

## An Evolving Freshman Engineering Design Program – The NJIT Experience

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**Abstract** - At New Jersey Institute of Technology (NJIT), there has been a great effort in curriculum redesign. Many institutions of higher learning have responded to curriculum reform encouraged by the initiatives created by the National Science Foundation (NSF) coalitions. In addition, the need for curriculum reform has been expressed by industrial colleagues, entering students, administrators, and Faculty. In response to these inputs, a disciplinary introductory freshman engineering design oriented program was initiated at NJIT in 1992 to introduce entering freshman to “real engineering” up front.

The stakeholder concerns ranged from administrators viewing retention as a problem, students asking “where’s the beef”, industrial representatives expressing concerns about interdisciplinary team work and communication skills, and finally, but not the least, energized faculty wanting upgrading and curriculum reform. In 1992, this effort, of a disciplinary nature, led to the development of department based experiential engineering learning modules of seven (7) week duration, meeting three (3) hours a week. Students were required to take two (2) modules from different disciplines sequentially in their freshman year which were coupled with a Computer Aided Design (CAD) based 14 week Mechanical Engineering course and a humanities, semester length, course emphasizing writing and the various aspects of engineering. The disciplinary oriented modules were taught by faculty from electrical, civil, mechanical, and chemical engineering. The courses had strong “hands on” efforts with an emphasis on communication skills, independent group work and team work. These courses were well received by students and the faculty alike.

In 1995, follow-up courses incorporating concepts of manufacturing with the engineering design principles were introduced for the second semester of the freshman year. However, these courses were interdisciplinary based, team taught, and were fourteen (14) weeks in length, meeting for either two and a half (2 ½) hours or three (3) hours per week. Also, the introductory computer science course was incorporated into the mix to upgrade computational skills required for the courses. Again, the efforts were well received by the students and faculty. Based on the history of the development of the various experimental freshman engineering courses at our Institute, and with pressure on the engineering curriculum to reduce credit hours, a review of the developmental program was initiated to consolidate the freshman year experience. This

re-evaluation at NJIT was institutionalized in the Spring of 1999 by the decision of the College of Engineering Faculty.

### Introduction

Over the past six or seven years an emphasis on the introduction of freshman engineering design concepts into the first year of the engineering curriculum has been widespread in institutions of higher learning. This approach has been in response to concerns raised by students, faculty, industry and academic administrators.

Many institutions that are a part of the various National Science Foundation Coalitions throughout the country have developed programs in freshman Engineering Design. In 1993, Regan and Minderman [1] discussed the integration of design across the curriculum as part of the ECSEL Coalition. Bucciarelli [2] discussed “ECSEL & the Integration of Design” and the effort at several universities. Millar and Regan [3] presented a case study showing how one Faculty member motivated four others to develop a process approach to teaching/learning, engineering design. Calkins, Plumb, Chou, Hawkins, and Coney [4] show how a team of instructors introduced freshman to design and communication skills. Howell [5] discussed a new course that was instituted to provide a vertical integration of design through the engineering curriculum and to improve student retention. Gramoll [6] reviewed past approaches to introducing design in the Freshman year and discussed the use of simulation models in such courses. Chrzanowski [7] presented a student perspective about the freshman Engineering Design Course at NJIT, a part of the Gateway Coalition. Cain [8] described her experiences at Ohio State. Moore et al [9] discuss Freshman Design Texts and the lack of consensus about the definition of the design process and the difference between design and simple problem Solving. Mullins et al [10] discuss the expectations of Freshman in Engineering programs.

Hanesian and Perna [11] discussed the use of a measurements laboratory to introduce freshman to design concepts since measurements are a fundamental part of all engineering disciplines. Similarly, Carlson et al [12] discussed a “new, creative, innovative” faculty to give experiential, hands-on learning across the engineering curriculum. Keilson [13] discussed a two-semester freshman course aimed at introducing students to design and problem solving, hands-on experience, critical thinking and written, oral, and graphical communication skills. Milano [14]

discussed retention and motivation in the freshman design experience. Froyd and Rodgers [15] discussed the Integrated, First-Year Curriculum in Science, Engineering and Mathematics (IFYCSEM) which focused on links between disciplines, improving problem solving and the enhancement of the ability to work and learn as part of a team.

