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# Technology Integration Across Additive Manufacturing Domain to Enhance Student Classroom Involvement

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# Technology Integration across Additive Manufacturing Domain to Enhance Student Classroom Involvement


## Abstract

In the current digital age, advanced technologies plays an integral role in defining classrooms where, it takes more than just using modern academic tools in curricula to enhance student's educational experience. The goal of effectively integrating technology in curricula should be geared towards enhancing active student engagement, team participation, and frequent interaction among peers. The challenge of integrating technology in curricula is in identifying how it helps students to be productive along with being cost effective for an unparalleled 24/7 access. In this paper, we discuss how mobile based technology integration was introduced in curricula to explore upon effective ways to design and develop complex geometries and customized shapes to rapidly produce student developed parts using Additive Manufacturing technology. Also, this paper outlines the application of reverse engineering combined with Additive Manufacturing by the students to expand technology application for enhancing their learning environment.



*Keywords: Additive Manufacturing; Technology Integration; SAMR Framework*


## Introduction

Technology integration is usually seen as integrating advanced tools in education aimed at improving student's application and problem solving skills. This implies to a curricular driven application of technology to keep in pace with new and continually evolving tools and trends. This creates a shift in traditional pedagogy techniques where in, students not only have access to basic technology such as use of computers but provides an unparalleled access to new emerging technologies in a given field of interest. Based on an article on Successful Technology Integration, integrating technology to curricula will not only prove effective but also creates a willingness among students to embrace the technology that is continually and rapidly evolving[1].

Towards understanding what successful technology integration is, according to International Society for Technology Integration *"Effective integration of technology is achieved when students are able to select technology tools to help them obtain information in a timely manner, analyze and synthesize the information, and present it professionally. The technology should become an integral part of how the classroom functions -- as accessible as all other classroom tools.*[1]"

Technology when effectively integrated to curricula will facilitate both the students and instructors in [1]:

- Learning new industry standards
- Keeping in pace with current research and technology trends
- Providing opportunities in exploring new application and problem solving domains
- Opening networking opportunities with cohorts around the domain

However, technology acquisition for educational settings is heavily relied upon cost effectiveness and investment by Universities, Schools and Colleges. This creates a boundary for accessibility and thereby limiting students in getting real-time experience on new technologies.
Towards addressing this problem and in providing unrestricted student access for learning, the authors in this paper describe on how the SAMR technology integration framework was used to introduce mobile based technology integration in Additive Manufacturing curricula at industrial Manufacturing and Systems Engineering dept. at University of Texas at El Paso to explore upon effective ways to design and develop complex geometries and customized shapes to rapidly produce student developed parts using Additive Manufacturing technology.

## Additive Manufacturing and Reverse Engineering

Additive Manufacturing (AM), often referred as three dimensional (3D) printing is a manufacturing technique that enables transforming a computer aided design (CAD) into a physical object. The worldwide use of additive manufacturing technology is steadily increasing based on the fact that it allows in creating complex geometries, customized shapes and even functional mechanisms that are not easily achievable with conventional manufacturing techniques[2]. AM technology started out as a way to build fast prototypes; however it is now used to create products in several domains ranging from medical, aerospace, automotive to defense industries.

AM is dependent on 3 dimensional models that are often created with the aid of CAD software. However, a recent technological innovation has made it possible for obtaining the data directly by scanning real life 3D objects. Scanning is usually categorized as Reserve Engineering (RE) process where, a finished product aids in acquiring its corresponding design data. According to Society of Manufacturing Engineers (SME), RE is defined as the process of taking a finished product and reconstructing the design data in a format from which new parts or molds can be produced[3]. This technology aids in exploring many potential application areas one of which is the integration of RE and AM technologies. The most commonly observed use of this approach is in replacement of obsolete parts, extension of original designs for new applications and medical devices such as dentures and prosthetics.

Later sections of this paper outline the use of RE and on how it is combined with AM in Curriculum to enable students in understanding on how cost effective solutions can be integrated in industrial grade technologies along with providing a platform enhanced understanding of effective technology use.

## Substitution, Augmentation, Modification, Redefinition (SAMR) Framework

The SAMR framework developed by Dr. Puentudura[1] is aimed at guiding the process of technology integration in a classroom with an ultimate goal of redefining teaching and learning methodologies. Figure 1 illustrates on how the course curriculum developed for Additive Manufacturing course at XXXXXX reflects upon SAMR framework.

