A PEDAGOGICAL CONCEPT OF INTEGRATING MULTIDISCIPLINARY DESIGN AND TECHNICAL COMMUNICATION

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Abstract The Engineering Clinic is an eight-semester sequence, based on the medical school model, taken by every engineering student at Rowan University. In these clinics, students and faculty from all four engineering departments work side-by-side on laboratory experiments, real world design projects and research. The solutions of these problems require not only proficiency in the technical principles, but, as importantly, require a mastery of written and oral communication skills and the ability to work as part of a multidisciplinary team. In the sophomore year, communication (written and oral) and design (semester long multidisciplinary design project) are integrated. The course is team-taught by faculty from the College of Communication and the College of Engineering. Students pick one of two design projects. The first is to design and build a guitar effects pedal. The second involves an economic and engineering analysis of the design and operation of a baseball stadium.

Introduction

In 1992, a local industrialist Henry M. Rowan made a $100,000,000 donation to the then Glassboro State College in order to establish a high-quality engineering school in southern New Jersey. This gift has enabled the university to create an innovative and forward-looking engineering program. Since 1996, the exceptional capabilities of each incoming class of approximately 100 engineering students at Rowan (average SAT score of 1260; average class rank of top 13%) have repeatedly verified the need for a quality undergraduate engineering school in the quickly growing region of southern New Jersey.

The College of Engineering at Rowan is comprised of four departments: Chemical; Civil and Environmental; Electrical and Computer; and Mechanical. Each department has been designed to serve 25 to 30 students per year, resulting in 100 to 120 students per year in the College. The size of the College has been optimized such that it is large enough to provide specialization in separate and credible departments, yet small enough to permit a truly multidisciplinary curriculum

in which laboratory/design courses are offered simultaneously to all engineering students in all four disciplines. Indeed, the hallmark of the engineering program at Rowan University is the multidisciplinary, project-oriented Engineering Clinic sequence.

The Engineering Clinics are taken each semester by every engineering student at Rowan University. In the Engineering Clinic, which is based on the medical school model, students and faculty from all four engineering departments work side-by-side on laboratory experiments, real world design projects and research. The solutions of these problems require not only proficiency in the technical principles, but, as importantly, require a mastery of written and oral communication skills and the ability to work as part of a multidisciplinary team [1][2]. Table 1 contains an overview of course content in the 8-semester engineering clinic sequence. As shown in the table, each clinic course has a specific theme although the underlying concept of engineering design pervades throughout. The solutions of these problems require not only proficiency in the technical principles, but, as importantly, require a mastery of written and oral communication skills and the ability to work as part of a multidisciplinary team. In the sophomore year, the attempt is made to integrate design and communication (written and oral) by serving the dual purpose of introducing students to formalized engineering design techniques and providing them with the necessary foundation for their careers as technical communicators. The course is team-taught by faculty from the College of Communication and the College of Engineering. In the fall semester, the thrust is on integrating discipline specific design modules with communication [3] by applying the principles of Total Quality Management (TQM) [4][5]. The focus of this paper is on the spring semester Sophomore Engineering Clinic II (the fourth of the 8-semester clinic sequence) where communication is integrated with a semester long multidisciplinary design project. Students pick one of two design projects. The first is to design and build a guitar effects pedal. The second involves an economic and engineering analysis of the design and operation of a baseball stadium. The theme is entrepreneurship in that students must be able to convince a consumer to buy their product. This necessitates an excellent design and communication with both technical and non-technical people.

Motivation

In the modern technological world, it is being recognized in many higher education institutions that an effective engineering education can no longer focus solely on the technical aspects of the curriculum, but must also provide training in both oral and written communication.

Year	*Engineering Clinic Theme (Fall)*	*Engineering Clinic Theme (Spring)*
Freshman	Engineering Measurements	Competitive Assessment Laboratory
Sophomore	TQM with 3-Week Discipline Specific Design Modules	16-Week Multidisciplinary Design Projects
Junior	Product Development	Process Development
Senior	Year-Long Multidisciplinary	Design and Research Projects

Table 1. Overview of course content in the 8-semester Engineering Clinic sequence.

Indeed, the ability to think critically and analytically (activities essential to an engineer) depends in great measure on the ability to communicate ideas in a structured and clear manner [6]. The communication skills students need to develop can be fostered by a curriculum that requires students to interact in productive and efficient ways. In particular, emphasis on the ability to function as part of a team is of key importance. Teaming skills are lacking in most students and faculty in many educational institutions. Team skills cannot be achieved within a single course, but should be integrated into the entire engineering curriculum [7]. Furthermore, success for team function depends on the degree of familiarity and comfort of students with interdisciplinary work [8], which makes it a desirable feature of a curriculum to encourage and facilitate such interchanges of knowledge and ideas, as is done at Rowan University.

