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The Effect of Project-Based Introduction to Engineering Course on Retention in Engineering Programs

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DRAFT THE EFFECT OF PROJECT-BASED INTRODUCTION TO ENGINEERING COURSE ON RETENTION IN ENGINEERING PROGRAMS

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Abstract

The main objectives of any introduction to engineering course are: to spark an initial interest in engineering, to expose students to different disciplines in engineering, and to educate them about overall engineering profession. Recently, there have been a lot of emphases on STEM-related programs across the nation and on the need for more capable, enthusiastic, and effective future engineers. Over many years, it has been realized that basic freshman and sophomore courses in engineering play an important role on retention, preparation of students for upper-division courses, and ultimately for a productive career in engineering.

Most universities and colleges have some introductory course in engineering. The credits vary from one to three hours. Some are discipline based and some are general. Some include basic laboratory experiments and projects and some are taught traditionally in a lecture type setting. Most try to emphasize the importance of mathematics and physical sciences in engineering and the need for understanding fundamental principles of science and engineering. It is crucial for students to realize that engineering uses mathematics as a tool to apply basic principles in Physics and Chemistry to practical problems.

Over many years, it has been realized that the drop-out rate of engineering students at UVU right after the completion of Introduction to Engineering course is about 30-35%. This percentage was based on the enrollment in ENGR-2010, Statics, compared to the enrollment in ENGR-1000 at the end of each school year. That is too high considering the fact that a few more students decide to change majors while completing their mathematics and science courses, increasing the drop-out rate by 10-20%. Prevention of losing potentially good engineers has been the focus of this research. To achieve some of those goals in our university, we have taught our Introduction to Engineering course three different ways and have compared their effects on student retention. These three methodologies encompass project-based teaching and teamwork versus traditional lecturing. Three sections of this course were taught for three to four years without projects, for a few more years with many small projects, and finally for several years with one semester-long project. This paper will provide the results of our efforts and studies to examine the gap between enrollments in our Introductory and Statics courses. Also, it will show if using hands-on projects in our Introduction to Engineering course has helped reduce the gap in enrollment with our Statics course. This paper will also provide some suggestions for future investigations and for identifying other factors related to retention in the freshman year of engineering programs.

Introduction

The significant enrollment difference between our Introduction to Engineering, ENGR-1000, and the next course which is Statics, ENGR-2010, has prompted us to monitor our enrollment and to investigate the reason/s for such a difference. The Pre-Engineering program in our institution, Utah Valley University, includes students majoring mostly in Mechanical and Civil Engineering. The overall average drop-out rate in our program from the time students had enrolled in ENGR-1000 to the similar time in ENGR-2010 has been about 40 to 55 percent.

Of course, there could be many uncontrollable reasons for this concerning decrease in enrollment such as financial difficulties, health and family issues. The consistency of these factors and their effects on enrollment in our program is extremely difficult to prove and justify. One would have to monitor each student and ask them specific questions which could interfere with their privacy. It is also difficult to accept that these factors would be major reasons for such drastic changes in enrollment consistently over many years. For our study we decided to concentrate on factors that were more controllable such as pre-requisites, projects, time of course offering, quality of teachers and improving their teaching skills, and class size.

To simplify our study further, we decided to avoid offering large classes by capping our enrollment for each section to 35 students. That made classes more manageable and it became easier to offer our students higher quality teaching. Experienced, mostly full-time, qualified, and more energetic instructors with consistently good student evaluations were assigned to teach these courses. We consider these introductory courses to be extremely important, since they directly affect our total enrollment in our program and tend to have serious impacts on attracting and retaining good students and producing quality and successful engineers. If needed, some semesters we used only one adjunct instructor who had very good credentials. They were carefully screened, given necessary instructions and similar lecture notes, and mentored. They were also required to cover similar topics, use exact teaching methods, and incorporate the same projects as in sections taught by full-time faculty. We also decided to offer these classes in the middle of the day and avoid really early or late times of the day. To accommodate as many students as possible, two sections were offered on MWF and two on TTh all at various times. The idea was to avoid turning away interested students prematurely. Of course, it is important to point out that fortunately students who express interest in engineering have a good understanding about dependence of engineering on mathematics and science. They also realize that the field of engineering in academia and professional environment tends to be more rigorous than some other professions and requires high level of ethics and responsibility.