As shown, integrating mobile based scanning technology to additive manufacturing for realizing student project designs with the help of SAMR framework helped in significantly enhancing and transforming the course outlook over the semester. The course enhancement helped in exposing the students to effectively integrate mobile based scanning technology, a reverse engineering approach for identifying and addressing interface challenges.

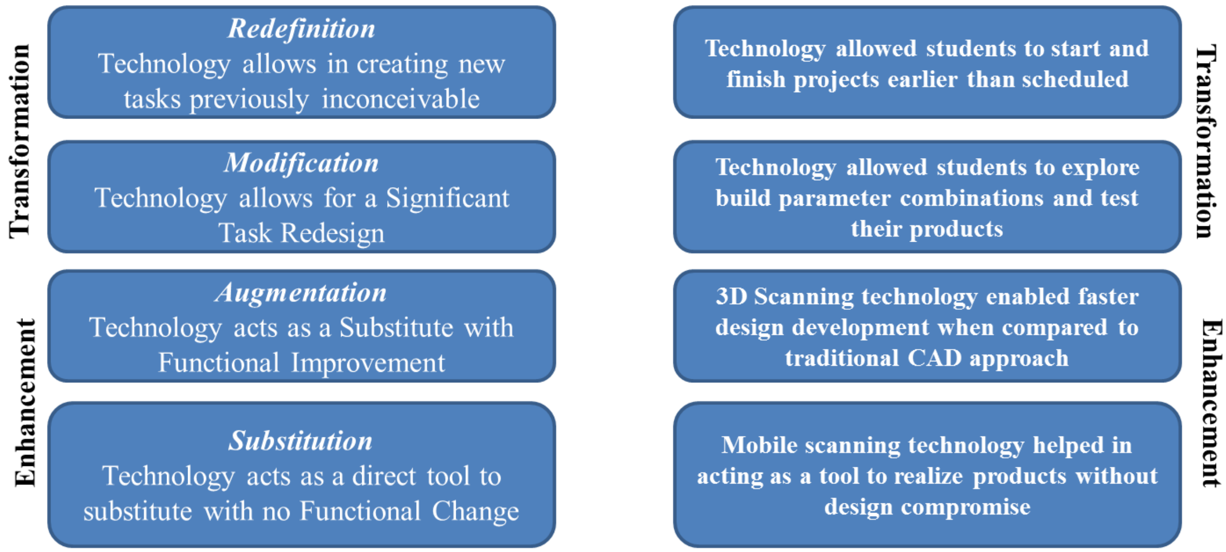


Figure 1: SAMR Framework and its Reflections

Also, transformation of the course by integrating RE and AM technologies helped meeting the curriculum objectives and in enhancing active student engagement, team participation, and frequent interaction. Explained in the paper is example of an in-class student developed project based on integrating RE and AM technologies. Appendix-A illustrates another example of student projects, the third-party tools used and their influence on AM process towards realizing the product.

## Technology Integration Enabled In-Class Student Project

### *Project Aim*

This project is aimed at demonstrating the applicability of an effective mobile based RE tool for Additive Manufacturing towards developing time efficient designs and for exploring different possible interface challenges.

### *Scanning Software*

AutoCAD 123D Catch Software was used for scanning in this project based on its ease of use and high accuracy when compared to others. This software is based on vision system algorithms that facilitate in tracking features of any object based on a series of pictures taken by a simple camera. To obtain 3D representation of an object the software requires the user to take a broad range of pictures from different perspectives of the object covering a 360-degree view around its centroid.

### *Processing*

Once the images have been loaded to the program, the software takes about 15 minutes to obtain a 3D representation of the uploaded pictures. Once processed, the file is viewed as a 3D representation as colored surfaces or meshes.

### *STL File Conversion*

The unwanted objects and meshes scanned while file processing stage are deleted using the software interface. After finalizing on the desired objects, the model is then saved as an .STL file.

### *Editing STL Models using MeshLab*

MeshLab is one of the pioneers in open source mesh edition software developed with the support of the 3D- CoForm project, 2005[4]. This software facilitates in editing STL and other popular 3D triangulation file formats. The key components of MeshLab used for this project are: re-meshing, simplification, filtering, cut and fill-hole tools[5].