In parallel with the increased emphasis on communication and teaming skills, there is a trend in education to shift to a "student centered" education paradigm [9], where students are given more control over and expected to take a more active role in their own education. This idea can be neatly integrated with Rowan University's educational objective in the Sophomore Clinic course, where teamwork, design and product-oriented material, together with the emphasis on education, can help enhance the students' active participation in their own learning and development as engineers. Educators are recognizing that design, as a formal part of the undergraduate curriculum, is not only important to help achieve a more student centered education, but also to better prepare engineers for the demands to be placed upon them when entering industry [10]. Over the last decade, there has been a growing effort across universities in the United States to increase the design content in the engineering curriculum [11][12][13]. It is of special importance to note that early design courses can provide a rich introduction to the engineering world and enhance the student's comprehension of engineering principles and methods [14]. This is one of the motivations for the Sophomore Clinics at Rowan University.

At Rowan, the themes of design and communication are closely linked. In Sophomore Clinic II, the emphasis is on oral communication and design for consumer benefit. This is a key concept in our attempt to teach entreprenurial, business and economic skills which are essential for any engineer in today's marketplace. We now describe the two semester-long design projects that students can pick from.

Guitar Effects Pedal

The following are the objectives for the guitar effects project [15]:

1. Design, develop, test and build a real electromechanical product.
2. Organize your product development team into a company structure and consider the intellectual property issues, economic issues, marketing strategy and competitor products associated with the development of your product.
3. Culminate the project by rapid prototyping a fully operational device, ready for mass production.

Each product development team has a company structure of 4 students. Duties are divided approximately as follows:

1. Project Leader: Logistics, Engineering Economics, Web page.
2. Marketing Manager. Requires an interest in music, focus on the customer.
3. Mechanical Engineer: ProEngineer solids modeling, stress analysis, rapid prototyping, machining.
4. Electrical Engineer: Electronics, signal processing, PSPICE, Quickcircuit.

Classroom instruction is given on simulation of sound effects and on three-dimensional solid modeling using ProEngineer. For simulating sound effects, the MATLAB software is used in the digital domain. For the analog domain, circuits with operational amplifiers and diodes are built and simulated using PSPICE. The students build on the competitive assessment skills acquired in the Freshman Clinic II course [1][16][17] and first conduct an assessment of existing guitar effects pedals before designing their own prototypes. The deliverables include:

1. Company Web page: The team web page will be the primary form of communication amongst team members, between the team and instructors.
2. Company binder: Each team will maintain a binder that will contain hardcopies of all technical material related to the project.

3. Weekly progress design reports: Each report outlines all of the company activities and are posted on the company web page.
4. Mid-semester design report and presentation: This describes the proposed final design in detail and focuses on customer benefits.
5. Mid-semester Alpha Prototype: The Alpha Prototype will consist of a breadboard, Commercial-off-the-shelf (COTS) items and a generic enclosure.
6. Final semester design report and presentation: This describes the actual final design in detail and focuses on customer benefits.
7. Final Semester Beta-Prototype: The Beta Prototype is the market-ready device, built using steroelithography, QuickCircuit and COTS.

Figure 1 shows a photo of guitar effects pedals designed by the students.

Figure 1 Guitar effects pedals designed by the students

Development of the prototype effects pedals in only one semester was accomplished using the unique set of resources in place at Rowan that enable undergraduate students to engage in rapid product development. The Competitive Assessment Laboratory (NSF DUE-9850563) features dedicated test stations for the complete engineering assessment of consumer products.

Stereolithography: A Distributed Partnership (NSF DUE-9751651) has created a rapid prototyping center featuring a 3-D systems SLA-250 stereolithography machine, an Actua 2100 multi-jet modeling (MJM) rapid concept modeler, and a QuickCircuit rapid circuit prototyping machine.

Baseball Project

The Baseball project focused on site location, geotechnical issues, and engineering economic [18] aspects of constructing a new stadium. The site selected had to meet the following requirements:

- Have a sufficient client base,
- Sufficient area of land to accommodate the stadium and the parking facilities,
- Meet local land use and zoning requirements, and
- Suitable soil conditions at the site so as to construct a large structure with not too much expense.

Once a site has been selected, the focus of the project shifted to economic considerations. Students spent several weeks learning concepts of engineering economics including time value of money, compound interests, present worths, rates-of-return and sensitivity analysis [18].

Student teams presented a formal proposal including specific recommendations for the size of the stadium, means of obtaining funding, team payrolls, attendance projections, and sensitivity analysis. This presentation occurred in a formal business setting (in a conference room with appropriate professional dress). The presentation was given to a committee of owners (the engineering faculty) and city leaders (the communications faculty). The objective was to convince this committee to select the team's stadium proposal. Students learn that communication is an integral part of the design process. They learn that communication is an active and creative process rather than a static tool or artifact, and, that it is a communicative and interactive process that engages writer/speaker and reader/audience.

