

Advanced Manufacturing Laboratory to Enhance STEM Learning

Dr. Kee M Park, Queensborough Community College

Dr. Park is an Assistant Professor at Queensborough Community College, teaching various mechanical engineering courses including statics, strength of materials, thermodynamics and fluids, and materials laboratory. Dr. Park has extensive industrial experiences, working in design of consumer products, design of power plants and research for U.S Department of Defense. Dr. Park's research interest include STEM education, simulation and modeling, solid mechanics and renewable energy.

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Abstract

This paper presents the design of a new Advanced Manufacturing Laboratory at Queensborough Community College that enhances Science, Technology, Engineering and Mathematics (STEM) learning by focusing on visualization, hands-on approach teaching and research. Outdated traditional machining equipment, such as lathes, drilling, milling, band saw, etc. were replaced with new state-of-the-art equipment, as well as addition of a water-jet cutter and a laser cutting machines. The new prototyping center is equipped with advanced 3D printers capable of using a plethora of thermal plastics and photopolymer resins and enables large foot print parts, and digital scanning systems widely used in industries. In addition to research and learning, the Advanced Manufacturing Laboratory also serves as tools for recruitment of high school students and developing continuing education program as well as retention of students in STEM fields to improve the graduation rates. With such a high potential, students begin to understand and appreciate the extraordinary advantages of pursuing a career in the STEM area. Advanced Manufacturing Laboratory's hands-on research and learning environment fosters students to function effectively in collaborative environments with other disciplines, and provides opportunities to better prepare them to enter the workforce. Providing learning environment that can incorporate high level science and technology curriculums will create the next generation of top scientists and engineers to begin solving many technological challenges facing our future.

Introduction

Manufacturing has been the core of our technology growth and economic indicators as more work forces are needed to move towards economic prosperity. In order to attract more students into manufacturing as well as STEM oriented careers, academic institutions must create new types of learning facilities. Learning tools must be continued to evolve to accommodate tech-savvy students and keep their interests while completing their degrees in STEM majors. The Advanced Manufacturing Laboratory can serve the need to equip students to enter a competitive workforce with high technology skills, adaptability and critical thinking to accelerate in their fields.

A number of higher learning institutes have built undergraduate STEM facilities that incorporate the unique attributes of teaching and research into a single academic center. One such example is a Monmouth College's Center for Science and Business that incorporated multi-disciplinary integration of biology, chemistry, physics, mathematics, computer science, psychology, political economy, commerce, and accounting^[1]. All the disciplines are located in one central building that promotes innovative research, collaboration of departments, and the integration of the business and science curriculums. Harvard University also has a similar teaching laboratory that accommodates interdisciplinary program such as chemistry, biology, machine shop and prototyping center which provides large workable area per student^[2]. Harvard University's

learning lab suite imitated other advanced research facilities such as Syracuse University's Biomaterials Institute (SBI), which accommodates research focused primarily in Biomaterials. SBI is a multidisciplinary center with a number of distinct adjacent lab facilities for polymer synthesis, biology for tissue culture and molecular biology, and engineering for materials characterization. SBI is conducting research in the areas of new technologies for joint replacement and soft tissue repair, fundamental research into the interactions between biological matter and nonliving materials, as well as studies of cell behavior to better understand the progression of diseases such as cancer or asthma^[3]. The Santa Clara University (SCU) School of Engineering's Frugal Innovation Hub laboratory has enabled students to create real-world problem solving skills based on core beliefs such as human centric design, affordability, simple design and ruggedness. Students work with common goals such as working to benefit social oriented organization, to form a group made up of not only their SCU classmates, but organizers from across the world to collaborate their research and projects^[4].

The Queensborough Community College's Advanced Manufacturing Laboratory houses additive and subtractive manufacturing technologies to provide students and faculty with comprehensive fabrication and training capabilities, as well as hands-on learning. The subtractive capabilities (see Figure 1) include manual and CNC turning, milling and drilling machines. The additive capabilities (see Figure 2) are centered on 3D Printing machines that use advanced plastic materials such as thermoplastic and photopolymer.

Typical projects range from patient specific anatomical printing to lost-wax investment casting. The lab is capable of 3D printing across multiple systems using following materials; PLA, ABS, ASA, nylon, polycarbonate, ULTEM 9085 & 1010, wax, all PolyJet materials except MED610 & SUP707.