#### *Mesh removal and Fill-Hole Tools*

Unwanted features were deleted using the cut selection tool of the software. It was important to remove portions of meshes that would remain a part of the main object to prevent errors. Deleting meshes from the main object usually produces open sections. A special tool was used to detect and automatically fill any open sections as illustrated in figure 2

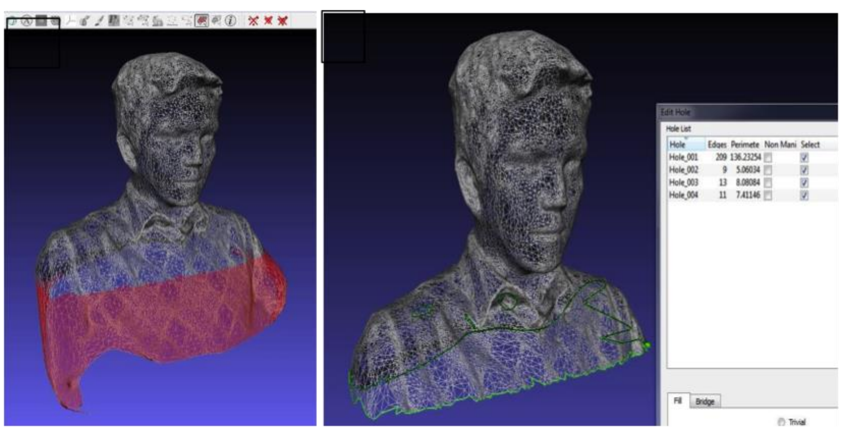

Figure 2: Figure illustrating the use of Mesh Removal and Fill Hole Tools

#### *Filtering*

Environment variables like lighting and moving objects around the 3D body can introduce errors such as unexpected features in the scanned object. To eliminate or lower the presence of noisy features, filter tools are added to the most important areas. In this project a Laplacian Smooth Filter (1 iteration) was preferred among others filters because it produced good surface finish without being aggressive with the important features.

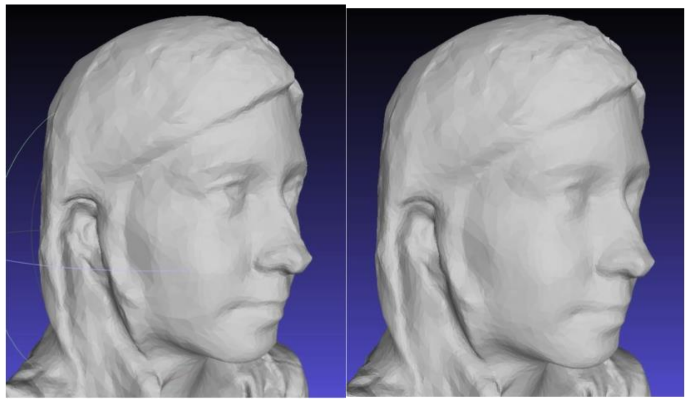

Figure 3: Figure illustrating model before and after use of filter

*Re-Meshing*

A human head has thousands of features that differ from person to person. Representing all those features in an STL file requires a large amount of memory to process the files. As a fact, Solid Works cannot convert STL files to solid if the file has more than 20,000 triangles. To prevent file-processing errors and to accelerate modeling, the amount of triangles defined in the mesh were reduced to less than 20,000[6]. Using MeshLab software, specific and non-important features of the body were re-meshed as illustrated in figure 4.

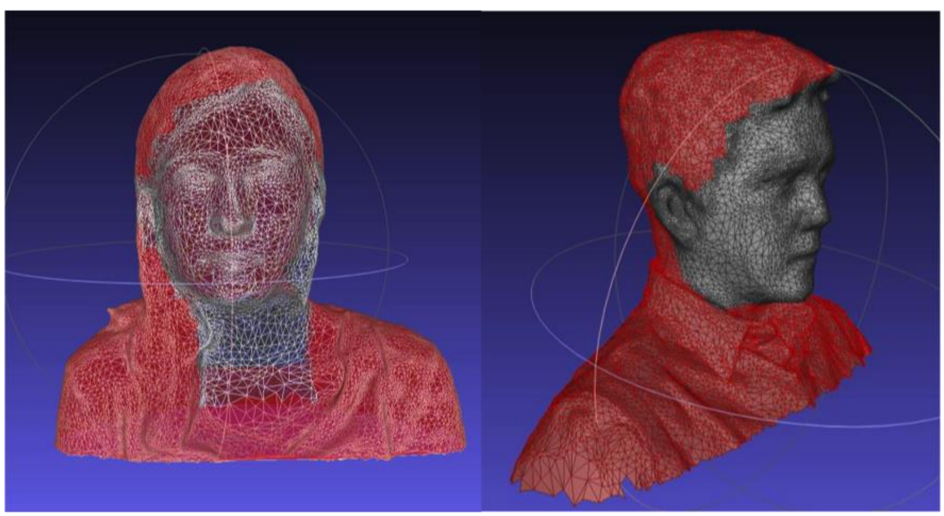

Figure 4: Application of Re-Meshing to Project Models

*Editing Solid Models*

Solid Works Student Edition is used for this project. In order to be able to modify the 3D structures and make an assembly, the simplified STL files were converted to a 3D solid model. The parts were assembled in a single structure and finally the assembly was converted back to .STL format for 3D printing.

