Assessing the Motivational Impact of Including Rapid Prototyping into a Freshman CAD Class

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Abstract

Northern Arizona University's College of Engineering and Natural Sciences is incorporating the use of a rapid prototyping machine into its freshman computer-aided design (CAD) course, ME 180. The authors have created a simple, online instrument using an internet survey tool. The current effort is to collect data from sections of ME 180 which do not have rapid prototyping incorporated into the class offering. This data will then be compared that collected the following semester, using the same instrument. However, the following semester offering will include a module for the students to use the rapid prototyping process to create assemblies from their selected CAD assignments. An exploration and comparison of the data between the two course offerings will be examined. Data collection categories include motivational information to continue in the Engineering major as well as demographic information. The students are also requested to evaluate the CAD course's support for several of the Mechanical Engineering Department's learning objectives. The data collected from the pre-prototyping course is of interest, as it indicates an already moderate motivational influence on student retention.

Introduction

Northern Arizona University has been exploring methods by which to recruit and retain engineering students into their undergraduate program. Two of the Mechnaical Engineering faculty have recently been engaged in modifying a freshman CAD class with these motivations in mind. They are implementing "Rapid Prototyping" (RP) into the ME 180 Freshman CAD class. This paper will document the work in progress on this effort to date.

RP is the process which converts a CAD model into an artifact or product.[1] This process has been used increasingly over the past two decades in engineering firms to produce first-article designs. Advantages of using RP machines over using tradition fabrication methods include reduced scrap, less skilled technician labor required, minimal setup requirements, and of course a more rapid delivery time for prototypes from the initial designs.

Office-oriented RP systems may be defined as those systems which require no infrastructure beyond a typical business office—i.e., common household electrical current and preferably an internet connection to a personal computer with basic CAD graphics capability. The cost of office-oriented RP systems has been rapidly declining over the past decade, to the point that these systems can be obtained by academic institutions for under $30,000. There is currently even promise of newer systems to be offered on the market for under $5,000.[2] Thus, these systems have been making their way into more undergraduate engineering academic instructions for use as teaching aids.

A sampling of research in the use of RP in freshman engineering and technology classes gives insight into how to use RP as a means of accomplishing educational objectives in the classroom.

Several technology-oriented departments implemented RP as part of their design classes.[3,4,5] They had various primary educational objectives in their assessments, but they all noted an improved students' enthusiasm towards the RP technology as well as towards their curriculum and careers. Other authors have noted the use of RP in the classroom as a means of attracting attention to their program from both pre-college students and potential industrial contacts.[6,7] Interestingly, all the authors cited noted a marked increase in instructor preparation time when introducing RP, inferring that the RP process integration required more time than a typical new course preparation would ordinarily require.

We at Northern Arizona University noted the dual reports of increased student enthusiasm and increased visibility from using RP in the academic environment. Thus, we acquired a Fused Deposition Modeling (FDM) machine, the Dimension 768 SST system, in the summer of 2007. This purchase was made from a collection of small grants and industrial sponsorships, for the dual purpose of supporting applied research and Engineering education projects. We present our first endeavor in the latter activity, introducing RP into our freshman Mechanical Engineering Computer-aided Design (CAD) class, ME 180.

Approach

This initial introduction of RP into ME 180 was to accomplish several objectives:

1. Motivate students to stay engaged in the mechanical engineering curriculum.
2. Give students knowledge of advanced computing techniques.
3. Give students an experience of product realization in their first year of engineering.
4. Give students a simple but practical example of geometric dimensioning and tolerancing.

The last three objectives were part of the learning objectives for the course, and are not the primary topic of this paper. On the other hand, the first objective was a strategic issue for the College of Engineering and Natural Sciences (CENS). The Engineering program at NAU is fairly unique in its admission requirements among U.S. engineering programs: Accepted students at NAU are allowed to enroll in the Engineering program without constraints on their mathematics or science admission scores. This policy is an effort by Arizona to engage as many students as possible into the Science, Technology, Engineering and Mathematics (STEM) programs through NAU enrollment. The consequence is that students who are poorly-prepared for Engineering must take remedial courses at NAU initially, resulting in an extended academic career of five years or more. The CENS has been encouraging pedagogical methods which will engage these students early, such that they may be less inclined to be discouraged and leave the program before they begin their engineering coursework. The RP introduction was viewed as one means of assisting in that objective. Our paper addresses primarily that motivational issue, as it is a one-time comparison of the previous ME 180 offering in an old format verses the new format to come.

