Improving Accessibility to Additive Manufacturing

Ranjeet Agarwala
Department of Technology Systems
East Carolina University

Robert A. Chin
Department of Technology Systems
East Carolina University

Abstract

Initiatives to increase the prominence and visibility of and improve accessibility to additive manufacturing are proceeding. The first, which is underway, is intended to provide greater physical accessibility to additive manufacturing. With the second, a three day, additive manufacturing event was offered to a diverse sample of a university community. Pre- and post-event polls were administered. According to the pre-event poll data, the participants included an administrator, faculty and staff members, and an undergraduate student. The background of this sample was mixed with respect to their experience with additive manufacturing; it ranged from a little experience to no experience. According to a post-event poll, the participants were for the most part "very satisfied" with their experiences, have action plans for what they learned, and have means for measuring the success of their actions. The intent of this second initiative was to begin building an additive manufacturing advocacy coalition, whose role would be to help facilitate greater physical accessibility to additive manufacturing.

Introduction

Additive manufacturing refers to the use of digital data to lay-down and control the disposition of material in order to produce objects. The materials from which the objects are made can include plastics, metals, composites, and ceramics. In contrast, to produce objects by means of subtractive manufacturing, material is removed from a solid block of stock.

Additive manufacturing at a very rudimentary level, in contrast to subtractive manufacturing, can be compared to the production of plywood and glulam beams. With the former, thin layers of wood plies are assembled with the aid of an adhesive, heat, and pressure to form the sheets of plywood. With the latter, and similar to the production of plywood, dimensioned lumber is assembled in layers to form larger assemblies referred to as beams.

While additive manufacturing has not yet achieved the status of the personal computer—one in every home, it is approaching mainstream status because of its affordability and "3D printing". Unlike the traditional printing process where images are reproduced on paper, or other flat stock,

as two dimensional or three dimensional representations or images through one of many transfer processes, 3D printing involves the disposition of material in layers to produce three dimensional solid objects or their representations.

Additive manufacturing has also gained traction as a result of its use to produce models that can be examined, tested, and replicated. As a result, additive manufacturing has become a universal visualization and communications tool by way of "rapidprototyping", another term that characterizes additive manufacturing (Cerejo, 2010).

Rapidprototyping and 3D printing have become ubiquitous terms that characterize additive manufacturing (Rotman, 2013; Wohlers & Caffrey, 2013). Additive manufacturing no longer resides solely in the domains of design, engineering, technology, and manufacturing, and continues to branch out with respect to its applications (V3.co.uk., 2013), growth (Transparency Market Research, 2013), and its ability to help facilitate economic development, regional transformation, and domestic competitiveness (Kensinger, 2014; White House, 2013).

Deploying additive manufacturing by way of 3D printing in academic settings can contribute to sustaining this growth, expanding diversification, and stimulating economic development, regional transformation, and domestic competitiveness. The purpose of the two initiatives characterized in this paper was to increase the prominence and visibility of and improve accessibility to additive manufacturing.

Providing Greater Physical Accessibility to 3D Printing

In academic communities, 3D printing, while it is branching out, it generally is only available to a limited segment of the population—those who've completed the prerequisite courses associated with courses in which 3D printing is featured, as an example. In addition, and quite often there are numerous administrative and physical constraints that need to be overcome—time, high upfront equipment and maintenance costs, ongoing material costs, and access to facilities to name a few.

While there are still numerous matters of a logistical nature that need to be worked out, this paper's authors have overcome two key logistical encounters—a space in which members of a community can more readily access 3D printing and the availability of equipment.

Equipment. To support this initiative, this paper's authors negotiated the use of a still-serviceable monochrome ZPRINTER® 310 PLUS 3D printer, originally intended to be sent to surplus—see Figure 1. Introduced to the market in 2005 (3D Systems), the ZPRINTER® 310 PLUS is an entry-level, powder based, 300x450 dpi resolution 3D printer.

Space. Libraries, more and more frequently referred to as information or knowledge centers, are probably some of the most accessible facilities on university campuses. Most are accessible close to if not 24 hours a day and almost 365 days a year. Logic, as does practice, suggests that the

authors' campus library would be one of the better places in which to house equipment intended to increase the prominence and visibility of and improve accessibility to additive manufacturing.

