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Development of Multifunctional Educational Spaces

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Development of Multifunctional Educational Spaces

Abstract

This paper focuses on multifunctional educational space development for engineering programs, especially for mechanical and manufacturing engineering. The author has been designing and developing new instructional spaces in his school for the last ten years. Most of these spaces originally was aimed for a single function, laboratory or classroom. Due to limitations in space and growing research needs, this engineering program requires development of multipurpose learning and research spaces. Recent efforts included design and development of facilities in limited square footage for a combination of physical laboratories, teaching and computing spaces, in varying areas ranging from 3D Printing and Additive Manufacturing to Engineering Mechanics. Additional laboratory design activities have also been carried out for creative and innovative design spaces including some for integrated capstone and cross-disciplinary projects, along with off-campus development. This paper will summarize educational learning and research facility development trends in academia including selection of educational equipment, digital tools, flexible furniture, and utilization of white board paint or magnetic boards. Safety and environmental issues are covered. The trends in K-12 education and their applicability to college level efforts are also included within the scope of this paper, together with multiple design and development cases and their impact on the capabilities of programs. The development cases will also encompass reconfiguration of laboratories through lean principles and reuse purposes. The paper will be concluded with an assessment component and future work.

Introduction

The literature has shown a good number of projects focusing on improving educational facilities by making them more flexible. In a 1996 ASEE paper[1], Chandrupatla and colleagues presented an early example of flexible laboratory modules project that will allow for future modifications then, at the Rowan College. The proposed engineering programs at Rowan were envisioned to be hands-on, team oriented, and also relied heavily on laboratory spaces. These multifunctional laboratory spaces were designed for clinical projects, multiple different disciplines, teaching/research, and those accommodating multiple course instruction. In a 2009, ASEE paper[2], Strife presented improvements in the West Virginia University's Evansdale Library based on feedback from their users. Additional collaborative areas were added for students and faculty, and a multipurpose area was designed to provide 24/7 access all the time. In a 2012 ASEE Paper[3], MacNamara talked about adding engineering structural study ability to an architectural studio making it multifunctional. The project was to give a better understanding to architecture students as they choose structural materials for their designs, they learned about the scale of the structural members and the spaces those materials support. In one of the computing related examples in a 2010 ASEE paper [4], Spencer and Jaksic described their work on developing an innovative flexible multipurpose laboratory environment for a Computer Information Systems (CIS) curriculum. The environment enabled multi-booting and virtual computing.

The Learning Space Design[5] has a greater place in K-12 education because it may be less costly or easier to accomplish modern and interactive spaces with multiple purposes. Adding Epic LEGO walls for students to build things on as they collaborate or using whiteboard paint on the walls may be a couple of good ways to add to the functionality of the rooms. Maker movement is also imperative and exciting, but often falls short in terms of its tools. Utilizing a 3D Printer along with a few PCs loaded with CAD/CAM software rather than using basic arts and crafts tools may go a longer way for adding more purposes to the educational spaces.

Development of Multifunctional 3D Printing and Additive Manufacturing Educational Space

Robert Morris University (RMU) Engineering Department has been enjoying a strong partnership with Energy Innovation Center (EIC) and its education arm located in downtown Pittsburgh. Three 18 credit new certificates were developed during the collaboration, two of which are in manufacturing engineering (undergraduate) and advanced (additive) manufacturing (graduate) while the remaining one is in energy engineering. After getting permission from the Middle States Association of Colleges and Schools through the Substantive Change for Additional Location Request, a multifunctional 1440 square foot educational space was designated to the department by the Innovation Center. The project is supported by a grant worth more than $400K and additional grants are considered to improve the physical facility and expand the square footage.

The educational space is designed to serve simultaneously as a classroom and a physical and computing laboratory as illustrated in Figure 1. This laboratory is modeled after the multifunctional educational space in the Department's main campus location serving since 2014.