Method

The RP introduction was conducted within one of the existing topics of the course, "Geometric Dimensioning & Tolerancing" (GD&T). This topic addresses the issue of how parts have dimensional tolerances, how they may fit together, and standards associated with representing this information. In a larger context, GD&T follows a national standard ANSI Y14.5. In the pre-RP course, the topic was presented as a lecture over two weeks; all the material was in terms of the textbook information and lecture notes. GD&T was presented as a minimal introduction, with the objective to give the students a simple understanding of the importance of GD&T in mechanical assemblies and how it relates to features and geometry.

The post-RP course uses an assembly model as a class project. The model file comes from the Solidworks online tutorial database; images of the model are shown in Figure 1 and Figure 2.[8] The model consists of 9 components, not including the pins. The students in a class are divided into teams of 9 students, where each student is assigned one of the components and the associated model file. The problem is presented in the context of the CAD models being "perfect," where there is no tolerance for fitting in an assembly. Though the CAD assembly model appears perfectly assembled in the virtual CAD world, the parts produced from the models will not fit together in the real world. This problem is highlighted by showing the RP-produced parts, measuring them and then trying (unsuccessfully) to put them together in the classroom. The students are then assigned the task of modifying their CAD models so that they will indeed fit together properly when produced from new RP parts, a week in the future. They are also told that "backlash" will be measured from their physical RP models to indicate how well they calculated their assembly tolerances. In other words, the students need to design so that their team model will fit together, but not too loosely.

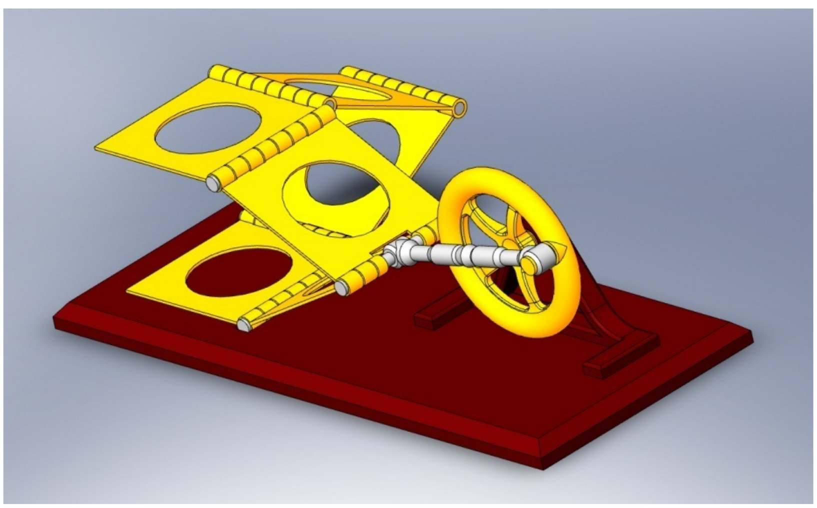

Figure 1. Solidworks Assembly Project Model, Isometric View.