Other Lab capacities include:

- Metrology and 3D-Scanning/Reverse Engineering using the Ziess Contura, FARO Arm & FARO Focus XD.
- Laser Materials Processing using the Universal System XLS Fiber/CO2 Laser System
- Vacuum Forming using the Formech 508FS Vacuum Former.
- Circuit Board Manufacturing using the LPKF ProtoMat S103

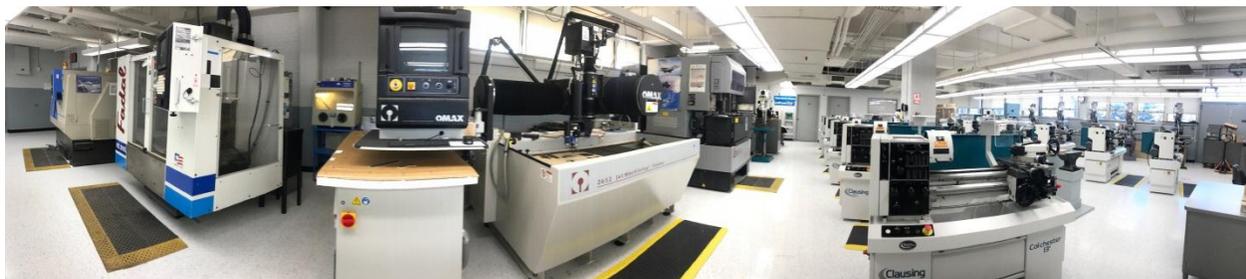


Figure 1: Advanced Manufacturing Subtractive Center



Figure 2: Advanced Manufacturing Additive Center

Laboratory Design

The Advanced Manufacturing Laboratory is housed in two old existing laboratory facilities by renovating the space to fit the new equipment and a classroom. The initial design of Advanced Manufacturing Laboratory was given to the mechanical engineering technology and architectural students who have experience using SolidWorks and AutoCAD software to best place the new equipment in order to optimize the existing floor space. The students first obtained the overall dimensions of equipment, created the 3D model of the equipment and then placed each equipment into the given space. Figure 3 shows the initial design of the Advanced Manufacturing Laboratory using SolidWorks software. Once all the equipment and the class room space have been optimized, the final floor plan has been issued for renovation of the new laboratory (see Figure 4). The laboratory has three sections:

- **Subtractive Center:** The 12 Lathes, 3 Drill Presses 5 Mills and a plethora of manual equipment afford students hands-on exposure to machining best practices. The OMAX Water-jet, Laser Cutter/Engraver, CNC Lathe, CNC Mill and Wire EDM expose students to computer based manufacturing.
- **Additive Center:** The lab is capable of 3D printing across multiple systems in the following materials; PLA, ABS, ASA, nylon, polycarbonate, ULTEM 9085 & 1010, wax, all PolyJet materials except MED610 & SUP707.
- **Computerized Classroom:** This classroom is capable of accommodating 24 students with 24 PC workstations with 6 MakerBot wireless 3D printers enabling students to quickly 3D print their design within the classroom environment.

The proximity of the lab, classroom and the office will promote visual connection and ease of integration. The glass partitions between additive and subtractive centers give students and faculty open space environment and encourage students to participate. The Advanced Manufacturing Center also displays sample parts (see Figure 5) and ongoing projects (see Figure 6 & Figure 7) to foster a learning culture amongst students as well as support cross-discipline engagements. For example, students from mechanical and electrical engineering technology and physics departments have collaborated on their work to create an electric go-kart project (see Figure 7).

In order not to disrupt the classroom schedules, the renovation took place during the summer of 2016. The Advanced Manufacturing Laboratory was fully functional by fall of 2016, enabling faculty and students to fully utilize state-of-the art equipment for research and learning. In the

winter of 2016, students inspired by the Advanced Manufacturing Laboratory presented their research at the Undergraduate Research Day conference, which demonstrated a showcase of Queensborough's faculty-led undergraduate research efforts across the STEM disciplines. Among the highlights of the symposium were the presentations from the department of Engineering Technology on state-of-the-art applications for the new 3D printers. The engineering students demonstrated how 3D printing is being incorporated into mainstream fabrication to alter the future of manufacturing technology. The science students proposed how to better understand the human body by 3D printing biomedical models of internal organs, tissue and bones.