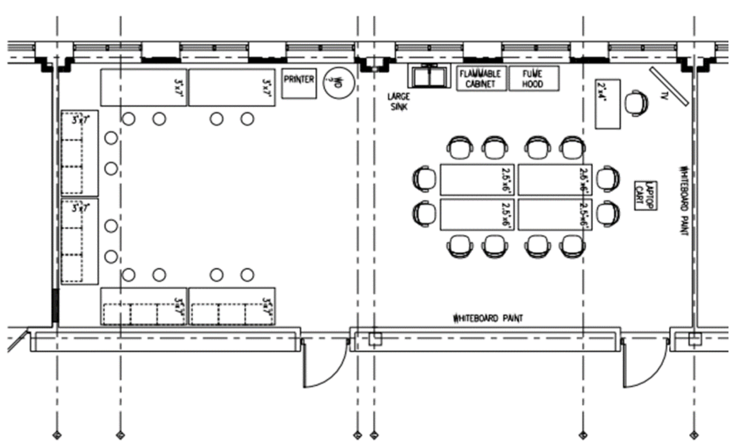

Figure 1. Furniture layout of the 3D Printing and Additive Manufacturing educational space at the Energy Innovation Center

The educational space will be broken into two halves separated by a portable partition. The left side is dedicated to the laboratory workbenches, 3D Printers and their consumables storage, while the right side is the teaching space with foldable furniture including tables/chairs and a few additional physical laboratory needs including an ADA compliant sink, a 4-foot fume hood and a 45 gallon flammables cabinet. The educational space also hosts a laptop cart with multiple laptops. Details of each space are given below.

Educational space is to be used in instruction of the certificate courses, accelerated work-shops and any other form of instruction along with applied research meetings or presentations. It has the following features:

- 60 inch HDTV for presentations with WIFI connectivity
- Magnetic boards covering two of the walls
- Four foldable 2.5 x 6 foot tables and an instructors desk
- Thirteen foldable chairs
- A VoIP phone
- WIFI capability
- A laptop cart with at least 8 laptops for group work

Figure 2. Foldable tables and chairs selected for the educational space allowing space to be converted for standing type of events

Physical laboratory space will be hosting the laboratory style butcher-block top work-benches, high capacity wall, combinations of premium and four drawer pedestal storage shown in Figure 3 along with a waste-drum for sorbent 3D printing waste. The laboratory exercises and some 3D printing related computing work will be conducted in this side of the educational space, along with applied research or engineering projects. It has the following features:

- Six 3 x 8 foot butcher block-work benches with premium and 4 drawer pedestal storage cabinets (Figure 3)
- Twelve 26 inch wall mount cabinets (Figure 3)
- Twelve swivel stools
- A Stratasys F170 printer (an FDM printer)

- A Objet 30 Prime (a Polyjet Printer)
- A Desktop Metal Printer and Its Sintering Oven
- Two Series 1 Pro Type A Machine (a composite FDM printer)
- A MIT Formlabs 2 Machine (an SLA printer)
- 6 PCs, one for each printer
- A waste-drum for sorbent waste collection

The educational space will seat at least 25 persons, with the folding and stowing away of the educational tables and chairs, the room can also handle good number of standing persons. HDTV and magnetic boards attached to two walls will allow effective instruction and discussions to take place. The room will also have at least 14 computers, possibly 18. This will also enable pre-printing work to be conducted along with CAE simulations. In terms of the physical capabilities, the six 3D printers will allow printing with a large number of different materials spanning from simple polymers, epoxy resins, composites, and metals.

Figure 3. Wall-cabinets, butcher-block-top workbenches hosting 3D Printers and their PC located in the main campus laboratories

Application of Lean Manufacturing Principles to Laboratories

According to Scharton-Kersten and Reynolds[6], Lean Principles are critical for industrial manufacturing laboratories with good decisions that include those on design, layout, or the placement of the laboratory, leading to better flow, less waste, visual management, standard work, and excellence in workplace organization. Some of these principles can be applied the educational manufacturing laboratories with more flow. In a 2007 ASEE paper[7], Sreedharan and Liou studied the applicability of Lean Manufacturing Principles for educational laboratories. They implemented lean manufacturing principles to a university rapid manufacturing laboratory. The approach included the use of value stream mapping to identify gaps between the current and future state maps. Lean manufacturing techniques were then used to achieve the future state map.