Figure 1. Monochrome ZPRINTER® 310 PLUS 3D Printer.

Following a meeting with the campus' library chief administrator and selected library staff members, a small room was made available in the library to the authors—room 2000A. Figure 2 suggests room 2000A is in an easy-to-find and higher visibility area of the second floor. In addition to housing some of the library's stacks, the library's second floor houses the library's Teaching Resource Center (TRC) and administrative offices (ADM).

Figure 3 reflects the authors' thoughts on the placement of equipment. The final decision on equipment placement will be made in conjunction with the appropriate staff members of the library.

Building a 3D Printing Advocacy Coalition

A three-day training event that focused on 3D printing was developed and delivered. The purpose of the event was to introduce up to 8-10 selected administrators, staff, and faculty members to additive manufacturing—aka 3D printing. Upon completion of the event, it was anticipated the participants would be more knowledgeable and skilled in the fundamentals of 3D printing and would be able to advocate on behalf of this innovation technology and production tool, and to help facilitate access to additive manufacturing. The event included training with the aid of resources housed in the College of Engineering and Technology. The goal of this initiative was to begin developing a pool of 3D printing advocates who are also economic development, regional transformation, and domestic competitiveness advocates.

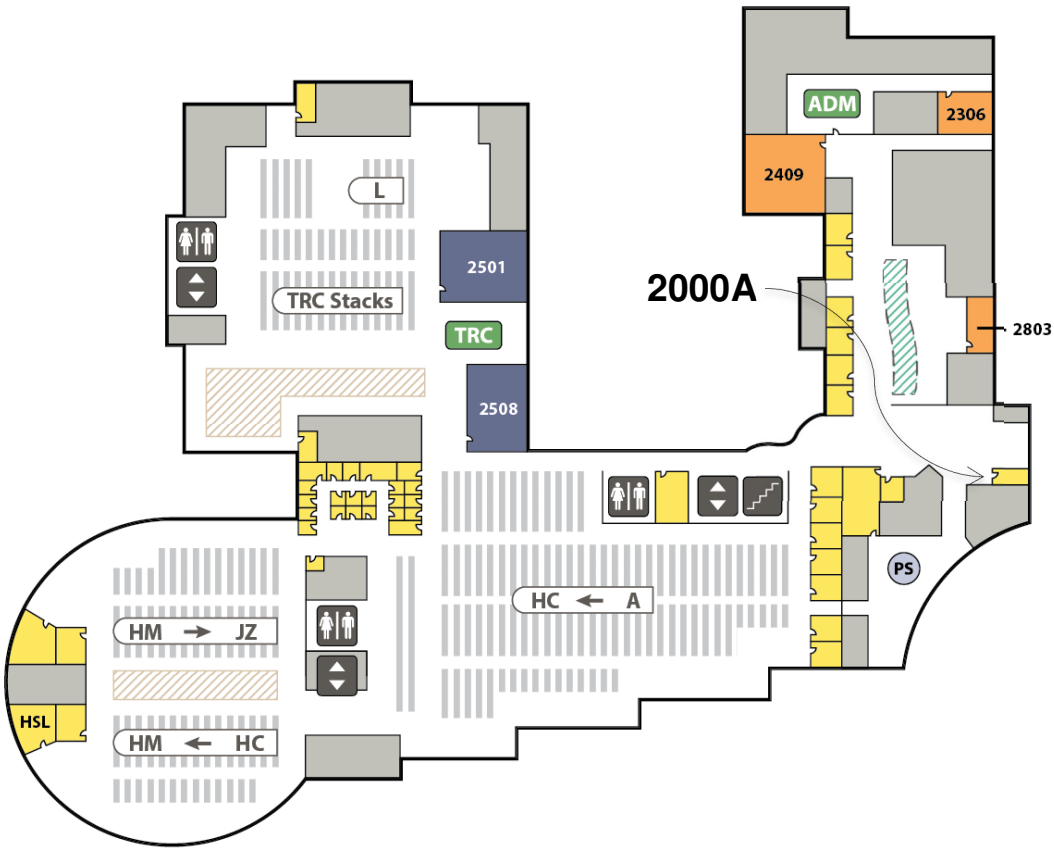


Figure 2. Library's Second Floor Plan.

