

## IMPACT - A Pilot Program

Creating an **I**ntegrated **M**athematics, **P**hysics and **C**ommunication Track in the Engineering Curriculum

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### Introduction

Like many other engineering institutions in this country, the College of Engineering at the University of Miami has encountered problems with student retention, particularly for the freshmen class. During their transition from high school to college, freshmen students often have difficulty adjusting to the new environment, especially with regard to study habits, prioritization of tasks, and time management. Many students fail their first calculus course and lose interest in engineering. Many students who have successfully completed the mathematics sequence are still unable to apply their math skills in solving physical problems (i.e., word problems). Several initiatives have been taken to help students adjust, such as proactive advising, early intervention, peer counseling, tutoring and the “Freshman Forgiveness Program.” All these efforts have produced some positive results. However, to educate students effectively and provide them with an engineering education for a changing world, the entire curriculum requires careful review and re-design with the development of an innovative delivery system.

In 1993, a faculty committee consisting of representatives from various departments was formed by the dean to develop an “innovative curriculum” for the college. In carrying out the task, the committee considered and used as reference several models from other institutions, including Drexel University’s “E<sup>4</sup> Educational Program<sup>1</sup>” and the “Integrated, First Year Curriculum<sup>2</sup>” at Rose-Hulman Institute of Technology. The new engineering curriculum developed at the University of Miami had the following objectives:

1. Facilitate the transition of students from high school to college environment,
2. Expose students to engineering in their freshman year,
3. Make the study of mathematics, basic sciences and English more relevant for engineering students,
4. Provide training in management, communications and leadership,
5. Emphasize engineering fundamentals and interdisciplinary study,
6. Adhere to professionalism and ethics,
7. Integrate design into the curriculum, incorporating social, environmental and legal considerations.

This curriculum was approved by the faculty and steps have been taken for its implementation. New courses have been developed and existing courses are being revised in line with the objectives of the curriculum.

### The Pilot Program

To test and refine the concept, this new curriculum was started as a pilot program with a sample group of students in the fall semester of 1995. Having a small number of students involved would enable concentrated



effort for a good start. The experience and knowledge gained from the pilot program would be used to refine the program when fully implemented.

## A. *Curriculum*

Four courses, namely, Introduction to Engineering, Engineering Mathematics, Engineering Physics and English/Technical Writing, have been jointly developed and taught by an interdisciplinary team of faculty. These courses are integrated to support and supplement each other giving students a holistic picture of these courses rather than a piecemeal experience. All these courses run for two semesters and are required for all entering Freshmen in this program.

### 1) **Introduction to Engineering**

During the first semester, the Introduction to Engineering course started with an orientation to the college environment. Study habits, time management, priority setting and discipline were emphasized. Computer literacy, E-Mail and Internet were introduced. Students were also introduced to the concepts of measurements, errors and statistical analysis. The students were asked to measure hundreds of resistors of the same kind using a digital multi-meter. These data were analyzed using a spread sheet program. In the future, it is planned to reinforce these concepts by asking the students to measure an object with verniers and micrometers and produce an engineering drawing. Other topics included in the past semester were Introduction to Engineering Problem Solving, Engineering and Scientific Computations, Engineering Graphs and Scientific Databases, AutoCAD and Orthographic Projections, Dimensioning and Tolerancing, and C and C<sup>++</sup> language. A simple design project was assigned in the beginning to stimulate the students' interest in engineering. Two other design projects were required later during the semester. These design projects are discussed in more detail below.

During the second semester, students will apply the concepts and tools learned in the first part of the course for more challenging engineering design projects. Concurrently, students will be introduced to various disciplines by working in selected laboratories and machine shop areas. This course will consist of three elements, namely, Engineering Design Process and Problem Solving techniques, Shop Practice and Laboratory Experience, and Group Design Project. They are described in more detail below.

#### a) **Engineering Design Process and Problem Solving Techniques**

Problem Solving is the foundation of all engineering activities. This part of the course is designed to help students develop problem-solving skills and to understand the general process in engineering design. There would be lectures on this subject and illustrations by case study. Certain relevant topics such as Product Safety and Liability, Professional Ethics and Environmental Considerations would be covered by guest lecturers.

#### b) **Shop Practice and Laboratory Experience**

In this part of the course, students will spend three sessions in the Machine Shop. The first session will be orientation to basic machines and tools, shop practices and safety guidelines. In the second and third sessions, students will practice the operation of tools by manufacturing simple products. Students will also visit laboratories in various departments to get exposure to different disciplines. Students will have the opportunity to use instruments in performing measurements or to conduct experiments.



