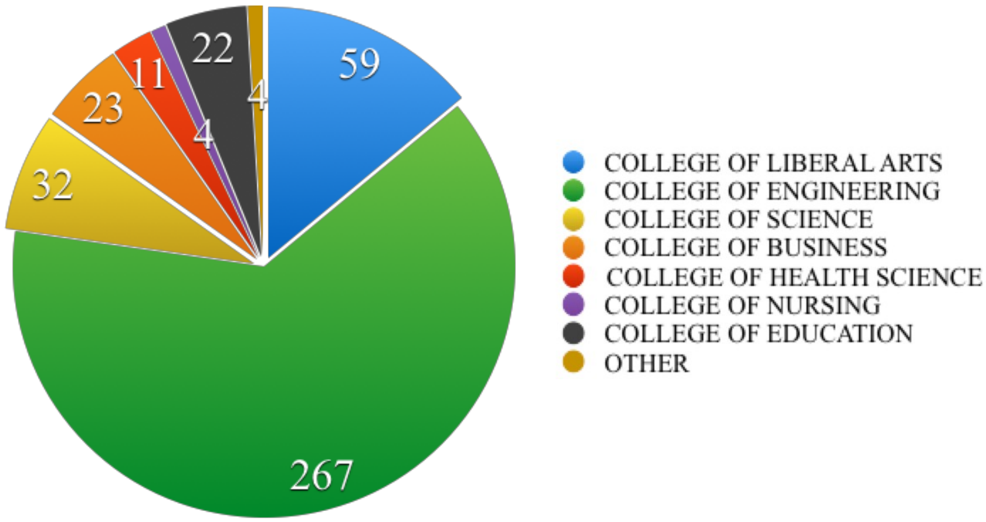


Figure 2. Pilot registrants by college, Phase I before January, 15 2016.

"If you want 3D printing you have to have capital and understand it; you can't buy it as a service in a straight forward way"[6]. Having the right amount of resources and the proper trained personnel, it is a critical key point to implement and design a new 3D open lab printer structure without any bumps along the road. Creating a 3D print charge system and forecasting the usage of filament per printer in a week daily basis under regular and overkill usage could make it a nightmare. Still under work of creating the most reliable print system; critical parameters, from lowest to highest, are arranged and accounted for a print charge system can be classified as the next 3 subsets. Some parameters that are included affect mainly the total object weight and total print time, such as infill percentage, layer height and print speed.

Subset Parameters

A. Weight Parameters: Total Object Weight, include support and platform adhesion (1), Infill % (7)
B. Time Parameters: Price per Hour (3), Total Print Time Hours (4), Layer Height (5), Print Speed (8)
C. Miscellaneous Parameters: Filament Cost (2), Workforce / Supervising (6), Failure Rate (9), Repair Costs (10), Disposable Material Cost (11) and Electricity (13)

The most important parameters based on our criteria are shown in Figure 3, on which we would only take into account the Total Weight, Total Print Time and Print Time Charge per Hour. The substantial parameter that will determine how much it could increase the price is Print Time Charge per Hour. Under the row "Our Service", refer to Figure 3; there is a comparison with only charging the total weight versus adding an extra charge of Print Time Price per Hour. It shows how much it could increase by just adding 50 cents per hour up to a 264% increase in total price. With only taking these three main parameters, it could possibly cover basically all the other parameters such as failure rate, repair costs, disposable material cost and electricity. The questions that have arose are: could it cover completely or partially the workforce / supervising parameter and should it even be consider to cover such element?

| | Layer Height | Infil % | Print Speed | Print Time Price/ hour | Print Time (hrs) | Meter | Gram | Price/ gram | Price Electricity /KWh | Printer Power | Volume (cm3) | Surface Area (cm2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | .125 mm | 50 % | 30 mm/s | $ 2 | | | 88.11 | 0.053 | 0.0938 | 200 W | 95.92 | 280.63 |
| **Our Service** | .125 mm | 50 % | 30 mm/s | | 13.1 | 9.51 | 75 | | Just charging Gr | | 3.975 | |
| | | | | | | | Gr and $.5 Print time charge / hour | | | | 10.525 | |
| | | | | | | | Gr and $1 Print time charge / hour | | | | 17.075 | |
| | | | | | | | Gr and $2 Print time charge / hour | | | | 30.175 | |

| **Market Services** | | Cheapest Price | Highest Price | **Standard Calculators** | Cheapest Price | Highest Price |
|---|---|---|---|---|---|---|
| | 1 | 15.1364 | | 1 | $ 9.49 (Charging just Gr ) | 62.88 (Charging Gr and Print Time) |
| | 2 | 22 | 51 | 2 | 13.73 (Charging Gr and 10% Failure Rate) | 18.72 (Charging Gr and 10% Failure Rate) |
| | 3 | 23.98 | 55,759.46 | Web-base calculators to estimate the cost | | |
| | 4 | 41.90 | | | | |
| | 5 | 61.30 | 520 | | | |

Figure 3. Print Charge System.