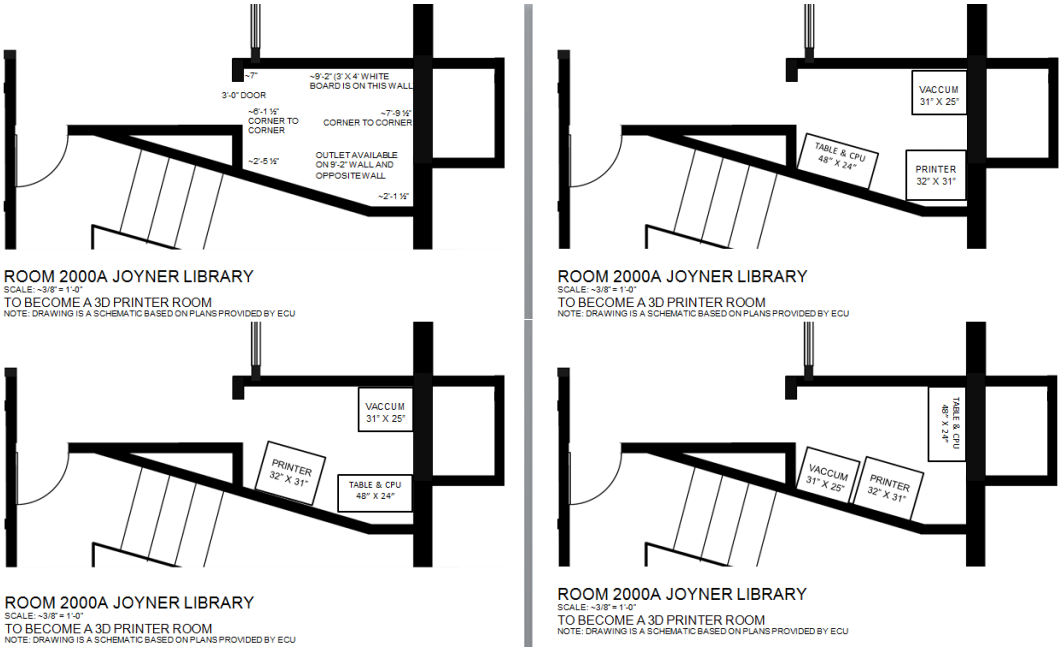
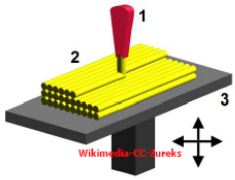


Figure 3. Room 2000A Floor Plan Options.

With the aid of an internal listserv, an initial announcement was made of the event offering—see Figure 4. Two subsequent reminders were sent to ensure sufficient notification and an adequate pool of participants. The announcement and subsequent follow-ups yielded eight viable participants: a Technology Support Analyst, School of Medicine; an undergraduate student



3D Printing Workshop

Department of Technology Systems

College of Engineering and Technology

GOAL

The purpose of this workshop is to introduce up to 8-10 selected administrators, staff, and faculty members to additive manufacturing—aka 3D printing. Upon completion of the workshop, the participants will be knowledgeable and skilled in the fundamentals of 3D printing and will be able to advocate on behalf of this innovation technology and production tool. The workshop will include training with the aid of resources housed in the College of Engineering and Technology. The goal of the workshop is to begin developing a pool of 3D printing advocates who are also economic development and regional transformation advocates; and for taking 3D printing from a consumer-friendly mini 3D printing hobby to the ability to print food as an example and to innovate.

WORKSHOP DESCRIPTION/STEPS

- **Step 1: Hands on demo of a 3D Printer-3 Hour**
  The participants will be introduced to 3D printing technology including the hardware and how it works. The presentation will cover 3D printing basics and a demo of part production.
- **Step 2: Print Prototypes-3 Hours**
  Once the participants become familiar with the 3D printer, they will print a simple prototype under the supervision of the workshop sponsors. They will be allowed to select any part from a vast library of parts/models to print.
- **Step 3: Create Prototypes-6 Hours**
  At this stage, the participants will independently design and create a part/model. The participants will be walked through basics of how to create simple geometry on a 3D Printer.

Want to Participate?