The actual information provided to the students is shown below.

Baseball Project - Main Assignment

You are a small consulting company that has been hired to propose a plan for building a new stadium. Student teams will present a formal proposal including specific recommendations for the size of the stadium, means of obtaining funding, team payrolls, attendance projections, and sensitivity analysis. This presentation will occur in a formal business setting (in a conference room

with appropriate professional dress). The presentation will be given to a committee of owners (engineering faculty) and city leaders (communication faculty).

Obviously, the primary objective for the owners is to maximize rate-of-return, regardless of the success of the team. After all, baseball is a business. Conversely, the city leaders have a very different agenda. The prestige of their city (and their political careers) are enhanced by having a winning team. Also, fans from the suburbs and surrounding areas drive to town, eat in local restaurants, stay in area hotels, and drink responsibly in local taverns. After all, running a city is a business.

Your objective is to convince this committee to select your stadium proposal. After all, running a consulting company is a business. You may conduct the business meeting as you see fit, but the committee may not be cooperative. You MUST have the detailed and correct calculations to support your recommendations. One of the owners is really into the engineering economics, so you'll probably get asked about it. Do not expect a typical presentation. You will be interrupted, asked questions, and sometimes ignored. Even so, this is the biggest project your company has ever been associated with and you need the job!

By the way, the committee will select a proposal and each member of that company will receive ten extra points. A separate handout on the grading of the meeting will follow. Consider the following data.

Sources of Revenue

Television Money - $20,000,000 in year one, increasing 10% per year for the next ten years.

Merchandising - $3,000,000 per year guaranteed plus $100,000 per win above 60.

Ticket Sales - There are 81 home games per year. Currently, the mean ticket price is $12. Ticket prices can be raised, but projections indicate the attendance will fall by 10% for every dollar increase in price. Each ticket holder averages an additional $10 in food, programs, parking, etc.

Sources of Expenses

Stadium Construction, Maintenance and Operations Costs.

Stadium Size	Cost of Construction	Annual Upkeep
70,000	$147,000,000	$15,000,000
55,000	$123,750,000	$12,000,000
45,000	$108,000,000	$10,000,000
30,000	$75,000,000	$7,500,000

Payroll

The minimum payroll in the major leagues was $8,400,000 and the maximum was $72,000,000. Average player salaries are expected to increase by 8% per year. Obviously, reducing payroll would be one means of reducing expenses. However, there is some correlation (although not a perfect one) between the number of games a team wins in a season and its payroll. In general, better players are more expensive. The following table lists the salaries and won-loss records for all 30 major league teams in 1998.

Team	1998 Salary (in millions)	1998 record
Baltimore Orioles	72	79-83
New York Yankees	66	114-48
Los Angeles Dodgers	63	83-79
Atlanta Braves	62	106-56
Texas Rangers	61	88-74
Cleveland Indians	60	89-73
Boston Red Sox	59	92-70
New York Mets	59	88-74
San Diego Padres	53	98-64
Chicago Cubs	50	90-73
San Francisco Giants	49	89-74
Anaheim Angels	48	85-77
Houston Astros	48	102-60
Colorado Rockies	48	77-85
St. Louis Cardinals	44	83-79
Seattle Mariners	44	76-85
Kansas City Royals	36	72-89
Chicago White Sox	35	80-82
Toronto Blue Jays	34	88-74
Milwaukee Brewers	32	74-88
Arizona Diamondbacks	32	65-97
Philadelphia Phillies	29	75-87
Tampa Bay Devil Rays	27	63-99
Minnesota Twins	25	70-92
Oakland A's	22	74-88
Cincinnati Reds	21	77-85
Detroit Tigers	19	65-97
Florida Marlins	15	54-108
Pittsburgh Pirates	14	69-93
Montreal Expos	8.4	65-97

Table 2 1998 Major League Team Salaries and Records

Attendance Information

The current stadium seats 62,382 and is need of major repair. Essentially everyone (fans, players, the media, the city) HATES the current stadium. Attendance has varied greatly with the performance of the team. Even when the team is terrible, it draws a loyal 1,500,000 (many of these tickets are season tickets owned by companies). For every win over 70, the team can expect about 70,000 additional fans in a typical year. In the best year in team history, they drew 3,700,000 fans (and won 103 games).

Funding

The owners are prepared to spend $20,000,000 of their own cash on the stadium project. The balance will have to be made up by either borrowing the remaining construction costs at 6% compounded daily with quarterly payments due, or by convincing the city to share in the construction costs. The minimum attractive rate of return for this project is 18%.

Conclusions

Students appreciate that communication is an integral part of the design process. They learn that communication is an active and creative process rather than a static tool or artifact, and, that it is a communicative and interactive process that engages writer/speaker and reader/audience.

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Biography

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