***FDM Printing and Final Model***

uPrint® SE Plus 3-D printer manufactured by Stratasys was used for printing student designed models. This printer uses thermoplastics to print models and prototypes with highest accuracy using FDM technology. The building parameters used for printing the model realized in figure 5 is illustrated in Table 1.

Table 1. FDM build parameters comparison.

| Parameters | 1st Build | 2nd Build |
|---|---|---|
| Layer Resolution | 0.0100 | 0.0100 |
| Model Interior | Sparse – low density | High Density |
| Support Fill | SMART | SMART |
| Number of Copies | 1 | 1 |
| STL Units | Millimeters | Millimeters |
| STL Scale | 0.5 | 0.65 |
| Direction | Assembly-bottom facing plate | Assembly-bottom facing plate |

Figure 5: 3D Printed Project Model

## Class Approach Assessment and Feedback

To understand the reception of technology based integration model in the classroom, a survey was distributed to the students for assessing the effectiveness of the methodology. This helped the authors to measure the level of interest among the students before and after the class. The question formulated also helped to identify the topics on which the students were more interested. Students when asked to provide a self-assessment on their understanding of the Additive manufacturing process, a noticeable increase was observed when compared to before and after taking the class (It can be seen in figure 6 that the percentage of students significantly shift from a 'Weak' and a 'Very Weak' understanding to 'Good').

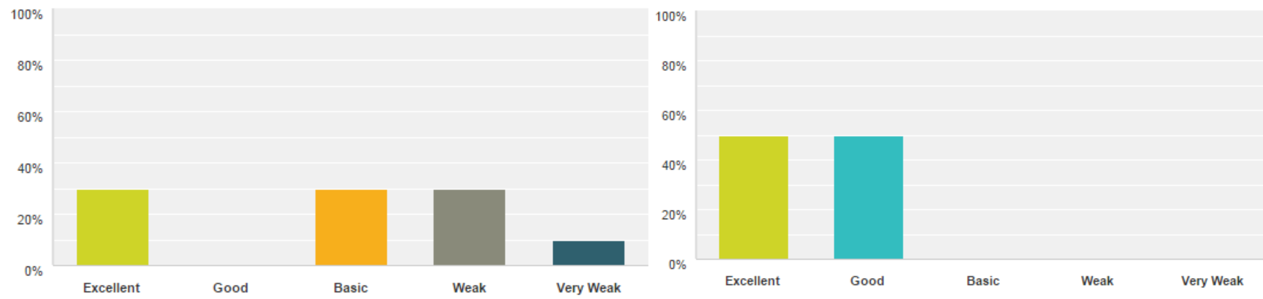

Figure 6: Survey Results on Student understanding of Additive manufacturing process before and after taking the class. *Note: Leftmost Graph illustrates the results before taking the class and the right most illustrates the results after taking the class*

Students when asked if Integrating Technology i.e. the use several third party tools influenced in identifying their class project designs along with enabling them to achieve the class learning objectives, the entire sample of student who responded to the survey agreed.

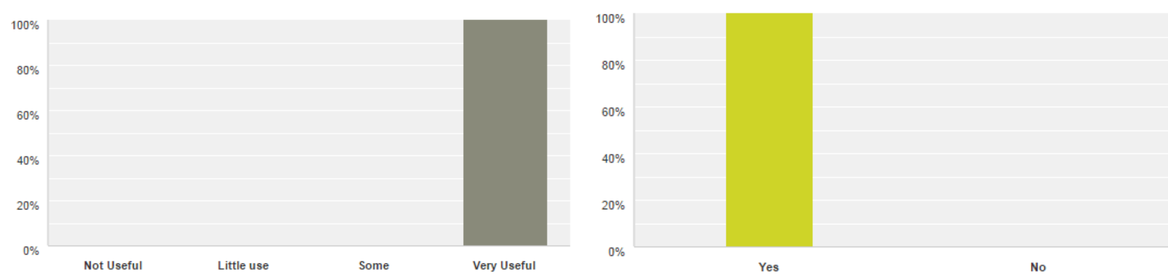

Figure 7: Survey Results on the influence of integrating third party tools on student project designs and class learning objectives. *Note: Leftmost Graph illustrates the results on the influence of technology integration on student project designs and the right most illustrates its influence on achieving class learning objectives*

To further understand the influence of technology integration on the technical aspects of the class projects, students were asked to provide their assessment on if the effective integration helped them to analyze various product build parameters towards finding an optimal combination of printing parameters to build and test their project designs. Results indicate that 80 % of the class was able to explore and identify optimal project build parameters. Illustrated in figure 8 are the results.