If you are interested in participating in this workshop, email the workshop hosts at agarwalar@ecu.edu AND chinr@ecu.edu by the close business, local, **Wed Jun 11, 2014**. Please provide the following in the email:

- Statement of your interest.
- Statement of how you and your unit will benefit from this workshop.
- Statement on how the knowledge and skills gained will be used.
- Describe your time constraints during the workshop period. That is, will you be unable to attend and participate in all the sessions?
- Your unit and your contact information.
- An endorsement from your supervisor. This may be in the form of a separate email message.

If the list of participants exceeds the seat limits, the applicants will be waitlisted.

Hosts
Mr. Ranjeet Agarwala
Dr. Robert Chin

Science and Technology Building
Room 141
Greenville, NC-27858
Phone: (252) 328-9642
E-mail:agarwalar@ecu.edu
chinr@ecu.edu

Workshop Schedule

Date	Time	Activity
Jun 30	10:00AM -11:30AM 2:00PM-3:30PM	Step 1
Jul 1	10:00AM -11:30AM 2:00PM-3:30PM	Step 2
Jul 2	9:00AM -12:00 PM 1:30 PM-4:30PM	Step 3
Jul 3	10:00AM -11:30AM	Reserve

Figure 4. Announcement for the Three-Day 3D Printing Training Event.

working with a faculty member, Surgical Oncology Department; a retired associate dean, who is still engaged and active in a part-time capacity, College of Business; a faculty member, Technology Systems Department; a Technology Transfer Fellow, Office of Technology Transfer;

a faculty member, Department of Engineering; a faculty member, institution's library; and a Tech Support Specialist, institution's library. Due to a situation beyond their control, one participant had to withdraw from the event before it began.

Shortly before the start of the event, a poll was administered to gage the participants' awareness of 3D printing and to begin developing a 3D printing state of mind—see Appendix A. The participants generally had mixed experiences coming into the event. That experience ranged from possessing a little experience with 3D printing to possessing no experience at all.

An outline of the event and the event's schedule was provided the participates—see Figure 5.

Day 1	
Morning Session: 10:00 AM-11:30 PM	• Introduction to 3D Printing • Introduction to the hardware and interface for 3D Printing • Demo of 3D Printing Machines: Z Corporation Colored Powdered based machine and Stratasys Plastic Based Dimension Machine • Observe the process of printing the parts on the 3D Printer • Group Discussion
Afternoon Session: 2:00 PM-3:30 PM	• Hand-on engagement with the 3D Printer • Post processing of parts created during the demo in the morning session • Preselecting parts to be printed on July 1st • Group Discussion
Day 2	
Morning Session: 10:00 AM-11:30 PM	• Individuals import parts into the 3D Printing software • Check and Scrutinize Parts to be printed • Fix errors/prep parts to be printed in the 3D Printer • Check the hardware and material levels • Print the parts
Afternoon Session: 2:00 PM-3:30 PM	• Post processing of parts created in the morning session • Apply polymer and strengthen the parts printed • Lecture on what is an .STL File. • Lecture on Advanced Applications of 3D Printer
Day 3	
Morning Session: 9:00 AM-12:00 PM	• Create simple parts using Autodesk Inventor/Google Sketch-up • Convert part files to .STL files • Prep parts to be printed in the 3D Printer • Check the hardware and material levels • Print the parts
Afternoon Session: 1:30 PM-4:30 PM	• Post processing of parts created in the morning session • Apply polymer and strengthen the parts printed • Media invited to conduct a press release-Ms. Turner • Display of parts produced. • Exit Survey Conducted

Figure 5. Event Outline and Schedule

Key to the success of this event was participant engagement. The participants were first introduced to the additive manufacturing resources, capabilities, capacities, and products that could be produced. They were then introduced to several processes underway, including the one with which they would be engaged during the balance of the event. The introduction also included supervised processing and post-processing. Once a level of participant hands-on confidence with 3D printing was achieved, they were provided the opportunity to process canned products, which they could have personalized, and then 3D print designs they developed.

During the end of the last session of the event, the participants were administered a post-event poll to gage their satisfaction with the event and to ascertain their plans for the use of the knowledge and skills gained from the event—see Appendix B. Generally speaking, all the participants were very satisfied with their event experiences. The descriptive statistics that characterize the participants' level of satisfaction with the event appear in Table 1.

Table 1. Level of Satisfaction with the Event.

