Integrating Makerspace in First-Year Engineering Curriculum

Dr. Ashish D Borgaonkar, New Jersey Institute of Technology

Dr. Ashish Borgaonkar works as Asst. Professor of Engineering Education at the New Jersey Institute of Technology's Newark College of Engineering located in Newark, New Jersey. He has taught several engineering courses primarily in the first year engineering, civil engineering, and mechanical engineering departments and won multiple awards for excellence in instruction. He also has worked on several research projects, programs and initiatives to help students bridge the gap between high school and college as well as preparing students for the rigors of mathematics. His research interests include engineering education, excellence in instruction, water and wastewater treatment, civil engineering infrastructure, and transportation engineering.

Dr. Jaskirat Sodhi, New Jersey Institute of Technology

Dr. Jaskirat Sodhi is a University Lecturer in the department of Mechanical and Industrial Engineering at New Jersey Institute of Technology. He is interested in first-year engineering curriculum design and recruitment, retention and success of engineering students. He is the coordinator of ENGR101, an application-oriented engineering math course for students placed in pre-calculus courses. He has also developed and co-teaches the General Engineering Fundamentals of Engineering Design course that includes a wide spectra of activities to teach students the basics of engineering design using a hands-on approach which is also engaging and fun. He is an Institute of Teaching Excellence Fellow and the recipient of NJIT's 2018 Saul K. Fenster Innovation in Engineering Education Award.

Mr. Ludvik Alkhoury, New Jersey Institute of Technology (NJIT)

Mr. Ludvik Alkhoury is a Ph.D. Candidate in the Department of Electrical and Computer Engineering, Newark College of Engineering, New Jersey Institute of Technology (NJIT), Newark, NJ. He is currently the Lab instructor of Fundamentals of Engineering Design (FED) 101, a course that reviews the basic concepts of engineering and introduces some tools used for the design and implementation of devices and systems.

Work-in-Progress: Integrating Makerspace in First-Year Engineering Curriculum

Abstract

Makerspace and similar advanced manufacturing labs are becoming commonplace at engineering colleges and universities throughout the United States. Although these spaces are hugely popular with students and faculty, only a select few students take full advantage of the opportunities available through such spaces. In order to get more students to utilize Makerspace and similar high-tech labs, it is important to introduce them to such spaces as early as possible. New Jersey Institute of Technology (NJIT), a mid-size polytechnic university, recently opened a large Makerspace. Students in select few sections of the first-year fundamentals of engineering design (FED) course participated. The idea was to (1) teach students what Makerspace can offer to them; and (2) have them complete one or two simple 3D printing projects. Project 1 served primarily to get students to complete the required training and to learn about the Makerspace and 3D printing, whereas, Project 2 focused on engaging students in a competition based on the products they have designed and 3D printed. The winners of the competition from each of the participating section were allowed to 3D print a medium-sized object of their choice. This initiative was very successful as evidenced by strong satisfaction reported by the students in a post-activity survey. We have since made it a permanent part of the course.

Introduction

The Makerspace is a facility where engineers, architects, designers, and scientists can create and test design ideas, put theory into practice, and turn ideas into reality. Makerspaces typically house industrial-grade tools and technologies that today's STEM students must master in order to become tomorrow's innovators and leaders. It provides them a venue where they can test ideas, visualize, create prototypes, and apply complex technologies, machines, and materials used in state-of-the-art technology. Through this process, all participants gain real-world experience across an array of industries. Among other functions, the Makerspace offers equipment and devices for 3D printing, additive manufacturing, material cutting and shaping, metrology, visualization, computing, emulation, and simulation.

For the past three semesters, the authors have specifically dedicated a few sessions in their Fundamental of Engineering Design (FED) 101 classes to showcasing the newly built state-of-the-art Makerspace and having students run a few activities in it. The students are made aware of all the tools and technologies that are available to them in this facility and are enabled and inspired to engage in hands-on learning. This would also encourage them to become "repeat-customers" of the Makerspace and thus come back to use it for future academic and personal projects.

Implementation

FED101 at NJIT is a two-credit course that meets for 1.5 hours of lecture and 1.5 hours of lab. The lab component of the class involves teaching students a 3D modeling software for the first 7-8 weeks that concludes with a reverse engineering project in week 10. Since the Makerspace was inaugurated at our university in Spring 2018, the last 3-4 weeks of this lab class were dedicated to doing the following activities in the Makerspace.

Tour of the Facility and Trainings - In order to prepare students to utilize the Makerspace, we offer in-class safety training followed by specialized equipment training in the Makerspace. Although students are specially trained on the specific equipment they will use, they are given tour of the facility and learn about everything the Makerspace has to offer.

Makerspace Design Activity I - For the first Makerspace design exercise, students are tasked to design a keychain that can be used as a promotional item by the university (uses the university name, the logo or the mascot). Students work individually on this exercise. These keychains are 3D printed and once graded, the students get to keep them. Extra credit is given to the most innovative/creative designs. This simple activity enables students to implement the 3D modeling skills learned during the semester to create a design of their own. Once printed, it gives them a sense of accomplishment of holding a physical object that they created from scratch on a computer. It also helps students learn about 3D printing and the slicing software. A few students' samples are shown in Figure 1.

