Teaching Engineering Content to First-Year Students: Does it Impact Success in Future Coursework?

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Abstract

This paper details a course developed at the University of Arkansas - Fort Smith called Engineering Analysis. The course was designed for first year students in engineering to learn critical content that should boost their chances of success in their sophomore year. This content included vector math, computer programming, and solving systems of linear equations. The course was first implemented in fall 2011 and this work represents the first analysis of the effect of the course on sophomore performance in engineering. The performance of the Engineering Statics and Engineering Physics I courses were used to gauge the impact of the Engineering Analysis course.

Introduction

Recently many engineering schools have sought to redesign their freshman engineering curriculum for various reasons such as to increase retention[1] or to increase the skill set of their students. Many schools have made changes to incorporate more team-based projects[2], improve writing skills[3], or teach mathematics more effectively[4]. The University of Arkansas – Fort Smith recently redesigned its freshman engineering curriculum and introduced a new course called Engineering Analysis. The University of Arkansas – Fort Smith offers bachelor’s degrees in Mechanical and Electrical Engineering through an agreement with the University of Arkansas – Fayetteville. The University of Arkansas – Fayetteville also redesigned its freshman curriculum by creating a general freshman experience that all first year students take, regardless of major[5]. Engineering students on both campuses take the Introduction to Engineering I and Introduction to Engineering II courses. But at the University of Arkansas - Fort Smith students take the additional course Engineering Analysis. Engineering Analysis was developed specifically to address deficiencies that were observed by faculty with teaching sophomore level engineering classes.

Engineering Analysis places emphasis on teaching freshman engineering students problem solving skills, unit conversion, vector related math, solving systems of linear equations, and computer programming. Teaching vectors and computer programming typically comprise about five weeks each of the 16 week class, with the remaining weeks for the other topics or exams. The course emerged from the following observations made by faculty:

- Many sophomore engineering students struggle with learning vector related math fast enough to keep up with the pace of the Engineering Statics course.
- While most students can solve systems of linear equations, they often choose slower methods. This can slow them down greatly on exams.
- Learning to program a computer can be a significant hurdle for sophomores in engineering. Many are intimidated and don't know where to start.
- Many students don't ask the question, "Does my answer make sense".
- Students are often frustrated with their Physics course and feel like it moves too quickly through topics.

With these observations in mind, the goal was to create a class that would try and remedy some of these problems. It was hoped that the creation of this class at the freshman year would have a measurable effect on student success in the sophomore year. The goal of this paper is to examine what effect the Engineering Analysis course has on the sophomore engineering and physics classes.

Description of Engineering Analysis Course

The engineering analysis course meets two days a week and is typically a course for first semester freshman. The pre-requisite is placement in either a pre-calculus math course, Calculus I, or higher level math. The course is designed to be interactive and team based. Each week a new topic is delivered and there is typically some type of group exercise related to the topic. Much of the work is done in groups, but some work is done individually as homework as well. The two topics with the greatest emphasis are vector mathematics and computer programming. Table 1 shows the topics of the course by week. With vector mathematics students learn what vectors are and some of the things they can represent. Students learn how to add vectors graphically as well as analytically. The class uses physical examples with force and velocity to try and connect the vector math with physical intuition. Students work with vectors of two and three dimensions. In computer programming students are led through simple program formation and conclude by working together to construct programs that typically take 20-30 lines of code. We typically use MATLAB for programming since it seems to be fairly easy for students to learn as a first language.

Week	Topic
1	Problem Solving
2	Unit Conversion
3	2D Vectors – Graphical Method
4	2D Vectors – Parallelogram Method
5	2D Vectors – Component Method
6	3D Vectors – Position Vectors
7	3D Vectors – Dot Products

8	Quiz 1 / Linear Equations – Substitution
9	Linear Equations – Matrix Methods
10	Linear Equations – Matrix Algebra
11	Quiz 2 / Programming Fundamentals
12	Programming
13	Programming
14	Programming
15	Programming
16	Review
Final Exam	Quiz 3

Table 1: Weekly topics in Engineering Analysis Course

Students also learn how to solve systems of equations using substitution, Cramer's rule, and matrix methods. Students are encouraged to use matrix algebra to solve all but the most trivial problems. Specific examples show how inefficient substitution can be with a large number of unknowns. Students also learn the engineering problem solving process and apply it to several case studies. The case studies often involve estimation and unit conversion. Feedback on the course has generally been positive, with students enjoying the interactive, team-based activities done often in class. Because most work is done in class, there is not a large amount of homework to distract focus from other critical courses such as Calculus or Chemistry.