Characterization	Level of Satisfaction[1]
Overall quality of the workshop	4.0
Overall effectiveness of the instruction	3.6
Usefulness of the workshop's subject matter to you	3.9
Presentation of the subject matter	3.4
Achievement of **your** goals for taking the workshop	4.0
The workshop announcement	3.7
Extent to which the announcement described the workshop	4.0
The workshop application process	3.7

[1]Scale: Very Satisfied, 4; Satisfied, 3; Dissatisfied, 2; Very Dissatisfied, 1.

As well, all the participants appear to have plans for their new found 3D printing knowledge and skills and have a sense for how to measure the application of their new found knowledge and skills. One participant noted that they "will download Inventor and Google SketchUp and attempt to replicate the drawings I have done and a few more". In their measure of success, they noted that "if I can take the drawings to the library eventually and print one or more with some changes".

Another participant indicated that "over the next 45 days I will encourage our inventors to explore 3D printing as a viable option for prototyping. I will also explore 3D printing as a potential business idea I have been working on". In their measure of success, they noted that "if I can direct inventors or students to explore 3D printing at ECU I believe my time at the workshop will be a success".

Conclusions

Additive manufacturing/3D printing is a technological leap from the current approaches to the production of selected goods. It offers a more efficient means for forming materials into very complex shapes and, as a result, complex products that are anticipated to meet the demands of consumers. Improving accessibility to additive manufacturing by marketing the various dimensions of 3D printing will help stimulate economic development, regional transformation, and domestic competitiveness. Not only will it provide an additional impetus to the various manufacturing sectors, but it will provide an additional impetus, as V3.co.uk (2013) has pointed out, for cultivating and advancing manufacturing in developing countries; healthcare, particularly surgery; medicine; warfare; transportation; advertising and marketing; home 3D printing; open-source 3D printing; personalized gifts; and in the production of food.

One of the keys with respect to advocating on behalf of additive manufacturing is engaging administrators, faculty, staff, and students with the aid of 3D printing. The authors' 3D printing event, a means to an end, was a success. According to the participants, the event delivered what it purported it would deliver: knowledge and skills in the fundamentals of 3D printing and participants who will be able to advocate on behalf of additive manufacturing. Moreover, the participants look forward to accessing their library's 3D printing capabilities. Over time, the authors will determine whether they were successful in the development of a pool of 3D printing advocates who are also economic development, regional transformation, and domestic competitiveness advocates.

Recommendations

One of questions most frequently posed during the course of the 3D printing event dealt with the cost of producing products. In anticipation that the authors will be sought out for answers on the cost of 3D printed products, the authors will prepare a formal statement of costs associated with the current capabilities/technologies at their disposal and complete costs projections.

Follow-ups should be completed on the participants to ascertain their level continued engagement with additive manufacturing, what their actions yielded, and what additional actions will be pursued. This should include the tabulation of their original vision and plans for the newly acquired knowledge and skills, what actually materialized, and what additional initiatives were undertaken or are to be undertaken by the participants. Optimistically the additional actions will include the use of additive manufacturing as an engine to help facilitate economic development, regional transformation, and domestic competitiveness.

References

3D Systems. (2005). Z Corporation raises 3D printing quality and affordability standard with ZPrinter 310 Plus. Retrieved from http://www.3dsystems.com/press-releases/z-corporation-raises-3d-printing

Cerejo, L. (2010). Design Better And Faster With Rapid Prototyping. *Smashing Magazine*. Retrieved from http://www.smashingmagazine.com/2010/06/16/design-better-faster-with-rapid-prototyping/

Transparency Market Research. (2013). 3D Printing in Medical Applications Market (Medical Implants (Dental, Orthopedic, Cranio-maxillofacial), Surgical Guides, Surgical Instruments, Bio-engineered Products) - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013 - 2019. Retrieved from http://www.transparencymarketresearch.com/3d-Printing-medical-applications.html

Kensinger, L. (2014). Deputy Secretary Newhouse discusses economic impacts of 3D printing and additive manufacturing at expo. Retrieved from http://www.newpa.com/newsroom/deputy-secretary-newhouse-discusses-economic-impacts-3d-printing-and-additive-manufacturing-expo

Rotman, D. (2013). The difference between makers and manufacturers. *MIT Technology Review*. Retrieved from http://www.technologyreview.com/review/508821/the-difference-between-makers-and-manufacturers/