Hesketh, Slater and Gould [16] discuss a number of examples showing the effort of multi disciplinary teams in industry and the use of these approaches in undergraduate education. Kallas, Sathianathan and Engel [17] discuss the use of industry and faculty collaboration in bringing “real world” problems into the freshman year engineering design course. Johnson, Cannon and Fleming [18] discuss a new approach to produce engineers who can communicate effectively, work in teams, think critically and understand business and social needs. Ramachandran, Slater and Schmalzel [19] discuss an eight semester project oriented, inter-disciplinary freshman clinic with details of the second semester course.

The literature reported at conferences, especially the ASEE Annual Conference Proceedings, ASEE regional conferences, and the ASEE Frontiers in Education Conferences, all have differences in the approach to introducing freshman to design. However, the common theme in all discussions and approaches at various universities is hands-on experience, team effort, improving oral and written communication skills, an interdisciplinary approach to problem solving, critical thinking, “real world” problems, and application of computer techniques to the solution of engineering problems very early in the Freshman year.

While numerous paradigms have been developed throughout academia in response to the various stakeholder concerns expressed, at NJIT, the use of both disciplinary and interdisciplinary lecture/laboratory experiential oriented “real engineering” design courses were developed [20]. This approach uses these courses as vehicles for students to learn elements of teamwork, independent research methods, responsibility and oral and written report techniques [21].

Freshman engineering as a course at NJIT is not new and actually began in 1977 and was terminated in 1979. The main reasons were lack of faculty commitment and grant leadership. The initiative was sponsored by the National Science Foundation (NSF) which gave a Cause grant to NJIT for \$200,000 to develop Freshman Engineering Design. The concept was to introduce design concepts in the freshman year similar to the current NSF Coalition incentives. The program at NJIT was not required of freshman, it was unstructured, and both students and faculty volunteered. The teaching faculty each presented their views about Engineering and primarily related their industrial experiences. The majority of the Faculty were less than enthusiastic about the course and cited the inappropriateness of teaching freshman design when the

students lack adequate background and preparation. In 1979, NJIT had an almost completely new administration trying to establish itself and when the grant ended, so did the program. In 1991, there was a resurgence of interest throughout the country mainly fueled by the NSF funded coalitions with NJIT being part of the ten school Gateway coalition.

As an outgrowth of administration concerns and this educational initiative by the NSF Gateway Coalition, a series of introductory disciplinary freshmen engineering design courses were developed in civil, mechanical, electrical, and chemical engineering at New Jersey Institute of Technology (NJIT). The goals of the undertaking were to move engineering design into the freshman year, ignite interest in freshman about engineering by “hands on” experience, improve student retention and initiate curriculum change. The courses developed were coupled with humanities and computer components to integrate these course contents with the engineering course. The overall objective was to enable freshman to work on real engineering problems as they begin their education rather than leaving the design experience as a traditional senior capstone design course. Thus freshman would gain “hands-on” experience, learn how to develop feasible solutions to an open-ended problem, work in teams, and learn how to present the results of their effort orally and in written form.

In investigating who has an interest in a freshman engineering program initiative we identified four groups of stakeholders and their respective needs. These are:

### INDUSTRY

Our industrial colleagues were interested in student technical skills and were almost always satisfied with student technical abilities. However, they almost always were dissatisfied with the students’ abilities in both written and oral communication skills. The problem is not new. In 1941, in his book “Technical Report Writing”, Professor Fred Hoffman (Dusty) Rhodes of Cornell University cited the two following quotes made in the late 1930’s [22]. These are:

*“One of the most outstanding faults, if one is looking for faults in the young men, is their inability to use ably the English language. The writing of simple reports and the expressing of themselves verbally seem to be two things in which they are notably deficient.” (V.L. King, Technical-Director, Calco Chemical Co.)*

and

*“The most striking defect in the training of practically every man we employ is the lack of knowledge of English composition.” – (Allan F. Odell deceased, formerly chemical director,*

*Plastics Department, E.I. du Pont de Nemours and Co.)*

The comments were made 60 years ago and very little has changed. In addition, industrial colleagues wanted our students to learn to be team players, be skilled in computer techniques and be “off and running” the first day of their new job assignment.

### ADMINISTRATION

Our administrations were very interested in student retention, in curriculum revision to meet the needs of society, in Engineering Design “upfront” to ignite interest in Engineering and finally, they had a desire to expose students to all engineering disciplines to enable students to choose wisely.

### FACULTY

Our faculty were interested in teaching the concepts of measurements, using the chemical engineering Senior Unit Operations Laboratory at NJIT. Understanding measurements is common to all engineering and requires “hands on” experimentation in the laboratory. Students would work in teams, gather data, reduce data, correlate data and then present their results in written form and orally. In essence, it was desired to give our students a “real” engineering exposure [23, 24]

### STUDENTS

Our students didn’t want to be bored and were always asking for more interesting and exciting programs. They had come to study engineering and didn’t want to wait until the junior year for their engineering exposure. They also wanted to acquire experience with minimal effort and were always asking us “where is the beef”.

In an effort to satisfy our constituents, a series of disciplinary courses were developed. The overall objectives were:

- To enable freshman to work on real engineering problems, and
- At start of their education and not only in the traditional senior capstone design courses.

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 freshman about engineering with “hands-on” experience,
- to improve student retention,

- to initiate curriculum change and enable the teaching of engineering design concepts throughout the four years of the undergraduate program,
- to couple freshman engineering design with computer science and humanities courses,
- and to learn computer applications early and learn to communicate both orally and in written reports early.

During the development of these courses, a very strong working relationship was established with the humanities faculty and their course was interfaced with the freshman engineering modules. Required reading assignments related to the specific discipline oriented modules were given to the students. Oral presentations on their work in the modules were made, and direction on technical communication formatting was introduced in the humanities course. All of these were reviewed and developed by joint faculty efforts. The strong relationship between engineering faculty and humanities faculty continues today.

The program structure was initiated in 1992 and consisted of department based experiential engineering modules. Each freshman student was required to take three modules and assigning the students to modules, was random and was made by the Dean of Freshman Studies. All freshman were required to take the 14 week Mechanical Engineering module which had a strong Computer Aided Design (CAD) basis and two, seven week modules in either Civil, Electrical, or Chemical Engineering. The course ran three hours a week for the ME module and, in addition, three hours per week for the other modules. It was a one semester course earning two credit hours. Classes were kept small at 15-18 students working in 5-6 groups of three each. The course was coupled with the three credit hour Humanities course. Each course had one or two teaching assistants. The courses had a very strong “hands on” component with a strong emphasis in 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 Orientation format.

The various discipline specific modules were:

#### **Chemical Engineering**

- Measurement Laboratory

#### **Civil and Environmental Engineering**

- Water Supply from a Reservoir to 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 Manhattan

#### **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

These efforts previously described were so well received by the students that it was decided to evolve a second set of courses which would integrate manufacturing into the course content and have them be interdisciplinary in nature. These courses were team taught and followed natural interdisciplinary interests of the involved faculty.

The second semester course (14 weeks) was two credits, 4.5 hours and integrated graphics and CAD with Engineering Design and Manufacturing. It was team taught by Graphics Faculty and Engineering Faculty and the projects had an emphasis on Design and Manufacturing. The Engineering part of the course met for 2 ½ or 3 hours per week. In the Spring semester of 1996, pilot interdisciplinary courses were initiated with a strong tie to the introductory computer science course and the humanities courses. These interdisciplinary courses were:

### **Biomedical and Electrical Engineering**

- Electrocardiographic Device, Prep-check

### **Electrical and Mechanical Engineering**

- Floppy Disk Drive of the Computer
- Heat Sink of the CPU Fan

### **Industrial and Mechanical Engineering**

- Lawn Sprinkler
- Step Ladder

### **Chemical Engineering**

### **Civil and Environmental Engineering**

- The Siting and Design of a Municipal Landfill Facility
- The Siting and Design of a Municipal Wastewater Facility
- The Siting and Design of a Major Connecting Highway
- The Siting and Design of a Hazardous Substance Manufacturing Facility (Aspirin Manufacturing)
- 

Overall student evaluations of the Freshman Engineering Design courses show that they are impressed, enjoy the experience, and enjoy working as part of a team. The students complain about too much work, which is true, and they dislike being forced into a module in an engineering area not of their choice.

The Faculty enjoy working in an area of educational development with other equally interested Faculty. They enjoy developing the new teaching methodologies and the potential for curriculum change.

The Faculty find it particularly exciting to take a very complex problem and simplify it for the Freshman in a lecture/laboratory environment. The positive impact on student development and the fact that the students never

forget you during their NJIT studies whether in your discipline or not are particularly rewarding aspects of this experience for the involved Faculty.

## **Conclusions**

The conclusions of this developmental work are:

### **STUDENTS**

An early exposure to the various engineering disciplines:

- did not help the students decide on a career
- the students were inspired by the course
- they enjoyed “hands-on” experimentation the most
- they disliked oral presentations the most
- they disliked the lengthy lab reports
- they disliked the analysis of data and calculations without adequate background
- the students developed some mind-set on pollution prevention and abatement
- their experience was very enjoyable
- the reaction to the course is very highly related to the instructor

### **FACULTY**

- The feeling is that these courses are worthwhile developing and the goals were achieved
- The best instructors in the department should be assigned to the course

### **ADMINISTRATION**

- The administration is very enthusiastic with the curriculum revision and is supportive of the program, but is concerned about resources
- It is too early to measure the effect of this program on student retention

### **INDUSTRY**

- The “hands on” experience enhances the students’ technical skills
- The goal to emphasize written and oral communication has been realized
- The students are taught to incorporate the computer during the courses developed
- The team effort required during these courses is firmly established
- However, only the last few graduating classes have been exposed to this program, and it is early to get industrial feedback on our students who have completed this program

## **The Future**

Based on the history of the development of the various experimental freshman engineering courses at our Institute, with pressure on the engineering curriculum to reduce credit

hours and a cost conscious administration, a fresh evaluation was made during the Spring Semester, 1999, to consolidate the freshman year experience.

The College of Engineering Faculty wanted to incorporate a single semester engineering design course into the freshman year. The course is two credit hours with two components, each with 2.25 contact hours per week for fourteen weeks. The course will no longer be scheduled by the Dean's office, but each department will establish their own schedule. The first component of the course will be either disciplinary or interdisciplinary according to the department's wishes and coordination with other departments. The second component of the course, which will be required of all freshman engineering students, is a computer aided design, CAD/Graphics component given by the Mechanical Engineering department. This new two credit hour course will be offered for the first time during the Fall semester, 1999 and will be based upon the developmental experience of the last seven years.

### Acknowledgements

The authors would like to thank the

NSF-Gateway Coalition and  
The State of New Jersey

for financial support for the programs.

They are also appreciative of their numerous students over this entire period of time without whose help, these programs would not have been possible. Finally, they would like to thank Chin-Yu (Jenny) Lin who typed this manuscript and finalized it for publication.

### References

1. Regan, T. M. and Minderman, P.A. Jr., "Administration, Infrastructure, and Linkage with ECSEL" Session 2525, P. 1126 – 1128, 1993 ASEE Annual Conference Proceedings, Urbana-Champaign, IL, June 20-24, 1993.
2. Bucciarelli, Louis, L., "ECSEL & The Integration of Design", Session 2525, p. 1135 – 1139, 1993 ASEE Annual Conference Proceedings, Urbana-Champaign, IL, June 20-24, 1993
3. Millar, Susan Boylard and Regan, Thomas M., "A Process Model of Teaching/Learning for Designing First-Year Engineering Design Courses, Session 2653, 1993 ASEE Annual Conference Proceedings, Urbana-Champaign, IL, June 20-24, 1993.
4. Calkins, D.E., Plumb, C.S., Chou, D., Hawkins, S.E., Coney, M.B., "Technical Communications Based Freshman Design Engineering Course, "Session 1630, p. 754, 1994 ASEE Annual Conference Proceedings, Edmonton, Alberta, Canada, June 26 – 29, 1994.
5. Howell, Steven K., "Engineering Design in a Freshman Graphics Course", Session 1238, p 245 – 247, 1994 ASEE Annual Conference Proceedings, Edmonton, Alberta, Canada, June 26 – 29, 1994.
6. Gramoll, Kurt, "Using 'Working Model' to Introduce Design Into a Freshman Engineering Course", Session 2525, p 1628 – 1633, 1994 ASEE Annual Conference Proceedings, Edmonton, Alberta, Canada, June 26 – 29, 1994.
7. Chrzanowski, Chris, "Student Perspective Freshman Engineering Design", p 2988, 1994 ASEE Annual Conference Proceedings, Edmonton, Alberta, Canada, June 26 – 29, 1994.
8. Cain, Kelli, "My Experiences in the Gateway Program at Ohio State, p 2974, 1994 ASEE Annual Conference Proceedings, Edmonton, Alberta, Canada, June 26 – 29, 1994.
9. Moore, Pamela, L., Atman, Cynthia J., Bursie, Karen M., Shuman, Larry J., Gottfried, Byron S., "Do Freshman Design Texts Adequately Define the Engineering Process?", Session 1230, p 164-169, 1995 ASEE Annual Conference Proceedings, Anaheim, CA, June 25 – 28, 1995.
10. Mullins, Carie A., Atman, Cynthia J., Shuman, Larry J., Gottfried, Byron S., "Freshman Expectations of an Engineering Program", Session 1230, p 173-177, 1995 ASEE Annual Conference Proceedings, Anaheim, CA, June 25-28, 1995.
11. Hanesian, Deran and Perna, Angelo J., "Fundamentals of Engineering Design – A Freshman Measurements Laboratory", Session 2326, p 1392 – 1394, 1995 ASEE Annual Conference Proceedings, Anaheim, CA, June 25-28, 1995.
12. Carlson, L.E., Sullivan, J.F., Bedard, A.J., Etter, D.M., Pleszkun, A.R., Session 2653, p 2039 – 2043, 1995 ASEE Annual Conference Proceedings, Anaheim, CA, June 25-28, 1995.
13. Keilson, Suzanne, "Freshman Design on a Shoestring", p 117 –121, Proceedings of the ASEE Mid-Atlantic Conference, November 1-2, 1996, Wilkes University, Wilkes Barre, P.A.
14. Milano G., "A Freshman Design Experience: Retention and Motivation", The Eight National Conference on College Teaching and Learning, Jacksonville, FL., April 16-19, 1997.
15. Froyd, Jeffrey E., and Rogers, Gloria, J., "Evaluation and Curriculum, Session F4H, p 1107 – 1112, 1997 Frontiers in Education Conference, Pittsburgh, PA. November 5-7, 1997.
16. Hesketh, Robert P., Slater, C., Stewart, Gould, Ronald M., "Multidisciplinary Teams in Industry and Engineering Education", Proceedings of the ASEE Middle Atlantic Section Conference, DuPont Experimental Station, Wilmington, DE, October 31 and November 1, 1997.
17. Kallas, M. Wabil, Satheanathan, Dhushy, and Engel, Renata, "Industry-Faculty Collaboration in Instituting