Figure 1. A few creative student-designed keychains

Makerspace Design Activity II - For the second Makerspace design exercise, students are tasked with designing a spinning top with an objective to maximize the spinning time. Students work in groups of 2-3 for this exercise. The tops are constrained to be no more than 2 inches high and 2.5 inches wide. During the last week, a competition is held in each section where each team is given three tries to record their longest spin. Each member of the winning team from each section is allowed to 3D print anything of their liking with a maximum print time of 3 hours for free. The teams are allowed to take inspiration from online designs, but the 3D model that they print should be created by them and not copied from the World Wide Web. Once again, extra credit is given to creative/ innovative designs. The competitive aspect motivates students to

do some research on what makes a top spin and how can they increase its spin time. Figure 2 shows top designs created by student groups from one section. Figure 3 shows a spinning top in action during the competition.

Figure 2. Examples of student-designed spinning tops

Figure 3. A spinning top in action

Discussion

This activity served several learning outcomes including having students work together as a team, being introduced to the product design process, doing online research and applying their problem-solving skills. We assessed the effectiveness of these activities using an online survey at the end of the activities.

Student Participation and Feedback - After the activities were concluded, an online survey was conducted to help better understand the effectiveness of these activities and possible ways to improve them for the next semester. 64 students from Spring and Fall 2018 semesters responded to the survey. Table 1 presents the results.

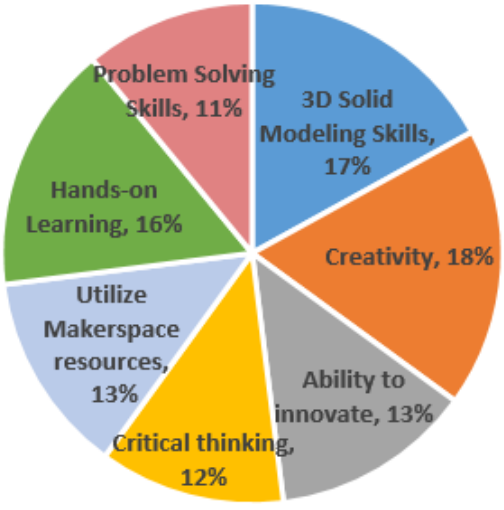

Figure 4. Contribution of this activity for improvement on each aspect based in survey results

Table 1. Average scores on Likert scale (1-5) obtained from students

Q #	QUESTION	AVERAGE RATING (1 – 5)
1.	The 3D Printing Design Activities helped me improve my creativity and ability to innovate.	4.3
2.	The 3D Printing Design Activities helped me gain "hands-on experience" on designing and creating models.	4.3
3.	The 3D Printing Design Activities are a good way to introduce a 3D Modeling software based assignment to first year students.	4.4
4.	I think it's important that students be introduced to the 3D Printing Design Activities early in their academic life in college.	4.5
5.	The 3D Printing Design Activities were a fun and exciting.	4.4

Students were also asked to indicate if these activities helped them improve/learn/explore their understanding and skills. Figure 4 presents their responses in a pie chart. Students were also asked to provide any comments that had about the activity. Some of them are presented below.

General Comments:

- It was a very great way to get students interested in working with 3D modeling software, especially because they get to keep the key-chain and tops they design.
- It was cool to print something I made. I have experience with 3D printing already but it is a great way to teach students about design and 3D printing which is really important in modern engineering.
- What I liked the most of these activities was that how it inspired one to put their knowledge of solid modeling to create a key chain and top. Although it seems simple it can be tricky and serves as good practice to be able to put the design I made in my head and make it physical.
- The spinning top activity was also another great project that motivated students to work more with 3D modeling software, especially because there a competitive aspect to it, which made it more interesting.
- I think every FED class should do these types of exercises. I enjoyed and learned a lot.
- I really enjoyed the projects. It allowed for students to use their creativity to create something fun and simple. It also gave me personally a sense of accomplishment seeing the end product of something I created.
- I loved every detail I made from the slightest flaws to the exact image I was replacing on the computer. It just opened my eyes more on engineering as a whole and it's a very interesting subject. I can't wait to keep exploring and learn new things as the years go by.

- Since the lab portion of the course focusses on 3D modeling and design software, I think it is really important to have the projects be printed out to bring the 3D design into the real world. It makes the design process a lot more exciting and interesting knowing that it will be 3D printed, so the success of the design isn't just for a grade, but to function properly in use.
- Being an entrepreneur is something that always appealed to me. By designing our keychain, we were directly involved in a problem solving environment. We had to create something from scratch, use creativity, and implement the skills which we learned throughout the course. We were our own bosses in this production, something which I believe will help build someone's confidence and ability to create.
- Utilizing the 3D printers within the Makerspace was a good piloting tool in order to see what the engineering program was about at NJIT. I personally enjoyed making creations and seeing them being beyond the realm of a computer screen, and has increased my interest in the program.

Summary

This paper presents the results of a work-in-progress implementation of an idea to integrate the Makerspace into first-year engineering curriculum. So far, we have seen encouraging results, active participation and liking among the student participants as shown in Table 1.

Since this was started a year ago, we plan to conduct future surveys to track whether these students used the Makerspace in the future semesters since the time they were exposed to the facility as part of this FED101 course offering.