

Implementation of 3D Printing Design Project in First Year Mechanical Engineering Course to Aid in Understanding of Engineering Design Process

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Abstract – Three years ago a new project was introduced into the first year mechanical engineering course to help initiate the idea of engineering design early in the engineering curriculum. The overall goal of the project was to design a child’s “shooting toy” that was tasked at launching an object the maximum distance possible. Students were split into groups and given a list of design requirements for their toy, including limits on size, material, etc. Each group then proceeded through engineering design process including conceptual design, prototype fabrication, testing and validation, and final product presentation. The prototype fabrication was done through 3D printing of solid models designed and drawn by the students. The project concluded with a demonstration of the launching capability of their final product and a submission of a design report that encapsulates the process they went through from start to finish. Project evaluations from the most current year were used to measure the students’ attitude toward the project. Evaluations found that the majority felt that the project increased their knowledge of engineering design and agreed that the project was a good way to teach engineering design. Moving forward it is desirable to observe if this knowledge of engineering design is carried forward in future classes throughout the engineering curriculum.

Index Terms – engineering design, 3D printing, CAD

INTRODUCTION

The importance of introducing students to engineering design has been documented by many studies over the past few decades [1-3]. In 1986 a National Congress on Engineering Education report stated: “It is design which distinguishes the engineer from the scientist. It is design which ties us to the marketplace, which gives vent to the creativity of our profession” [4]. However, it has also been observed that the first two years of engineering education are often devoted to the basic sciences, and don’t always contain an element of design [1]. In our department it was noted that when students took a junior level design course they had little knowledge of engineering design. Because of this, it was decided to add an introductory design project to the first quarter of the curriculum. The goal of this project

was to introduce the students to the idea of design and give them a hands-on project that would get them excited about studying engineering. Using 3D printing in the classroom has become a tool for instructors from the elementary to college level in the past few years, and has proven to spark enthusiasm in students learning about STEM fields [5].

COURSE DESCRIPTION

University of Denver has a unique curriculum, in that all three engineering disciplines offered (mechanical, electrical, and computer engineering) take identical courses until the spring quarter of their sophomore year. Because of this, the goal is to introduce all freshman students to each discipline by having them take an introductory course from each department. The first course they take is Introduction to Mechanical Systems with Computer Aided Design (CAD), and is offered by the Mechanical and Materials Engineering Department. This course includes both lecture and lab, and is focused on teaching basic simple machine mechanics, CAD (using SolidWorks), and helping first year students acclimate to a university environment. After noting that the first two years lacked an element of engineering design, the 3D printing project was also added to the course.

The course was also design to support the following Accreditation Board for Engineering and Technology (ABET) outcomes:

- (d) Students will have the ability to function on multidisciplinary teams.
- (e) Students will have the ability to identify and formulate solutions to engineering problems.
- (g) Students will have the ability to communicate effectively.
- (k) Students will have the ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

PROJECT DESCRIPTION

As mentioned above, an engineering design project was added to the course to introduce students to the idea of engineering design. The goal of the project was for students to work in groups to design, build, test, and present a “shooting toy” that was tasked at launching an object the

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maximum distance possible. These objects have changed each year, and have included marbles, poker chips, and ping-pong balls. The toy was to be made with the parts provided to the students (listed below), as well as three to seven parts that the students were to design and manufacture out of ABS plastic using a 3D printer. The students were given the following design restrictions and requirements:

Design Restrictions and Requirements

- All designs will be created in SolidWorks then printed on the rapid prototyping machine.
- Each group will use an engraving designator (within SolidWorks) to engrave their initials onto each part (if the part is large enough).
- Device must be loaded like a toy and have some sort of actuation mechanism.
- Entire device will be a planar device attached to the wood base provided (meaning it must be able to be set on the base on a table without anyone holding it while being launched).
- Each rapid prototyped part can be no less than 3 mm thickness.
- The largest dimension of any part cannot be larger than 20 cm.
- Device must contain a minimum of 3 rapid prototyped parts and no more than 7
- Teams will be limited to 20 cubic centimeters of material total for the rapid prototyped parts.
- **Provided Materials:**
 - One 10 cm x 10 cm wood base
 - 6 pegs /smooth nails
 - 4 elastic bands
 - 1 launching object*
*objects have included poker chips, ping-pong balls, and marbles.

Groups were given a week to brainstorm and come up with three to four conceptual designs. Students developed a design matrix to analyze and rank each of their designs. A final design was then selected based on their analysis, which sometimes included a combination of conceptual designs. Once a final design was selected, the students performed a mathematical analysis of the design. The goal of this was to use the knowledge the students had gained from learning about mechanical analysis of simple machines earlier in the course. The students used this knowledge to optimize a portion of their design, usually focusing on the velocity/acceleration of the payload from the applied force/torque or velocity of launching arm/mechanism.

Once the students had selected and optimized their design, they presented this design and their selection process to the “customer,” i.e. the instructor and teaching assistants (TAs). If the design was approved, the students then began modeling their parts in SolidWorks, which they had also been introduced to earlier in the course. If the design was not approved, the students had a chance to fix their design

and present these changes to their TA a few days later. Once the students completed their 3D modeling, they sent their designs to their TA who checked that the parts met all the design criteria before being sent to the 3D printer.

Upon receiving their 3D printed parts each group was given access to the engineering Machine Shop, where they could build their devices. A testing and validation plan was required from each group. In this plan they needed to demonstrate a methodology for validating that their device worked, as well as testing any modifications made to improve their design.