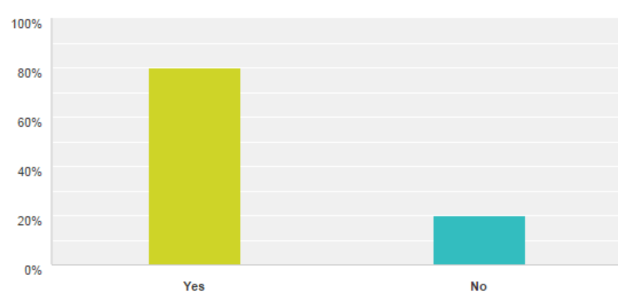

Figure 8: Survey Results on the advantage of effectively integrating third party tools in student projects.

## Conclusion

This paper describes on how technology integration with the help of SAMR framework was used in Additive Manufacturing curriculum at XXXXX to enhance student learning. The class students, to seamlessly develop a CAD model to be printed using additive manufacturing technology utilized a mobile-based 3D scanning application. Effective technology integration to the curriculum helped not only to achieve class-learning objectives but also provided enough time over the semester to the students for exploring and analyzing various build parameters geared for finding an optimal combination of printing parameters to build and test their designs. The effective use and integration of software tools for Scanning, Mesh Removal, Filtering, Re-Meshing and Modeling into the Additive Manufacturing curriculum, students had real time exposure on the use of cutting edge technologies and on how they positively impact product design and development.

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## Appendix -A

<table>
<tr><th>Student Sample Project</th><th>Third Party Tools Used</th></tr>
<tr><td>
<u>Design for additive manufacturing of a prosthetic leg</u>

Figure 1: Final product realized
</td><td>

<ul>
<li>Static Test to determine the realized products functional feasibility</li>
</ul>

Figure 2: ISO 10328 static test setup

<ul>
<li>CAD software to design and assemble prosthetic leg parts</li>
</ul>

Figure 3 : Student Designed prosthetic Leg

<ul>
<li>Finite element analysis tool to identify and test the stress concentration of the foot</li>
</ul>

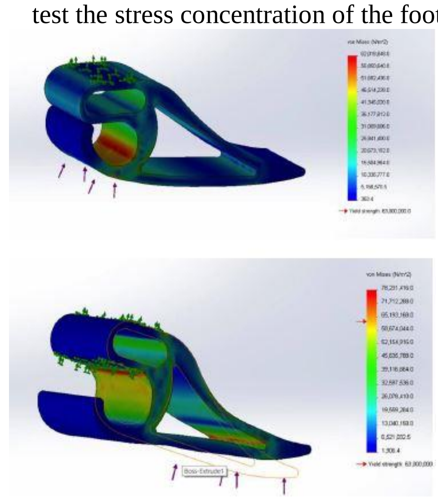

Figure 4: Finite Element Analysis for Static Test
</td></tr>
<tr><td>
<u>Design for additive manufacturing of Complex Geometries</u>

Figure 5: Final Realized Product
</td><td>

<ul>
<li>123D Catch Software for Scanning</li>
<li>MeshLab for: Mesh Removal ; Filtering; and Re-Meshing</li>
<li>Solid Works for Modeling</li>
</ul>
</td></tr>
</table>

| ***Third Party Tools Used*** | ***Influence on Additive Manufacturing process*** |
|---|---|
| AutoCAD 123D Catch Software for Scanning | • Decrease in product design time<br>• Accessibility to students with limited modeling skills<br>• Simplifying 3D printing process |
| MeshLab for<br>• Mesh Removal<br>• Filtering<br>• Re-Meshing | • Open source software that enables in editing of unstructured 3D meshes<br>• Realization of complex geometries<br>• Product pre-processing for editing, cleaning and inspecting complicated models to remove isolated components and fill holes<br>• Saves post processing<br>• Ease of design optimization |
| Solid Works for Modeling | • Creation of model assemblies and converting complex geometries to simplified STL files |
| Finite element analysis | • To understand stress concentrations and possible failure scenarios prior to product realization |