The authors claim to bridge the gaps between the industrial and academic practices by conducting experiential learning by "Hear, See, and Do" cycles in a modular learning effort. At this department, the administration has been following a similar concept through our Integrated Engineering Design class where student groups are asked to review our shops and laboratories for possible improvements through Lean Manufacturing principles. The results of these work will be compiled soon and presented at the ASEE Conference. In addition, the department had to repurpose our educational spaces for use or reuse in multiple subjects such as Statics and Strength of Materials and Machine Design where we mainly use software programs or bench-top laboratory equipment, allowing quick changes during instructional or laboratory needs.

Assessment

The importance of educational facilities on the quality of the education is clear. Accreditation Board for Engineering and Technology (ABET) states this in their 2016-2017 General Criterion under the Criterion 7 for Facilities as given below. An educational space such as the one for the 3D Printing and Additive Manufacturing is a good example satisfying multiple requirements listed in Criterion 7 with its modern tools and equipment, reconfigurable/flexible space for instruction or discussions, and computing resources:

"Classrooms, offices, laboratories, and associated equipment must be adequate to support attainment of the student outcomes and to provide an atmosphere conducive to learning. Modern tools, equipment, computing resources, and laboratories appropriate to the program must be available, accessible, and systematically maintained and upgraded to enable students to attain the student outcomes and to support program needs. Students must be provided appropriate guidance regarding the use of the tools, equipment, computing resources, and laboratories available to the program. The library services and the computing and information infrastructure must be adequate to support the scholarly and professional activities of the students and faculty." [8]

In addition, the components of the 2016-2017 ABET Criterion 3 for Student Outcomes will greatly impacted by the educational facilities including the outcomes b, c, e, j, and k, as given below[9]:

- (b) an ability to design and conduct experiments, as well as to analyze and interpret data
- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- (e) an ability to identify, formulate, and solve engineering problems
- (j) a knowledge of contemporary issues
- (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Curriculum focused Manufacturing criteria includes five student outcomes [9], 3 of which are given below also impacted greatly by the status of educational facilities similar to the one developed for the Innovation Institute and explained in this case.

- (a) materials and manufacturing processes: ability to design manufacturing processes that result in products that meet specific material and other requirements
- (b) process, assembly and product engineering: ability to design products and the equipment, tooling, and environment necessary for their manufacture
- (e) manufacturing laboratory or facility experience: ability to measure manufacturing process variables and develop technical inferences about the process

Student Projects

This laboratory development project mimicked already in-use RMU Rapid Prototyping Laboratory (shown in Figure 3) and its adjacent classroom. The space was developed in 2014, and has been used for teaching multiple classes/laboratories including the ENGR 4801 Rapid Prototyping and Reverse Engineering course. This course encompasses two projects, one for the rapid prototyping area and the other for the reverse engineering field. Over the years the rapid prototyping projects have been open-ended in nature, but focused on helping handicapped persons improving quality of their life or increasing their chances of employability along with construction toy development type project shown in Figure 4[10]. The reverse engineering projects have been centered on studying existing commercial toys, and recently 3D printers. Figure 5 demonstrates an in-progress Prusa 3D printer build. After studying its design, rather than disassembling an existing printer, students build the printer, but prepare a reverse engineering report that includes black box and glass box models, technical specifications and more.