## Discussion

"Why Open? Why Lab? The name OpenLab speaks to two important and pervasive themes of this initiative. Its open nature fosters community and connection"[7]. The Journal of Interactive Technology & Pedagogy states, OpenLabs could bring new assets to higher education and interactions between students, faculty and staff. Students can start to get together, see what others are doing, raise interest for new students to join, and form groups/associations where they could start to exchange ideas, concepts, methods for designing, and experience what factors could improve or worsen a 3D printed model. Being an open lab could lead to great potential where students could stay there for long hours; a student could oversee its print while doing homework, talking with someone about a new trending topic in 3D, gain feedback and knowledge from other students or part-time students that work in the lab. As for faculty members, they could benefit from changing their teaching methods by incorporating individual/team-based projects, class discussions and reinforce concepts with an interactive procedure instead of the usual lecture format. The students will be able to recognize and link patterns through experience rather than by just taking notes. Staff members could, in a sense, participate indirectly in the class in a manner that may not have been accessible to them in previous years. "For all members, the possibility of observing and participating in curricular and extracurricular activities are an exciting prospect, one that is only possible because the system is open"[8].

There are many questions that still need to be answered regarding best practices for open 3D printing labs and to deploy a campus-wide 3D printing system. For example, how do you support the population demand with over more than twenty-six thousand students, faculty and staff members with only four printers? How do you determine a cost for printing materials (filament) to sustain the pilot program with free printing (as the pilot has been up to this point) and then transfer said costs to students as the pilot phase closes? Which would be the best structure across all colleges? Should it be a centralized location or deploy multiple printers all over campus? Should mainly part-time students run it or is there a need to create new job positions as full time staff? Is there a limit for the number of people that that printer can handle without being overused? Due to the high queue in the system, people have started to add multiple models into one file, what is the limit, or should it be only one model per print? How many printers would satisfy the demand for only course-projects and how many printers for personal and/or hobby projects?

Another thing to consider is the man-hours needed to meet the demand for workshops and scheduling. The current registration system had three stages. Registrants needed to access a website to register, answer a survey and finally attend a workshop based on their skills. The workshops were scheduled to meet every Monday through Friday based on demand and availability of instructors. Workshops scheduled had to meet three criteria: reasonable hours that students could attend, availability of part-time students that could provide the workshops, and availability of computers and space to host the workshop.

## Conclusion

The long-term goal of this research is to measure the benefit of a 3D printing open lab for students at The University of Texas at El Paso. The privilege of being part of a pilot program should not be made available solely to freshmen students in an introductory engineering course. This kind of program should always be open to any student in any discipline from liberal arts, nursing, computer science, business, as well as engineering. As such, an open-lab concept was created as a pilot where students from any discipline could print for free. This allows students the ability to start thinking about what 3D printing is, and make connections as to how they can use this for the education and personal skill development.

The vision of this project is to provide enough resources to all students on which they could implement 3D printing for assignments to be used in all their courses. Our research intent is to open doors and start the discussions among faculty on how to incorporate this new technology in their classroom. For example, students could struggle on their senior project design thinking on using metal or wood, which could be expensive, compared to plastic as prototype. Having the opportunity to modify parameters and reprint in terms of hours could bring a substantial improvement on time management, cost savings and with different material properties. This development can potentially assist instructors in reinforcing concepts into applied examples and create huge impacts on student learning.

## Future Work

The future scope of work is to continue researching how to optimize a campus-wide 3D open lab and the ramifications of unrestricted printing. Should it truly be open to whatever a student wants to print? or should rules for printing items such as a 3D weapons be enforced? In addition, solid numbers on the needs of each college in terms of quantity of printers, different brands and types of printers, different types of materials, and printing limits per student based on classification, number of credits, or degree need to be addressed. Feedback on possible friendlier user-interfaces, faster model rendering, precise slicing software, intuitive print queue systems with new features that could expedite or improve printing must still be gathered and provided to manufacturers.

We are looking to develop and implement a single step registration system for new users, which ties in to the 3D print website and automatically classify the registrant according to what training he or she needs. “There is no 'best' 3D modeling software. The choice of 3D modeling software however is rather large. There is specific software for a myriad of disciplines like architecture, sculpting, animation, engineering, product design and jewelry design. With each software there are also various price points for licensing; how much money can be allocated to spend on 3D modeling software, which ranges from free to a few thousand dollars”[8]. And to that end, we will also develop more workshops with distinctive software that could potentially increase student’s proficiencies in 3D design for any kind of degree. Instructors that want to incorporate 3D design into their course must have already done background research on how 3D could complement their course content and create design activities that could reinforce the concepts. Finally, we will create a reliable print system within the university that could charge specific calculated costs based on type and amount of filament used by the students.

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