Description of method

After many years of teaching this course, it has been realized that the purpose of offering an introductory course in engineering could be threefold:

- a. To attract good students, especially minorities and females, to the field of engineering.
- b. To provide useful information about engineering for those who have undeclared majors and are considering the field of engineering as a career.
- c. Also to help those who are undecided about which field or type of specialty in engineering they would like to pursue.

That has made the course substantially more challenging to teach. Attracting minorities and female students to engineering was considered a separate issue that required a whole different approach and attention. As a result, this major concern was not part of this study.

Therefore; it was decided to focus on the other two objectives mentioned above. The course included lectures on engineering, different fields in engineering, profession of engineering, engineering societies, engineering as applied science and math, job opportunities, developing a successful career in engineering, design process, creativity, communication skills, and engineering ethics. Our Introduction to Engineering course, ENGR-1000, was taught traditionally in a lecture setting without any projects at first. The enrollment was monitored from year 1998 through 2003. The data show a clear overall increasing trend in enrollment for this course. Because of the rise in demand, it was decided to add another section of this course increasing the number of sections from two to three in the year 2001. The pre-requisite for the course was kept as Intermediate Algebra, Math-1010. Students in their evaluation of the course repeatedly asked that the course should include some hands-on engineering related projects or experiments. In order to bring more excitement to this course as requested by students, a few simple group projects were added to the course content. After carefully taking care of the more subjective factors as mentioned in the Introduction segment of this paper, it was decided to focus our attention on two factors namely inclusion of projects in the content for this introductory course and the change in pre-requisite/s beginning in year 2004. First, the pre-requisite was kept the same and several team projects were included. Students were divided into teams of three or four and were given instructions, limitations, and objectives for each project. They were encouraged to be creative by limiting; for instance, weight, size, and/or cost. The final project in the course included a team presentation to the class. The gathered data show a continuous increase in enrollment all the way through the year 2010. As a matter of fact, another section had to be added to accommodate students, which increased the total number of sections to four in 2009. We reached a peak of 128 students in total for all four sections in 2010.

In 2013, it was decided to change the nature and the number of projects to only one semester-long team project. From year 2011 to 2014 the first declining pattern in enrollment was observed. This decline in our introductory course did not seem to be very substantial, but failure rate in the Statics course had increased. Also, a large difference in enrollment between these two courses was observed. To be exact, a 40 to 50 percent decrease in enrollment was typical in our Statics course compared to our Introduction to Engineering course. To solve this problem, it was decided to change the pre-requisite for our introductory course from Math-1010 to Math 1050, College Algebra in 2013. Also, a co-requisite of Math 1060, Trigonometry, was added to encourage and help students to follow their mathematics courses in sequence. In the year 2015 the total number of students enrolled in ENGR-1000 dropped to a total of 94 forcing us to offer only three sections. Although the enrollment was suffering somewhat, this was done to prevent students from failing Statics course and to prevent a significant drop-out rate in our program

which occurred while students would focus on fulfilling their mathematics requirements. In other words, we were sacrificing quantity for quality and trying to prevent losing good prospective engineers. Despite the fact that quality of students in Statics course has improved significantly and fewer students fail this course, the total number of students enrolled in our ENGR-1000 continues to decline. The average for the year 2017 was 75 which is similar to our enrollment before year 2000. The interesting phenomenon was that our faculty last semester suggested that offering only two sections of this course should be considered, which would take us back to when we began our enrollment monitoring study.

Methods Used by Other Schools

At University of Colorado in Boulder, Dr. Daniel Knight¹ and colleagues used project-based teaching method for their introductory course to improve student retention. They analyzed retention rate over eight years for approximately 5070 students. Those who took the project-based course were significantly more likely to remain in the program than those who did not. They performed similar studies later and presented their results at an ASEE Conference². Their conclusion was the same as and consistent with their previous study mentioned earlier. Dr. Julie Mills³ at University of South Australia and a colleague at Curtin University performed similar study and concluded that the engineering profession and academics benefits from project-based teaching that the traditional problem-based method of instruction. Their study focused on drop-out rate and showed most universities that offered problem-based courses had an average drop-out rate of 20-25% whereas, those that incorporated projects in their curriculum had an average of 40% drop-out rate. The Mechanical Engineering Department at Brigham Young University has decided to combine Introduction to Engineering and Statics courses. The combined course is also project-based and appears to be successful, although no data is available since the change occurred one year ago. The University of Utah continues to teach a project-based Introduction to Engineering course in all their engineering disciplines. Since they have not made any significant changes, they could not provide any useful data.