### c) Group Design Project

In the latter part of the semester, groups of students would be engaged in more extensive design projects. The group may choose a project from a list provided by the faculty or the group may initiate their own topic with the approval of the instructor. Faculty members from various disciplines would serve as resource persons to provide consultation and guidance.

## 2) Engineering Mathematics and Physics

While the contents of these two courses were not much different from the regular course, emphasis was given to relating the material to application. More “Word Problems” were assigned and Maple software package was introduced for students to do exercises. Besides, course syllabi and teaching schedules were closely coordinated to ensure that students were provided with proper mathematics background for physics lectures. To train students to work in teams and to enhance leadership, homework assignments were worked out by students in groups of four and students took turns serving as leader. Each leader met weekly with the instructor and would convey the results of this discussion to team members.

## 3) Technical Writing/ English

In the first semester, this course reviews the fundamentals of English grammar and composition, with an emphasis on analysis of text, basic scientific research, and the evaluation and presentation of argument and evidence. Recognizing the intimate connection between distinguished academic writing and research on the one hand, and logic and hypothetical-deductive reasoning on the other, the course integrates coverage of basic writing skills with instruction in informal logic and practice in the analysis and the interpretation of verbal data.

The reading and writing assignments will provide background for topics covered in other Integrated Mathematics, Physics and Communication Track (IMPACT) courses. As far as possible, assignments in the English class correspond directly or indirectly with those of the physics, mathematics and engineering courses. This course will also develop the students' ability to link ideas between and across different fields and courses of study.

In the second semester, this course will provide instruction in the revising, editing, structuring, and formatting of text in a manner consistent with standard professional models in the pure and applied sciences. In the latter part of the semester, students will be taught research techniques in a given subject. In groups of two, the students will choose a research topic, present a progress report on their research, give a class presentation on the full project, and finally submit a full-scale research paper (the last done individually). The class will provide students with an introduction to library research, including use of CD-ROM searches and searches on the Internet. Emphasis will be on oral and written communication skills, explaining technical material to the lay person.

### **B. Student Body**

The pilot program consists of 32 students, about one-sixth of the college's new freshman enrollment. Participation is voluntary. Overall, they are average students who are ready for a calculus course in the first semester. These students enroll in the same four courses and are taught by a team of faculty who work closely with each other. These 32 students are divided into eight groups with four students each. The students work



together as a team in many projects during the semester. These students remain in this program in the first year before taking higher level courses in their respective degree areas.

### **C. Faculty**

The faculty consists of instructors from the Colleges of Engineering and the College of Arts and Sciences who believe in this innovative approach for better education and are willing to participate in its implementation. They work as a team in course development and teaching and meet regularly to exchange ideas. They also hold regular sessions with students for comments and feedback. These faculty members use their experience in the pilot program to further develop the curriculum.

### **D. Facility**

This program is supported with a specially equipped classroom, housing 16 working stations. Each working station has a personal computer with its monitor mounted below the transparent table top so that the table surface can also be used as working area. These working stations are also equipped with other instruments and tools for experiments and hands-on design projects. Two students would share one station. Sharing is part of the training in team work. A ceiling mounted projector is networked to the instructor's station and is used by instructors, for example, to teach C programming language or to show to the whole class while correcting students' grammar or writing style. Students have 24 hour access to this room and these stations actually become students' "home base" during the semester.

## **Some Experiences**

### **A. Selection of Participants**

In the Spring of 1995, incoming freshman students were informed of the availability of this pilot program and were invited to participate voluntarily. Out of more than 100 applicants, 32 were selected to join and 8 were chosen as alternates. The selection criteria were based on mathematics background and applicant's interest in and commitment to this experiment, as indicated on the application form. Since physics is taught concurrently with calculus instead of having calculus as a prerequisite as in the regular curriculum, participants should be readily prepared for calculus. On the other hand, students with advanced placement (AP) in calculus and physics were discouraged as all participants are to enroll in the same block of courses. Still, several of these students decided to participate in the program in spite of their AP credits.

### **B. Teaming of Students**

Participants were pre-assigned to groups of four prior to arriving on campus. The assignment was based on the idea of mixing; each group should consist of students from different majors and academic preparation. It was thought that less qualified students, working with stronger students, would be helpful and the better students would also be benefited by helping others. Since there were seven women students in the program, consideration was given to have more than one woman student in the team to avoid the woman student being dominated. Soon it was learned some students were not in favor of having teams with less qualified students working with stronger students. Certain stronger students were concerned their performance may be affected by weaker students in their team. Also, commuter students had encountered difficulties in meeting with residential students after class. Two weeks into the semester, the students themselves re-organized the groups.



