

## **An Assessment Study on Replacing the Engineering Graphics Course with the Fundamentals of Engineering Design Course**

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### Abstract

At New Jersey Institute of Technology (NJIT), there has been a great effort in curriculum redesign. The initiative for this redesign was generated by the National Science Foundation (NSF) coalitions and many institutions of higher learning have responded. Our principal stakeholders, industrial colleagues, entering students, administrators and the faculty have also advocated curriculum reform. Our industrial colleagues kept telling us that they were satisfied with the student's technical abilities but expressed concern about their abilities in communication skills and teamwork. Entering freshmen students wanted to get started with their engineering courses earlier in their studies and asked, "where is the beef"? Institute Administrators were addressing the problem of student retention. It seemed that even the faculty, who are generally conservative about curriculum reform, were ready to upgrade programs to meet the challenges of the new approaching millennium. Based on these inputs, at New Jersey Institute of Technology, a member of the Gateway Coalition, a fresh look at the freshman year curriculum was undertaken in 1992 resulting in a disciplinary, introductory freshman engineering design-oriented program. The objective was to introduce entering freshman students to "real engineering" up front.

In 1992, this effort, which was of a disciplinary nature, led to a number of department-based experiential engineering design modules. These learning modules replaced the Engineering Graphics (EG) course, which was a traditional two credit hour course in almost every Freshman Engineering program for many years. Engineering Graphics introduced students to the fundamentals of sketching, isometric and orthographic drawings, dimensioning and scales. Students were also taught the principles of charts and graphs including graphical calculus. Applications in the various engineering disciplines were studied by means of graphical vectors in force analysis, piping symbols and diagrams, electrical symbols and diagrams and plot plans. The new Fundamentals of Engineering Design (FED) course modules were of a seven- (7) week duration, meeting three (3) hours per week for the Chemical Engineering, Civil Engineering, and Electrical Engineering Departments. The Mechanical Engineering Department, which had previously taught the Engineering Graphics course, developed a fourteen-week module. This module included a Computer Aided Design component with a strong emphasis on using the software tool "Pro ENGINEER" for three dimensional, solid modeling. These modules were paired with a semester length course in Humanities, which emphasized writing and other communication skills. Students were randomly assigned to the modules by the Dean of Freshman Studies and were required to take the Mechanical Engineering module and two of the seven-week modules. These seven week modules were taught by faculty from Chemical, Civil and

Electrical Engineering, were very strongly discipline oriented and had a strong emphasis on “hands-on” experience, developing both oral and written communication skills, independent group effort and team work. The program was well received by both the faculty and students.

The Office of Institutional Planning and Research undertook a study as part of the assessment plans. The study compared the impact of the two courses in order to find out the affect of the FED course (as compared to the Engineering Graphics course) on engineering student graduation rates and the affect on academic performance, in general, and in English, Mathematics and Engineering, in particular. The study analyzed outcomes for students who took the Engineering Graphics course in the 1992-93 or the FED course in the 1993-94.

The study showed that there was a statistically significant difference ( $p = 0.01$  level) between student’s EG and FED grades and in groups’ graduation rates. There was also a statistically significant difference ( $p = 0.05$  level) between EG and FED students in English, Mathematics and Engineering and in the cumulative GPA.

## Introduction

In the past, the traditional engineering curricula has Mathematics, Physics and Chemistry in the first and second years, Engineering Science and Basic Engineering Courses in the second and third years and the Capstone Design courses in each discipline in the fourth year. At New Jersey Institute of Technology (NJIT), interest developed in the late 1970’s to introduce freshmen to the concepts of engineering design. In 1977, the National Science Foundation supported the CAUSE grant at NJIT to introduce freshmen to engineering design. The two-year grant was for \$ 200,000 and involved faculty volunteers. The program was unstructured and the faculty related their personal industrial experiences. In 1979, the program ended with a new administration, which had other immediate priorities that took precedence. New National Science Foundation initiatives in 1990-91 led to the formation of numerous coalitions in different sections of the United States and NJIT became a part of the Gateway Coalition consisting of ten Universities. These coalitions renewed interest in freshman engineering design courses.