Results and Conclusions

Our study focused on retaining and improving quality of students enrolled in our engineering program by trying to decrease failure rate in our Statics course and decreasing the overall drop-out rate in the program. Since the first course in our engineering program is Introduction to Engineering, the enrollment in this course was closely monitored and data gathered for over a twenty year period. In our study other controllable factors that could affect enrollment in engineering program were handled differently and were not included in our enrollment monitoring approach. Therefore; our attention was focused on project-based teaching and the effect of pre-requisites for the Introduction to Engineering course. Figure (1), illustrates how enrollment in Introduction to Engineering at UVU has varied over the course of nineteen years.

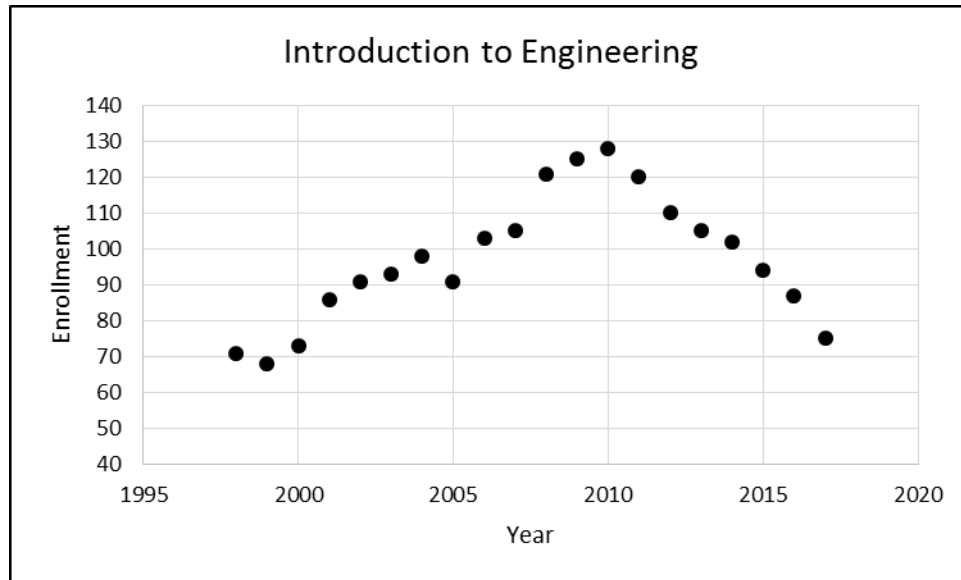


Figure 1. Enrollment in ENGR-1000 over twenty-year period.

It can be seen that project-based teaching, which we started in 2004, did not have a negative effect on our overall enrollment for our introductory course. The peak occurred in 2010 which was a total of 128 students for four sections of this course. The graph shows a steady decline since then. It appears that altering the content of the course to include only one semester-long project in 2013 did not affect this declining pattern. Changing the pre-requisite from Math-1010 to Math-1050 in 2015 did not seem to have affected enrollment either, since the declining pattern appears to have continued. Although this continuous decrease of enrollment in our ENGR-1000 is worrisome, the Statics class shows a steady increase in enrollment from average of twenty to around fifty students per year.