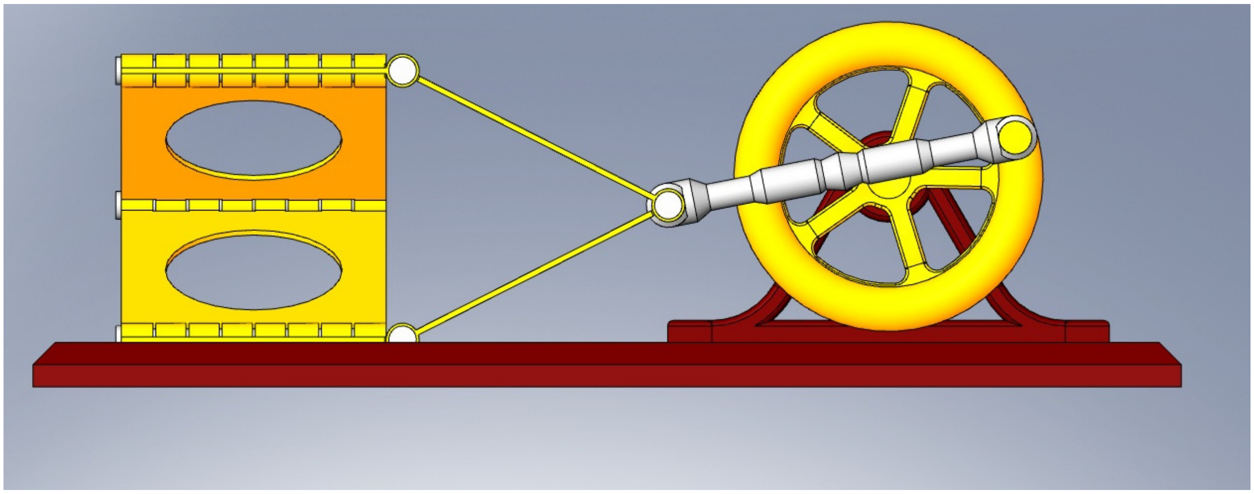

Figure 2. Solidworks Assembly Project Model, Side View.

In the context of the survey questioning, our immediate goal is to conduct a pre/post comparative survey of students who took the class without this physical prototyping experience, verses the students who did have this experience. A survey was constructed to gather information on the students' view of the course in terms of motivation and learning. We used the online tool "Surveymonkey.com," a commercial website service for creating and issuing surveys. A subscription to this site enabled us to quickly create and maintain a survey questionnaire for anonymous online access by the students.

The questions were divided into three basic categories: Motivation, Department Learning Objectives, and Demographics. The Motivation category was our primary one of interest in this study. This category consisted of two questions:

1. Does ME180 motivate you to stay in Engineering as a career?
2. If you were motivated to stay in engineering due to ME180, which topic in the course was the most motivational and why?

The first question provided a linearly scaled progression for response from 1 to 5, as shown in Table 1. If a respondent were to reply, "Question is not applicable," then the survey information would be excluded from the statistics. The second question allowed for the respondents to provide a more free-form response, in the form of short-sentence response, or even none at all if they so chose.

Table 1. Question Response Progression.

Does not motivate me	Somewhat Motivates me	Motivates me	Really motivates me	Extremely motivates me	Question is not applicable
1	2	3	4	5	Not included

Both questions intentionally omitted any reference to the RP technology. Aside from the introduction of the RP technology in the Spring 2008 class, the Fall 2007 offering was identical, in terms of the instructor, the course progression, grading scheme, and classroom environment. Additionally, the instructor had over three years and 13 sections of prior course offerings, insuring that his instruction ability was the same level of quality for the two semesters under review. Thus, any significant difference between the comparative studies of the pre and post classes' responses should be associated with the RP technology introduction.

Work in Progress—Results so Far

The goal of our work in progress is to address the hypothesis, "The use of Rapid Prototyping in the freshman course increases their enthusiasm towards Engineering as a major," and "The use of Rapid Prototyping in the freshman course increases their enthusiasm towards Mechanical Engineering as a career." We have thus far only collected the pre-RP course information, but it does show some interesting results.

The pre-RP class survey was issued towards the end of the Fall 2007 semester. Respondent results are shown in Table 2. 27 students out of 29 who took the survey answered this question.

Table 2. Responses to Question 1, Fall 2007 (before RP introduction).

Does not motivate me	Somewhat Motivates me	Motivates me	Really motivates me	Extremely motivates me	Question is not applicable
3.7%	14.8%	22.2%	25.9%	33.3%	0.0%

The students already show a relatively high enthusiasm for both their Mechanical Engineering major (question 1) as well as for their chosen career path (question 2), even before the RP technology is introduced. These high results reflect anecdotal observations from the Mechanical Engineering Department that introductory CAD classes are currently well received by newly enrolled students. Data from the post-RP class of Spring 2008 will be compared to this information to see if RP had any positive, negative, or no impact to the class.

For question 2, the students were requested to address topics from the class; we intended the students to answer in accordance to those topics listed in the syllabus. However, due to the open, short-sentence format, students gave a wide variety of personal answers in addition to the syllabus topics. 19 of 29 respondents addressed this question in detail. Paraphrased, the most-listed common topics are listed Table 3; we noted that most respondents listed multiple topics.

Table 3. Responses to Question 2, Fall 2007 (before RP introduction).

Motivating Topic Stated by Respondent	Number of respondents	Syllabus topic?
Creating/modeling three-dimensional products	6	Yes
Constructing Assemblies	6	Yes
Using the CAD software, in general	6	No
Teacher (a good motivator)	3	No

The responses from this question enabled us to realize that we need to include specific topics from the syllabus for the students to address in the next round of surveys (the post-RP introduction classes). We also will still provide the open-ended, short-sentence response format so that the students can still express varying opinions for our survey comparisons.

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