The literature, especially the ASEE Annual Conference Proceedings and the ASEE Frontiers in Education Conference Proceedings, began to contain many discussions about the varying approaches for the freshman engineering design programs. For example, in 1993, Regan and Minderman [1] discussed the integration of design across the curriculum as part of the ECSEL Coalition. Buccariarelli [2] discussed “EXCEL & the Integration of Design”. Calkins, Plumb, Chou, Hawkins, and Coney [3] showed how a team of teachers introduced freshman to design and communication skills. Howell [4] wrote about a new course that had vertical integration of design concepts through the entire engineering curriculum to improve student retention. Chrzanowski [5] gave a student perspective on the Freshman Engineering Design Course at NJIT. Moore [6] et al showed the lack of consensus about the definition of the design process and the difference between design and simple problem solving. They also discussed Freshman Design Texts. Hanesian and Perna [7] discussed their experiences in using the senior Chemical Engineering Laboratory as the basis of a measurements laboratory to introduce freshman to design concepts since measurements are a fundamental part of all engineering disciplines. Kielson [8] discussed a two-semester course, which introduced students to design and problem

solving, hands-on experience, critical thinking and written, oral and graphical communication skills. Milano [9] discussed retention and motivation in the freshman design experience. Hesketh, Slater and Gould [10] showed the effort of multidisciplinary industrial teams and applied these methods to the undergraduate program. Kallas, Sathianathan, and Engel, [11] discuss using industry and academic collaboration to bring “real world” problems to the freshman engineering design course. Purasinghe [12] presented on a Freshman Engineering Design course. Under the auspices of the Division of Experimentation and Laboratory Oriented Studies, ASEE, Montanez Wade devoted an entire session, Session 2236, to “Introducing Freshman to Engineering” [13]. Traver [14] discussed introducing freshmen to engineering design by developing the Weather Station Project. Other projects that Traver presents are the Newcomen Steam Engine and the Truss Bridge. This approach of developing a specific project to introduce design to freshmen is typical of the programs across the country. In all freshman engineering design programs throughout the various coalitions, the common theme is hands-on experience, team effort, improving oral and written communication skills, interdisciplinary approach to problem solving, critical thinking, “real world” problems, and the application of computer techniques to the solution of engineering problems very early in the engineering students program of study.

At NJIT, as a result of administrative concerns about engineering education and student retention and the NSF Gateway Coalition initiative, freshman engineering design courses were developed in civil, mechanical, electrical and chemical engineering. [15] This effort was aimed at moving engineering design into the freshman year to ignite interest in freshman about engineering by giving them “hands-on” experiences with the hope that retention would improve and there would be more initiative for curriculum change. These courses were coupled with humanities and computer science courses. The overall objective was to enable freshman to work on real engineering problems as they begin their education rather than leaving the design experience for the fourth year.

Four stakeholder groups were identified who had an interest in the freshman engineering design program. These were:

#### Industry

Industrial colleagues have always been satisfied with student technical abilities but were almost unanimously dissatisfied with their abilities to present good written and oral reports. They also stressed the importance of teamwork. The problem is not new and published quotes [16] corroborating this problem date back to the 1930’s.

#### Administration

The Administration has always been interested in student retention, curriculum revision to meet the social needs, engineering earlier in a student’s program to ignite interest in engineering studies and to expose all engineering students to the various engineering disciplines to enable them to chose their profession wisely.

## Faculty

The Faculty appreciated the importance of real engineering exposure, good oral and written communication skills, and team concepts in project development.

## Students

Our students wanted to start engineering studies very early in their academic careers. They wanted interesting and exciting programs but they have always complained about “to much work”. Nevertheless, they would ask, “where is the beef”? In other words, when are we going to start studying “real” engineering problems instead of only chemistry, mathematics, physics and humanities?

In an effort to satisfy all constituent groups a program at NJIT was developed that had the overall objectives to enable freshman to work on real engineering problems and to engage in this effort at the start of their program and not only in the senior capstone design course. The specific objectives were to add engineering design to the freshman year, to recognize, encourage, and teach the team approach to problem solving, to ignite interest in engineering by “hands-on” experiences and to improve student retention. Other specific objectives were to initiate curriculum change, to couple freshman engineering design with humanities and computer science courses to enable the students to learn and use computer skills early in their program and to learn to communicate effectively in both oral and in written reports.

The program structure was initiated at NJIT in 1992 and consisted of department based experiential engineering modules. Each incoming freshman student was required to take three modules. Assigning the students to modules was at random and was made by the Dean of Freshman Studies. All freshmen were required to take the 14-week Mechanical Engineering (ME) module, which had a strong Computer Aided Design/Graphics (CAD/Graphics) basis using the software program Pro ENGINEER. In addition, they were required to take two, seven-week modules in Civil, Electrical or Chemical Engineering. These learning modules which constituted a two credit-hour course, replaced the Engineering Graphics (EG) course, a traditional part of Freshman Engineering Studies for many years in almost every engineering program. The new freshman engineering course, called the Fundamentals of Engineering Design, was three hours per week for the ME module and three hours per week for the other modules. Classes were limited to 15-18 students working in 5-6 groups of three each. The course was coupled with a three hour Humanities course. Each course had one or two teaching assistants. The courses had a strong emphasis on “hands-on” experiences with a strong emphasis on communication skills, both written and oral. The Electrical and Chemical Engineering modules were a lecture/laboratory format while the Civil and Mechanical Engineering courses had a stronger design basis.