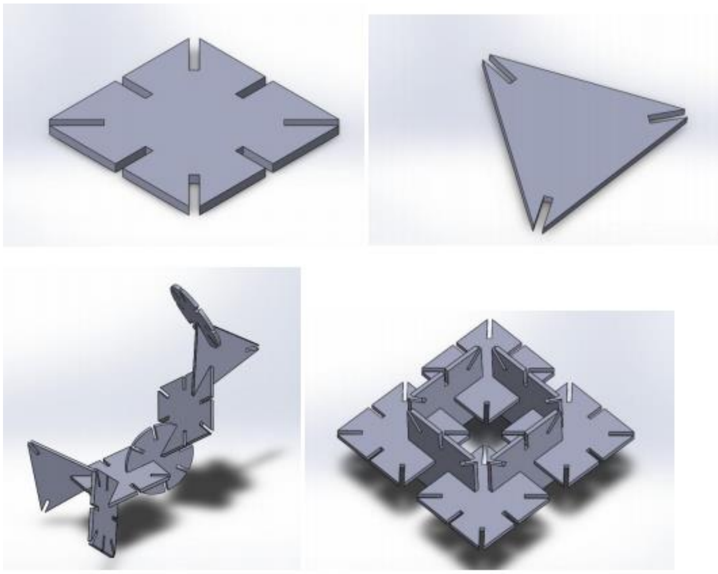

Figure 4. A construction toy concept [10]

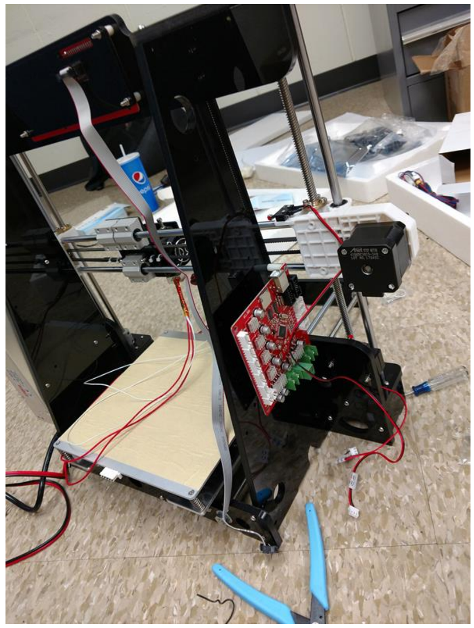

Figure 5. Prusa 3D Printer assembly in-progress

Having a multifunctional educational space allows the instructor to do a variety of activities that complement others. The instructional half of the space is used for lectures and tutorial activities for CAD/CAM/3D printing (ABET student outcome k) since it hosts multiple PCs. Students also use the instructional half for CAD/CAE modeling of their construction toy designs and their analysis including safety and sustainability (ABET student outcome e), assembling of their Prusa 3D printers, or disassembly of their commercial toys. The laboratory side is used for the 3D printing process, for fixed-goal laboratory assignments including the study of STL file generation (based on its type ASCII or binary and their parameters – ABET outcome b) or making the prototypes of the construction toys (Manufacturing student outcome a). Construction toy projects are ideal for introducing social and environmental constraints (ABET Student outcome c) in the context of product development exercises (Manufacturing student outcome b) while handicapped help projects addresses the ABET outcomes of c and j. Student feedback for practically oriented work in multifunctional spaces are usually positive since they have to design and develop a working prototype of a toy or build a 3D printer and optimize it. However, students often request more time for additional hands-on activities making it a very challenging situation where the instructor needs to balance the fundamentals/theory and the practical components.

Conclusions and Future Work

Educational spaces with multiple uses have becoming more common due to growing needs and reduction in resources. The work mentioned in this paper mainly covered developing joint and multipurpose educational spaces for laboratory, capstone project execution, research, and instruction purposes. It also includes questioning applicability of efforts of Lean Manufacturing in continuous improvements of laboratory facilities along with repurposing existing laboratories for teaching a wider range of similar subjects. The impact of these efforts on the quality of the education is clear and well documented by ABET, as shown in the previous sections including student projects. The most important area for educational facilities development will be flexible innovative spaces with design, analysis, and prototyping tools. These spaces can be used in many design and developmental projects, including some in product, tooling, or machine design, capstones, applied engineering and research projects along with K-12 outreach. With the availability of low-cost 3D printers and associated printing materials, converting a room of PCs and furniture into an integrated design and development space has become a reality.

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