The project came to completion with a presentation of the finalized device to the instructor. Students were given two chances to launch their device, and the longest distance was measured and scored. A bonus was given to the team who launched their object the farthest. Each group also completed a design report that documented their entire design process, including: conceptual designs, design matrix, final CAD drawings, testing and validation results, and a discussion of their design’s performance and the changes they would make if given the chance.

Final device designs varied greatly, and over 95% of groups successfully shot their object. The greatest challenge for most groups was implementing the actuation mechanism. Examples of finalized projects are shown in Figure 1.

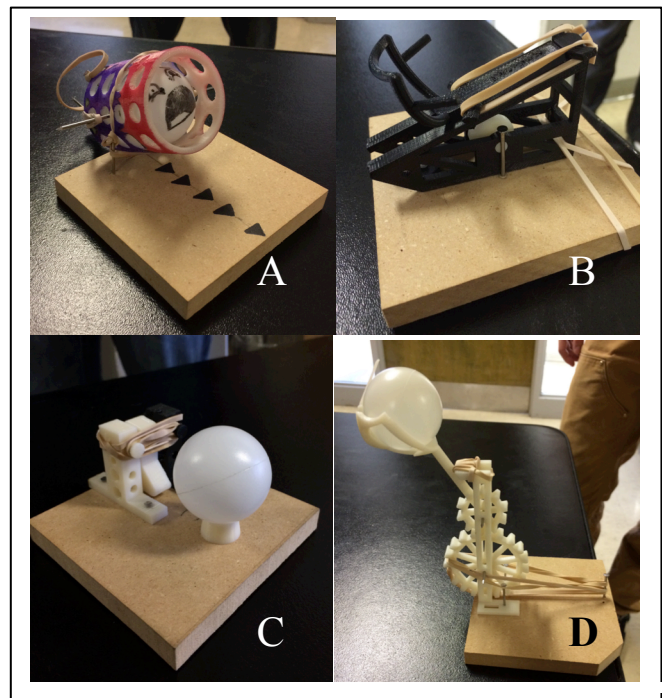


FIGURE 1
FINAL DEVICES FROM FOUR DIFFERENT GROUPS. FOR THIS YEAR THE GROUPS WERE TASKED WITH LAUNCHING A PING-PONG BALL AND THE RESULTS INCLUDED A) A CANNON STYLE SHOOTER B) A SLIDING AND RAMP SYSTEM C) A 'KICKER' WHICH SPUN AROUND AND LAUNCHED THE BALL D) A LAUNCHING DEVICE UTILIZING TWO GEAR WHEELS.

EVALUATION RESULTS

While the project has been used for the past three years, this past year it was decided to give the students a chance to evaluate the project and their attitude toward engineering design. Students were given 10 statements and asked to rank their thoughts toward each statement on a scale:

- 1 – Strongly Agree
- 2 – Somewhat Agree
- 3 – Neutral
- 4 – Somewhat Disagree
- 5 – Strongly Disagree
- 0 – No Opinion

Seventy-two students responded to the evaluation and the results, along with the statements given, are presented in Table 1:

TABLE I
EVALUATION RESPONSE RESULTS

STATEMENT	AVERAGE RESPONSE SCORE
BEFORE THE FINAL PROJECT I KNEW A LOT ABOUT ENGINEERING DESIGN	2.54
BEFORE THE FINAL PROJECT I KNEW NOTHING ABOUT ENGINEERING DESIGN	3.764
AFTER THE FINAL PROJECT MY UNDERSTANDING OF ENGINEERING DESIGN IMPROVED	1.471
THE FINAL PROJECT WAS A GOOD WAY TO TEACH ENGINEERING DESIGN	1.458
I THINK IT IS IMPORTANT THAT STUDENTS BE INTRODUCED TO THE DESIGN PROCESS EARLY IN THEIR TIME AS ENGINEERING STUDENTS	1.389
I FOUND THE FINAL PROJECT TO BE INTERESTING	1.444
I FOUND THE FINAL PROJECT TO BE FUN	1.583
I FOUND THE FINAL PROJECT TO BE BORING	4.403
I FOUND THE FINAL PROJECT TO BE FRUSTRATING	2.986
OVERALL I LIKED THE FINAL PROJECT	1.743

Evaluation responses indicated that the students felt both that the project was a good way to teach engineering design and that their knowledge of engineering design improved. In general the evaluations also show that the students found the project interesting and fun more often than they found it boring and frustrating.

One interesting outcome from the evaluations was that students felt that before the project they had knowledge of engineering design. This result indicates that some students are being exposed to engineering design concepts prior to entering college as an engineering major. It may be beneficial for our faculty to know what types of information students are learning prior to entering our program in order to develop their previous knowledge, as oppose to starting from scratch.

Along with responding to the statements students were also given the option to respond to a question asking how they would change the project, and give any other final thoughts on the project overall. Most of the comments about changes

were more administrative. For example comments included, “I’d like to pick my own group” or “It would have been nice to have more time.”

The general comments about the project were broad, but gave a sense that the students liked having a project that allowed them to be both hands on and creative. Some example comments included:

- “Being able to pick a design for an optimal device was fun. I liked the specific scenario that was given for this project.”
- “This is a fun project and I really learned a lot. Please continue this in future years.”
- “It was satisfying to hold something that I had designed on the computer.”
- “It (3D printing) is an incredible piece of technology. We’re the generation that should be using it and being the most excited and familiar with it.”

CONCLUSION AND FUTURE WORK

Overall students indicated a general enjoyment of the project, and many bring it up in their sophomore assessment interviews as a highlight of their first year. However, an official measurement of how much their knowledge of engineering design changes has yet to take place. Future work with this project includes an effort to measure if the students’ understanding of engineering design is improved when they start their design courses in the junior year.

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