The Engineering Graphics course introduced students to the fundamental of sketching, isometric and orthographic drawings, dimensioning and scales. Students were also taught the principles of charts and graphs including graphical calculus. Applications in the various engineering disciplines were studied by means of graphical vectors in force analysis, piping symbols and diagrams, electrical symbols and diagrams and plot plans.

The new Fundamentals of Engineering Design course modules were discipline specific. The various modules developed were:

#### Chemical Engineering

- Measurement module based on the Senior Chemical Engineering Laboratory Experiments

#### Civil and Environmental Engineering

- Water Supply from a Reservoir to a Local Community
- Transportation Study to Transport Passengers from Pennsylvania Railroad Station to Newark Airport
- Roadway Design to Move Traffic from Two Major Highways into Downtown Newark
- Donald Trump's Proposed Tower in New York

#### Electrical and Computer Engineering

- Design of an Electrical Circuit with a Photo Resistor
- Applications of Electrical Circuits in Computers

#### Industrial and Manufacturing Engineering

- Manufacturing Process and Floor Planning

#### Mechanical Engineering

- Toy Design
- Slider-Crank Mechanism Application
- Application Device for Photo Resistor Light
- Glider Airplanes

In all modules there was a strong emphasis on “hands-on” experience, developing oral and written communication skills, independent group effort and teamwork. The program was well received by both students and faculty.

In the interest of course evaluation and assessment, the Office of Institutional Research and Planning investigated whether quantitative student performance data would support findings from surveys and questionnaires on the freshman engineering curriculum change. The study compared the impact of the Engineering Graphics course and Fundamental of Engineering Design course on students' graduation rates, English, Mathematics and Engineering course grades and cumulative GPA. The outcomes of the students who took the EG course in 1992-93 academic year or the FED course in the 1993-94 academic year were analyzed.

#### Sample

The population in the study included two groups of students with similar characteristics: 240 students enrolled in the EG courses in 1992-93 academic year and 126 students enrolled in the FED courses in 1993-94 academic year. Total number of students who took the EG course in

1992-93 was 517, and the FED enrollment in the 1993-94 acad was 139. In order to achieve appropriate and matched samples, (a) only those students who completed EG or FED course were included to allow for post-completion analysis; (b) all non-engineering major students who took EG or FED were excluded; (c) all non-freshmen students who took EG or FED were excluded; and, (d) after mean math SAT scores for the FED students were calculated, EG students with low math SAT scores were excluded, so that by the beginning of the analysis, both groups had the same mean math SAT scores. Table 1 shows the group distribution before data analysis.

Table 1. Characteristics of the two matched freshmen groups: (1) those who took the EG course in 1992-93 and (2) those who took the FED course in 1993-94<sup>1</sup>

Characteristics	The EG (N=240)	The FED (N=126)
Gender		
Male	215 (90%)	105 (83%)
Female	25 (10%)	21 (17%)
Race		
White, non-Hispanic	127 (53%)	57 (45%)
Asian American	55 (23%)	26 (21%)
Hispanic	27 (11%)	19 (15%)
African American	23 (10%)	17 (13%)
American Indian	0	1 (1%)
Not reported	9 (4%)	6 (5%)
Average age	18.2	18.2
Average number of credits enrolled	15.5	15.3
High school rank		
Average percentile	75%	81%
Top 10 percent	20%	31%
Top 25 percent	52%	67%
Top 50 percent	90%	91%
Average math SAT	580	580
Average essay placement test score	7.6	7.8

<sup>1</sup> The percentages might not total 100 due to rounding.

#### Limitations of the study

1. The Engineering Graphics course was delivered in the 1992-93 academic year, and Fundamentals of Engineering Design was delivered in the 1993-94 academic year.
2. The study does not account or control for the effects of other variables over time which may have influenced results. There may, for instance, have been additional curricular and service changes that influenced the outcomes.

3. The placement test scores as well as high school rankings for some of the students were not available.
4. College cumulative GPA reflects different sets of courses for different students.

### Methodology

1. The source file was the institutional Student Information System file.
2. A database was created of all students who took the EG course in Fall-92 and Spring-93 and those students who took the FED course in Fall-93 and Spring-94.
3. The following data were included in the file: high school ranking; SAT scores; placement test scores; grades for all college courses; cumulative GPA; and 6-year graduation rates.

### Procedure

1. Graduation rates and GPA's in Math, English and Engineering courses<sup>1</sup> were calculated using PC SAS statistical software. (Table 2)
2. Graduation rates, English, Math, Engineering, and cumulative GPA of the students who took the EG were compared to those who took the FED courses.