V3.co.uk. (2013). Top 10 world-changing 3D printing innovations. Retrieved from http://www.v3.co.uk/v3-uk/news/2282813/top-10-worldchanging-3d-printing-innovations

White House. (2013). President Barack Obama's state of the union address—As prepared for delievery. Retrieved from http://www.whitehouse.gov/the-press-office/2013/02/12/president-barack-obamas-state-union-address

Wohlers, T & Caffrey, T. (2013). Additive manufacturing: Going mainstream. Retrieved from https://www1.eere.energy.gov/manufacturing/pdfs/sme_man_engineering.pdf

Acknowledgements

The authors wish to express their appreciation for the encouragement and financial support provided by their department chair and college dean. The work completed thus far is a reality because of them. The authors would be remiss if they did not acknowledge the contributions made by their many students. Their patience with us has resulted in the more extensive deployment of additive manufacturing and its use by local businesses and industry. Finally, the 3D printing event would not have been possible without the knowledge, skills, and support of Mr. Andrew Wilson.

Appendix A—Event Poll

3D Printing (aka Additive Manufacturing) Workshop Poll **Your Name:** _____

Please print this poll and respond to the following items in preparation for our 3D Printing Workshop, **AND** bring it with you to the workshop. Out of respect for your time, there is no need to conduct research to respond. As a matter of fact, we'd prefer you'd just respond/write based on your current understanding of 3D printing: this isn't necessarily a "correct answers" exam.

Directions: Indicate whether the following statements regarding 3D printing are generally true (T) or false (F) by circling T or F respectively:

Is a low-labor content, "pushbutton" technology.	T	F
Is fast.	T	F
Is greener than conventional manufacturing.	T	F
Can produce anything.	T	F
Is just as efficient to build one part at a time as it is to build many.	T	F
Is inexpensive.	T	F
Will replace conventional manufacturing.	T	F
Can print guns.	T	F
Every household will own a 3D printer.	T	F

Directions: Provide a written response to the following items. Try and limit your response to the spaces provided.

On a one to four scale, what you've learned and know about 3D printing is a result of (circle one):

Reading primarily what catches your eye or what comes across your desk. 1 2 3 4 Actively seeking out new knowledge on the various dimensions of 3D printing and, as an as an example, follow-ups on claims made about 3D printing.

Comments on your knowledge and what you've learned about 3D printing:

Generally speaking 3D printed products are produced from what material(s):

Generally speaking, and in USD (US Dollars), the cost of 3D printers only ranges from what to what—do not include operational costs, which includes materials and maintenance:

On the back of this sheet, list the academic disciplines, businesses, industries, etc that would benefit from a working knowledge of 3D printing including an appreciation of the role and value 3D printing.

Appendix B—Post Event Poll

3D Printing Post Workshop Poll **Name (optional)**_____

We make every attempt to improve all that we do. To that end, we'd appreciate it if you would respond to the following items with respect to the 3D Printing Workshop you just completed.

Directions: Rate the following items with respect to the workshop you just completed by checking the respective boxes:

	Very Satisfied	Satisfied	Dissatisfied	Very Dissatisfied	N/A
Overall quality of the workshop	☐	☐	☐	☐	☐
Overall effectiveness of the instruction	☐	☐	☐	☐	☐
Usefulness of the workshop's subject matter to you	☐	☐	☐	☐	☐
Presentation of the subject matter	☐	☐	☐	☐	☐
Achievement of **your** goals for taking the workshop	☐	☐	☐	☐	☐
The workshop announcement	☐	☐	☐	☐	☐
Extent to which the announcement described the workshop	☐	☐	☐	☐	☐
The workshop application process	☐	☐	☐	☐	☐

Please suggest how we can improve upon the aforementioned if you were less than satisfied:

Directions: Respond to the following items with respect to the workshop you just completed—tell us about:

What you liked best about the workshop:

The one thing that could be improved upon or we should change:

The most useful tips, techniques, or skills you're taking away from this workshop:

The actions you will take in the next 45 days (~6 weeks) to apply what you've learned:

How you will measure the success of your actions:

Those at ECU, by name—student(s), staff, or faculty member(s)—who might be interested in or benefit from this workshop:

Any additional comments: