A Change in the Freshman Engineering Education Paradigm: Bringing Engineering Design Up-front in the Curriculum

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Abstract: At New Jersey Institute of Technology [NJIT], there has been an emphasis on engineering curriculum re-design. Industrial colleagues, entering students, administrators, and faculty have expressed the need for curriculum reform. In response to these stimuli, a disciplinary freshman engineering program was initiated in 1992 to introduce entering freshman to "real engineering" up-front.

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 lastly, faculty wanting upgrading and curriculum reform. These concerns led to the development of discipline based experiential learning modules of seven weeks, meeting three hours a week. Students were required to take two modules from different disciplines sequentially in their freshman year coupled with a 14 week Computer Aided Design/Graphics, Mechanical Engineering course and a semester length, Humanities course emphasizing report writing, oral presentations and various aspects of engineering. Electrical, Civil, Mechanical, and Chemical Engineering Faculty taught the disciplinary oriented modules. The courses had strong "hands on" efforts with an emphasis on communication skills, independent group work and team work.

In 1996, courses incorporating concepts of manufacturing engineering design principles were introduced for the second semester of the freshman year. These courses were interdisciplinary based, team taught, and were fourteen weeks in length, meeting for either two and a half hours or three hours per week. Also, the introductory computer science course was incorporated into the mix to upgrade computational skills. Again, the efforts were well received by the students and faculty. With pressure on the engineering curriculum to reduce credit hours, a review of the program was undertaken to consolidate the freshman year experience. The new approach kept the interlocking Humanities-Freshman Engineering Design Modules, but uncoupled the Computer Aided Design Module into a separate course. This new paradigm resulted in two separate, stand-alone, courses, which were institutionalized in 1999 and the program was finalized in 2000.

Keywords: Freshman, Design, Engineering, Curriculum, Courses

Introduction

Over the past eight years an emphasis on the introduction of 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.

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 throughout 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 member of the NSF/ 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 Rodger [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 multidisciplinary teams in industry and the use of these approaches in undergraduate education. Kallas, Sathianathan and Engel [l7] 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. Farrell discussed reverse engineering in a microbrewery process [20].

The literature reported at conferences, especially the ASEE Annual Conference Proceedings, ASEE regional conferences, and the ASEE/IEEE 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 [21]. This approach uses these courses as vehicles for students to learn elements of teamwork, independent research methods, responsibility and oral and written report techniques [22].

The Interested Constituents

As an outgrowth of administration concerns and the 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. In investigating who has an interest in a freshman engineering program initiative we identified four groups of stakeholders and their respective needs.

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 [23]. 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 over 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.

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

Our **faculty** was interested in teaching the "hands-on" concepts of experimentation and project design. In Chemical Engineering, we focused students working in teams on the concept of measurements, data collection and data reduction to meaningful engineering quantities, using the Chemical Engineering Senior Unit Operations Laboratory at NJIT [24,25]. Understanding measurements is common to all engineering and requires "hands on" experimentation in the laboratory.

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 at the 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 in the curriculum.

Course Development

During the development of these courses, a very strong working relationship was established with the Humanities faculty and their freshman courses were interfaced with the freshman engineering modules. Required reading assignments, that were related to the specific discipline oriented modules, were given to the students. Oral presentations on their work in the modules were made, and instruction 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 to this day.

The program structure was initiated in 1992 and consisted of department based experiential engineering modules. Each freshman student was required to take three modules. The Dean of Freshman Studies randomly assigned the students to the different department modules. All freshman were required to take the 14 week Mechanical Engineering module which had a strong Computer Aided Design (CAD/Graphics) basis and two, seven week modules in either Civil, Electrical, or Chemical Engineering. The semester courses met for three hours a week 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, in **Chemical Engineering,** a Measurement Laboratory. In **Civil and Environmental Engineering** students worked on a Water Supply from a Reservoir to Local Community, a Transportation Study to Transport Passengers From Pennsylvania Railroad Station to Newark Airport, a Roadway Design to Move Traffic From Two Major Highways into Downtown Newark, and Donald Trump's Proposed Tower in Manhattan. In **Electrical and Computer Engineering,** the modules were The Design of an Electrical Circuit with a Photo Resistor and the Applications of Electrical Circuits in Computers. In **Industrial and Manufacturing Engineering,** the project involved a Manufacturing Process and Floor Planning. In **Mechanical Engineering**, students were involved in Toy Design, a Slider - Crank Mechanism Application, an Application Device for Photo Resistor Light, and Glider Airplanes.

These efforts 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. The 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 ½or 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 in **Biomedical and Electrical Engineering**, an Electrocardiographic Device, Prep-check, and in **Electrical and Mechanical Engineering**, a Floppy Disk Drive of the Computer and a Heat Sink of the CPU Fan. In the **Industrial and Mechanical Engineering**, the students worked on the design of a Lawn Sprinkler and a Stepladder. **Chemical Engineering and Civil and Environmental Engineering** Faculty teamed together and developed projects in 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, and 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 do 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 and like developing the new teaching methodologies and the potential for initiating curriculum change. The faculty find it particularly exciting to take a very complex problem and simplify it for the freshmen 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 authors and other involved faculty.

Conclusions

The conclusions of this developmental work are that an early exposure to the various engineering disciplines, did not help the **students** decide on a career. The **students** were invigorated by the course and enjoyed the "hands-on" experimentation the most. They disliked oral presentations the most, disliked the lengthy lab reports and disliked the analysis of data and calculations without adequate background. While students felt their experience was very enjoyable, the reaction to the course is very highly instructor related. The **faculty** felt that these courses are worthwhile developing and the goals were achieved, and the best instructors in the department should be assigned to the course. The **administration** is very enthusiastic with the curriculum revision and is supportive of the program, but is concerned about resources, and it is too early to measure the effect of this program on student retention. Our **industrial colleagues** felt that the "hands on" experience enhances the students' technical skills and the goal to emphasize written and oral communication has been realized. They felt that the students were taught to incorporate the computer during the courses developed and 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.

Reflections

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 hours and ten minutes contact per week for fourteen weeks. The course will no longer be administered by the Dean's office, but each department will administer their own course in accordance to a schedule established by the Registrar's office. 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/Graphics, component given by the Mechanical Engineering department. This new, two credit hour course was offered for the first time during the Fall semester, 1999 and was based upon the developmental experience of the last eight years. However, after reviewing the Fall 1999 semester experience, it was decided during the Spring 2000 semester to separate the two components of the course into two, independent, stand-alone courses of one credit hour each. All incoming, first time freshman, however, will be assigned the two separate courses in the same semester by the Dean of Freshman Studies. The Newark College of Engineering Faculty accepted his proposal and the plan would be institutionalized in the Fall semester 2000.

References

1. T. M. Regan, and P. A. Minderman 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. Louis L. Bucciarelli, "ECSEL & The Integration of Design", Session 2525, p. 1135 1139, 1993 ASEE Annual Conference Proceedings, Urbana-Champaign, IL, June 2024, 1993
3. Susan Boylard Millar, and Thomas M. Regan, "A Process Model of Teaching/Leaming for Designing First-Year Engineering Design Courses, Session 2653, 1993 ASEE Annual Conference Proceedings, Urbana-Champaign, IL, June 20-24, 1993.
4. D. E. Calkins, C. S. Plumb, D. Chou, S. E. Hawkins, M. B. Coney, "Technical Communications Based Freshman Design Engineering Course, "Session 1630, p. 754, 1994 ASEE Annual Conference Proceedings, Edmonton, Alberta, Canada, June 26 - 29, 1994.
5. Steven K. Howell, "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. Kurt Grail, "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. Chris Chrzanowski, "Student Perspective Freshman Engineering Design", p 2988, 1994 ASEE Annual Conference Proceedings, Edmonton, Alberta, Canada, June 26 - 29, 1994.
8. Kelli Cain, "My Experiences in the Gateway Program at Ohio State, p 2974, 1994 ASEE Annual Conference Proceedings, Edmonton, Alberta, Canada, June 26 - 29, 1994.
9. Pamela L. Moore, Cynthia J. Atman, Karen M. Bursie, Larry J. Shuman, Byron S. Gottfried, "Do Freshman Design Texts Adequately Define the Engineering Process?", Session 1230, p 164169, 1995 ASEE Annual Conference Proceedings, Anaheim, CA, June 25 -28, 1995.
10. Carie A. Mullins, Cynthia J. Atman, Larry J. Shuman, Byron S. Gottfried, "Freshman Expectations of an Engineering Program", Session 1230, p 173-177, 1995 ASEE Annual Conference Proceedings, Anaheim, CA, June 2528, 1995.
11. Deran Hanesian, and Angelo J. Perna, "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. L. E. Carlson, J. F. Sullivan, A. J. Bedard, D. M. Etter., A. R. Pleszkun, Session 2653, p 2039 2043, 1995 ASEE Annual Conference Proceedings, Anaheim, CA, June 25-28, 1995.
13. Suzanne Keilson, "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. G. Milano, "A Freshman Design Experience: Retention and Motivation", The Eight National Conference on College Teaching and Learning, Jacksonville, FL., April 16-19, 1997.
15. Jeffrey E. Froyd, and Gloria J. Rogers, "Evaluation and Curriculum, Session F4H, p 1107 -1112, 1997 Frontiers in Education Conference, Pittsburgh, PA. November 5-7, 1997.
16. Robert P. Hesketh, , C. Stewart Slater, Ronald M. Gould, "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. M. Wabil Kailas, Dhushy Satheanathan, and Renata Engel "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. James H. Johnson Jr., Joseph N. Cannon, and Larraine N. Fleeting, "Engineering Curriculum Reform for the 21' Century", Paper 3A2-1-3A23, ASEE Zone 1 Meeting, United States Military Academy, West Point, New York, April 25-26, 1997.
19. Ravi P. Ramachanchan, C. Stewart Slater and John L. Schmalzed, "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. Stephanie Farrell, "A Freshman Engineering Experience: Reverse Engineering in a Brewery Process", Third Regional Conference on Innovations in Teaching and Learning- A Millenium Event", New Jersey Institute of Technology, Newark, NJ, March 24, 2000.
21. Deran Hanesian, and Angelo J. Perna, "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.
22. Deran Hanesian and Angelo J. Perna, "Communications in the Chemical Engineering Laboratory - Then and Now ", Proceedings, 1994 Annual Conference, ASEE, Vol. 1, 1224-1228, June 2629, 1994, Edmonton, Alberta, Canada.
23. F. H. Rhodes, "Technical Report Writing", 1$` Edition, McGraw-Hill Book Co. Inc., New York, New York. (1941).
24. Deran Hanesian, (Editor), "Chemical Engineering Laboratory Manual", Fall 1984, New Jersey Institute of Technology (Revision and 2"d Printing).
25. Deran Hanesian, and Angelo J. Perna, "A Laboratory Manual For Fundamentals of Engineering Design", 1st and 2nd Editions, Copyright 1995 and 1997, New Jersey Institute of Technology, August 8, 1997.

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