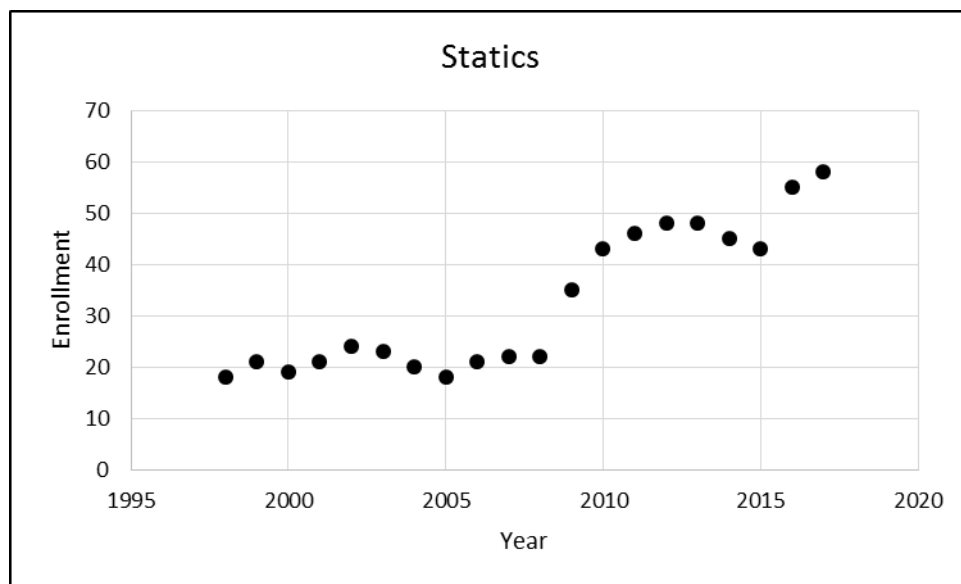


Figure 2. Enrollment in ENGR-2010 over twenty-year period.

Figure (2), shows the history of enrollment in ENGR-2010, Statics, over the same time period as in Figure (1). It can be seen that the enrollment in this course remained around 20 through the year 2008 despite a steady increase in our Introductory class enrollment. After the year 2010 the average enrollment in our Statics course hovered around 50 which demonstrates a substantial increase compared with a few years before. Also, the failure rate in our Statics course has dropped. It can be concluded that despite the fact the enrollment in Introduction to Engineering course continues to decline, more success is achieved in our Statics course. Table (1), summarizes the enrollment history of Calculus-I and Physics-I that serve as pre-requisite and co-requisite for our Statics course during the past nineteen years.

YEAR	MATH-1210	PHYS-2210
1998	94	65
1999	129	124
2000	131	126
2001	152	111
2002	160	126
2003	224	174
2004	280	164
2005	242	124
2006	242	91
2007	222	105
2008	237	97
2009	301	138
2010	337	173
2011	337	172
2012	394	175
2013	380	164
2014	337	221
2015	445	200
2016	500	242
2017	293	110

Table 1. History of enrollment for Math-1210 and PHYS-2210 over nineteen-year period

Both courses have had an overall steady increase in enrollment. From this increase in enrollment pattern one cannot conclude that there is any correlation between this pattern and the enrollment history in our Statics course. It is important to note that Calculus-I, or Math-1210, and Physics-I, or PHYS-2210, serve as two important required courses for many university programs. It would be very difficult to relate any conclusions to enrollments in our engineering programs. We have

maintained Math-1210 as the pre-requisite for ENGR-2010 for many years, although we are considering to change it to PHYS-2210 just to give our students a better foundation and understanding of principles of Mechanics prior to taking Statics.

From our studies, it can be concluded that the program is retaining more qualified students and our courses flow more sequentially than before. Our students are fulfilling and completing their remedial mathematics courses much earlier which will also serve as a screening criteria for us. However, it can be concluded that project-based Introductory course did not show any positive or negative effect on our enrollment in our ENGR-1000 or ENGR-2010. Projects provide other important opportunities for students to think about design process, teamwork, working with limitations, meeting deadlines, improving communication skills, and report writing. These are extremely important characteristics and qualities that students should develop in college. Also, projects do make courses more fun and interesting. But, do not seem to have a significant impact on enrollment. It does also help our program fulfill major requirements for engineering courses as outlined by ABET. These requirements were just mentioned above. Our efforts hopefully will help us produce more successful and contributing engineers.

As for recommendations, it seems to be more important to focus our attentions on a different and familiar issue in engineering programs nationwide which could boost engineering enrollment substantially. That is: attracting minorities and female students to engineering.

References

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