Table 2 Data analysis

Characteristics	The EG 101 (N=240) 1992-1998	The FED 101 (N=126) 1993-1999
Cumulative college GPA at Graduation	2.61	2.73
The EG/ FED courses GPA	2.17	3.06
English courses GPA	2.63	2.82
Math courses GPA	2.46	2.58
Engineering courses GPA	2.59	2.71
Graduation rates <sup>2</sup>	36.6%	54.1% <sup>3</sup>

### Results

The analysis showed that (a) there was statistically significant difference at .01 level between the EG and FED students' graduation rates and (b) there was statistically significant difference at .05 level between the two groups on EG and FED courses, English, Math, Engineering courses and cumulative GPA.<sup>4</sup> (Figure 1 and Figure 2)

<sup>1</sup> Courses required for getting a degree in engineering.

<sup>2</sup> NCE six-year graduation rates are 35.8 percent for the 1992 full-time first-time freshmen (FTFTF) cohort and 40.5 percent for the 1993 FTFTF cohort.

<sup>3</sup> The difference in graduation rates is statistically significant at .01 level on T-test.

<sup>4</sup> T-test.

Figure 1. Average Students' Grades on EG and FED, Engineering Courses and Math and Cumulative GPA

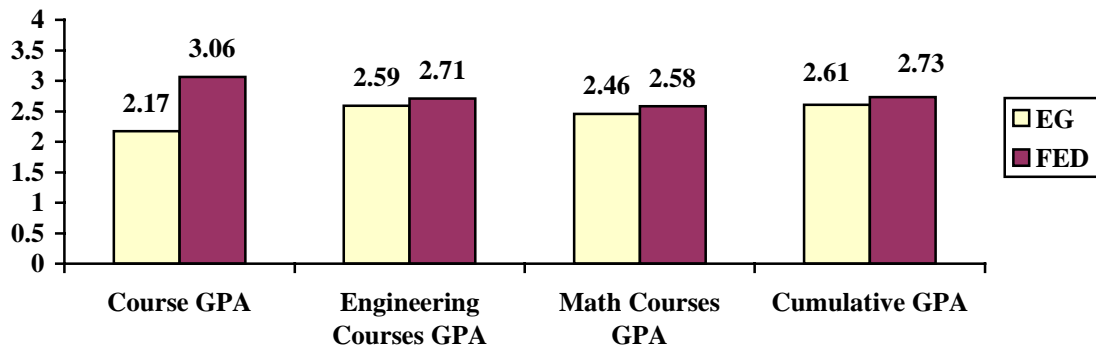
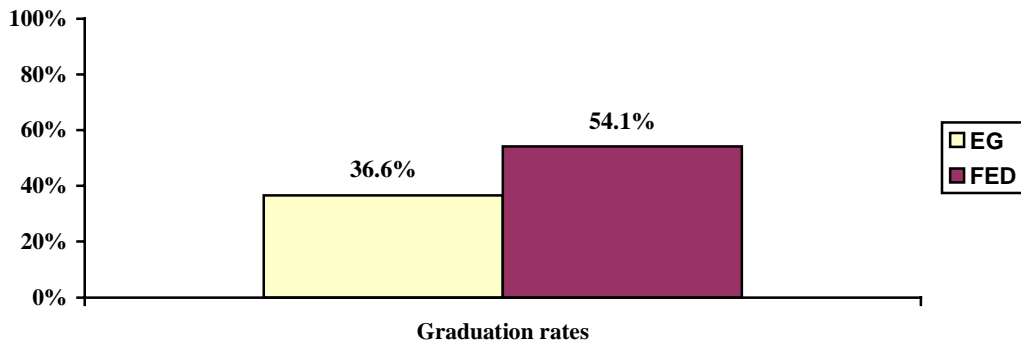


Figure 2. EG and FED Students' Six-Year Graduating Rates



## Conclusions

1. The analysis showed a statistically significant difference ( $p = 0.01$ ) between the student's Engineering Graphics (EG) and Fundamentals of Engineering Design (FED) achievement and between the groups' graduation rates.
2. There was a statistically significant difference ( $p = 0.05$ ) between the EG and FED students' achievement in English, Mathematics and Engineering courses and in cumulative GPA.

## Course Development

In the years that followed these disciplinary modules, courses were introduced as part of the Gateway studies incorporating manufacturing concepts with engineering design principles. Many of these courses were interdisciplinary in nature and were team taught by faculty from more than one department. A review of the program led to institutionalization in the Spring 1999 and Spring 2000 based on the history of the development of the various experimental



freshman engineering courses at our Institute and with pressure to reduce credit hours in the engineering curriculum. The Faculty replaced Engineering Graphics with the Fundamentals of Engineering Design course, which is in two parts, each one credit hour. FED 101C, the CAD/Graphics component and FED 101D, the design component each have two hours and ten minutes of class time per week for fourteen weeks during the semester. The FED coordinator has been designated to work with the Registrar, the Dean of Engineering and the Dean of Freshman Studies to establish continuity.

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