Methods

The goal of this paper is to examine the impact of the Engineering Analysis course on student performance in sophomore engineering courses. While the topics covered in the Engineering Analysis course have potential to impact nearly all sophomore courses, the Statics and Engineering Physics courses were chosen for this study. Since vectors were emphasized in Engineering Analysis and are also critical to success in Statics and Physics, it is theorized that students who take the Engineering Analysis course will have a measureable improvement over students who did not have this experience. The first Engineering Analysis course was offered in the fall of 2011 to incoming freshman. This group then took the Statics and Physics courses from spring 2012 to spring 2013. The same Statics and Physics courses also had a significant number of students who did not take the Engineering Analysis course, thus providing some comparison data. As the program gathers more student data, we will be able to get a better idea of the effect of the Engineering Analysis course on sophomore performance. This study considered students who took, but did not pass, the Engineering Analysis course as in the same group of students who did not take the class at all. Thus, the two groups are students who did successfully complete Engineering Analysis and all other students. For the group GPA calculations, a withdrawal was given zero quality points, just like if a student had failed the course. It is assumed that most students who withdrawal classes were likely headed towards failure. The pass rate was calculated by dividing the number of students who received a grade of C or higher by the total number of students enrolled. Finally, this paper only considered prior semester enrollment in Engineering Analysis. Any type of concurrent enrollment was rare and was disregarded.

Results from Statics Course

The fall 2012 Statics sections were the only ones considered in this paper since it is the only time we have offered the course with students that have taken Engineering Analysis. Statics is a course taken only by the Mechanical Engineering students in our program, thus this represents only a subset of the students who take Engineering Analysis. Combined, the two Statics sections had 43 students, 23 of which had taken the Engineering Analysis course and 20 students who did not take the course. Table 2 shows some comparison data from each of the two groups.

	Successfully Completed Engineering Analysis course prior to Statics	Did not successfully complete Engineering Analysis prior to Statics
Number of students	23	20
GPA in Statics course (includes withdrawals)	1.83	1.90
Pass rate	56.5	60.0

Table 2: Performance of students in fall 2012 Statics course.

The numbers suggest that there is no difference in performance in Statics between each of these groups. These results were surprising and disappointing as it was theorized that Engineering Analysis would boost performance in Statics. But there are several points that should be made about this data. First, the group that took engineering analysis was exclusively students who were first semester freshman in fall 2011. The other students were mostly students who had been at the university longer and had more experience. A few of these students had even taken Statics the year before. Second, the sample size of this study is still fairly small. In a few years the overall trend of performance in Statics can be compared before and after the Engineering Analysis course began. Regardless, the numbers do not prove the hypothesis that we will see improvement with students who took the Engineering Analysis course. Some students in Statics (many of whom had the same instructor for Engineering Analysis) said that they had forgotten what they had learned in Engineering Analysis since they had not touched the material for nearly 10 months.

Results from Physics Course

The University of Arkansas - Fort Smith offers a calculus based physics course for Engineering majors as well as some non-Engineering majors in Mathematics and Chemistry. This Physics I course is typical of many such offerings in the United States as it emphasizes mechanics. Table 3 shows the performance of engineering majors who completed Engineering Analysis prior to Physics I, engineering majors who did not complete Engineering Analysis prior to Physics I, and non-engineering majors in the course. None of the non-majors took Engineering Analysis. The results show a significant improvement in both GPA and pass rate for students who completed the Engineering Analysis course. This makes sense because these students would have had extra instruction in vectors, solving systems of linear equations, and the general problem solving process. The author of this paper was heartened to learn that Engineering Analysis did have at least a measurable positive impact on the Physics. It should be noted that the Physics results included students in both Mechanical and Electrical engineering while the Statics results were only from students in Mechanical Engineering. The sample size was too small to isolate a certain Electrical Engineering course for further study. More study is needed to confirm these results.

	Successfully Completed Engineering Analysis course prior to Physics I	Engineering majors who did not successfully complete Engineering Analysis prior to Physics I	Non-engineering majors who did not take the Engineering Analysis course
Number of students	52	38	31
GPA in Physics I course (includes withdrawals)	2.15	1.63	1.71
Pass rate	63.5	52.6	58.1

Table 3: Performance of students in Physics I course from spring 2012 to spring 2013.

Conclusions

Many engineering programs have revamped their freshman curriculum in the attempt to boost performance and retention of their students. The University of Arkansas – Fort Smith developed the Engineering Analysis course to help students overcome challenges that faculty have observed in their sophomore level classes. Specifically, basic vector math was taught in this course so that students would have improved outcomes in their Statics and Physics courses. Computer programming was taught in Engineering Analysis to help students in a variety of courses that require them to write programs. Solving systems of linear equations is common in fundamental engineering courses and this was also covered. Results show that students who took Engineering Analysis had an observable improvement in Physics I, with a 32 percent increase in course grade-point average. But students who took Engineering Analysis did no better in Statics than student who did not take Engineering Analysis. The University of Arkansas - Fort Smith will continue to refine the freshman curriculum to optimize retention and success of its engineering students.

Bibliography

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