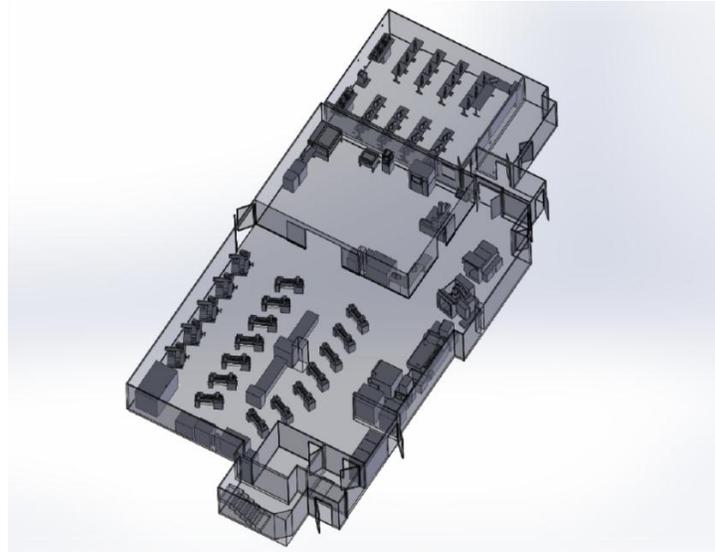


Figure 3: SolidWorks 3D rendering of the Advanced Manufacturing Laboratory

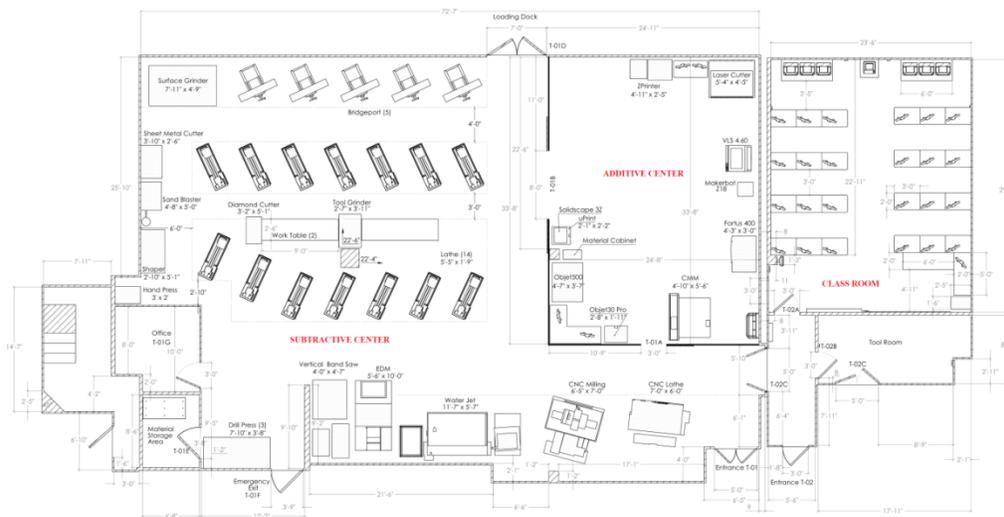


Figure 4: Floor plan of the Advanced Manufacturing Laboratory



Figure 5: Various design printed in 3D printer



Figure 6: Human arms and lung printed in Stratsys J750 3D printer



Figure 7: Electric go-kart with 3D printed body parts

Conclusions

Universities and colleges are beginning to recognize that laboratory facilities which enhances hands-on approach learning and research improves not only test scores, problem-solving skills and learning outcomes of the students, but that it increases attraction to and retention of students in the STEM fields. Several institutes of higher learning have built laboratory-based learning facilities that fosters and accommodates for multiple disciplines collaborations across a single facility. Queensborough Community College has recognized that providing cutting-edge technology facility to both faculty and students can improve teaching, learning and research collaboration between departments within college or other institute of higher learning. The goals of Advanced Manufacturing Laboratory is to improve graduation rates and increase the number of students joining the workforce through industry sponsored projects or internships. The laboratory also encourages cooperation, collaborations and endorsements among the City University of New York's Senior and Community Colleges, other nearby colleges and or universities, as well as corporations and research institutions. The laboratory provides strategic partnerships in order to eventually increase academic, research and economic benefits in urban areas.

The Advanced Manufacturing Laboratory can result in following student learning outcomes:

- Learning and understanding of additive and subtractive tools and technologies
- Utilize industry standard equipment in the analysis of mechanical systems comprised of structural or mechanical elements.

- Apply technical knowledge of manufacturing processes to the fabrication of mechanical parts.

The students whom have used the facility were able to accomplish these outcomes by demonstrating their abilities to understand the difference between the machining and 3D printing, based on different types of materials and complexity of their designs. The students in other discipline, such as biology, have shown interest in conducting research using Stratasys J750 3D printer to create internal human organs.

The outcome of such learning experiences from utilizing capabilities provided by the Advanced Manufacturing Laboratory can be expanded to hands on research and design approach, and collaboration with industry to enable students to conduct undergraduate research projects to enhance their learning experiences and career in STEM fields.

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