- Design in the First-Year Engineering Curriculum” Proceedings of the ASEE Middle Atlantic Section Conference, DuPont Experimental Station, Wilmington, DE, October 31 and November 1, 1997.
18. Johnson, James H. Jr., Cannon, Joseph N. and Fleming, Lorraine N., “Engineering Curriculum Reform for the 21<sup>st</sup> Century”, Paper 3A2-1-3A2-3, ASEE Zone 1 Meeting United States Military Academy, West Point, New York, April 25-26, 1997.
  19. Ramachanchan, Ravi P., Slater C., Stewart, and Schmalzed, John L., “Consumer Product Engineering: A Case Study of an Electric Toothbrush and Toothpaste”, p 7-11, Proceedings of the 1998 Fall Regional Conference of the Middle Atlantic Section of the American Society of Engineering Education, Washington, DE, November 6-7, 1998.
  20. Hanesian, D., and Perna, A.J., “The New Jersey Institute of Technology Experience in Fundamentals of Engineering Design (FED) and Freshman Engineering Courses, 1994-1997”, Manual prepared for the Summer School for Chemical Engineering Faculty, Chemical Engineering Division, American Society of Engineering Education, Snowbird, Utah, August 11, 1997.
  21. Hanesian D., and Perna, A.J., “Communications in the Chemical Engineering Laboratory – Then and Now “, Proceedings, 1994 Annual Conference, ASEE, Vol. 1, 1224-1228, June 26-29, 1994, Edmonton, Alberta, Canada.
  22. Rhodes, F.H., “Technical Report Writing”, 1<sup>st</sup> Edition, McGraw-Hill Book Co. Inc., New York, New York. (1941).
  23. Hanesian, Deran, (Editor), “Chemical Engineering Laboratory Manual”, Fall 1984, New Jersey Institute of Technology (Revision and 2<sup>nd</sup> Printing).
  24. Hanesian, Deran and Perna, Angelo J., “A Laboratory Manual For Fundamentals of Engineering Design”, 1<sup>st</sup> and 2<sup>nd</sup> Editions, Copyright 1995 and 1997, New Jersey Institute of Technology, August 8, 1997.
- 1994, the Outstanding Tenured Faculty Award, NJIT, 1994, and Distinguished Teaching Award, Middle Atlantic Section, ASEE in 1997, the Armenian Students Association of America (ASA), the Dickran H. Kabakjian Award for Outstanding Contributions in the Field of Science, June 13, 1998, the Excellence in Teaching Award for Lower Division, Undergraduate Instruction, October 1998, New Jersey Institute of Technology, the American Society of Engineering Education, Middle Atlantic Section, Outstanding Section Campus Representative, April 17, 1999, and the Centennial Certificate Award, American Society of Engineering Education, June 1993. He is a Fellow and Emeritus Member of the American Institute for Chemical Engineers and a Fellow and Life Member of the American Society of Engineering Education.
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