### ***C. Weekly Dialogue Session***

A weekly session was scheduled for informal dialog between instructors and students. Each Thursday afternoon, after the last class, all instructors sit down with the whole class for an informal conversation. Students were encouraged to express their grievances and identified problems to be resolved with the instructors on premises. Their inputs were solicited to refine the program. In the beginning, students were hesitant to speak out in front of the instructors. To encourage free expression, students were allowed to submit written notes in advance and their inputs were read by the program coordinator during the session for discussion and resolution. These dialogue session proved to be very valuable. Many of the students' concerns were addressed immediately and corrections made immediately. Sometimes, students were disappointed that not all their requests could be met, as actions must be appropriate for the whole class. In the latter part of the semester, as the program was refined, students felt weekly session might not be necessary; perhaps bi-weekly or monthly meeting would be enough. Regardless, it was found that these dialogue sessions were very valuable.

### ***D. Physics with calculus concurrently versus with calculus as a prerequisite***

In the regular curriculum, first semester calculus is required as a pre-requisite for freshman physics. However, it is thought that teaching calculus along with physics can provide many benefits. For example, students can immediately apply their mathematics to solve physical problems, making calculus more relevant. Furthermore, as physics is a three-semester sequence and many engineering courses require physics as a pre-requisite, advancing the physics course one semester would allow students earlier exposure to engineering subjects. This would in turn stimulate and reinforce their interest in engineering.

To determine the effects of this arrangement, it was decided that students in this program would take the same final examinations with other students in the regular calculus and physics courses. In general, students in the IMPaCT program performed better. The average score for regular physics students was 53, while IMPaCT students received an average score of 72. In calculus, IMPaCT students also scored better, particularly in "word problems." While there could be other contributing factors and the comparison is too preliminary to be conclusive, these preliminary results are still encouraging. It is believed that with the proper rearrangement of course material, students can be properly prepared for physics with calculus as a co-requisite. On the other hand, teaming with physics and emphasizing application does help stimulate student's interest in calculus and resulted in better handling of the material.

### ***E. Freshman Design Projects.***

During the first semester in the Introduction to Engineering course, the students were exposed to three small design projects. On the first day of classes the students were asked to design a bridge. As part of the project they also had to maintain an engineering laboratory notebook. This project was to give the students a flavor of engineering and it expected them to make use of their intuitive ability. The students did this as a group project. The second project was a circuit building project. This introduced the basics of circuits and was just a fun project. Each student made an electric buzzer that they could take home with them. The last project in the first semester was to design and build a device that can throw a tennis ball at least 30 feet. This project brought together all the different aspects that were covered in the semester. The students also had to maintain a laboratory notebook of their activities. Other than designing and building each project, the students had to write an engineering report with parts and assembly drawings done using AutoCAD. They also had to do some calculations using spread sheets, Maple or a program using C language. This project was done on an individual basis. These design projects received the most positive response from students. They were very enthusiastic

about the hands-on work and all felt the experience was very stimulating. However, some students resisted having to follow the required procedures.

During the second semester Introduction to Engineering class, the students will do a larger design project. This has been described elsewhere in this paper.

### ***F. Team Work***

Part of the process was to introduce students to the concept of Team Work. This was one area that received most resistance from students in the initial part of the pilot program. The students had complaints on the groupings based on a variety of reasons. Most of these disappeared after they were regrouped, based on their choices. The students, however, learned a valuable lesson. They were reminded many times that this is how the real world works and that very rarely do engineers work on their own. The initial difficulties were part of the maturing process for the students. Some of their suggestions, like commuter students having difficulty getting to meet students living on campus, will be taken into account when selecting groups next year.

### ***G. Field Trip***

As part of the whole engineering experience, it is desirable to expose the students to industries and a field trip gives students first hand experience how engineers work. During the first semester, the students visited an assembly plant for a major electronics manufacturer. Another field trip is planned for the second semester. Students responded to this field trip very enthusiastically. They were generally excited about field trips and requested more field trips in the future.

## **Evaluation**

### ***A. Student Evaluations***

Besides weekly dialogue sessions, two written evaluations were conducted during the first semester, one mid-term and one near the end of the semester. Questions in these evaluation forms were purposely made candid and students were encouraged to point out problem areas for future improvement. Questions and students' common responses are summarized below.

#### **1) Mid-term Evaluation**

- a) List three (3) things that you like most about the program.  
Hands on experience; own computer lab; team work; close relationship with instructors.
- b) List three (3) things that you dislike most about the program.  
Same classes - same students; overload of work; calculus & physics not always synchronized.
- c) List three good things about the program.  
(Note: things you like may not be good and things you hate may not necessary be bad !)  
Integrated curriculum; learning (by necessity) to work in groups; faculty-student meetings; hands on project; caring instructors; teaching of concept rather than formula; Own computer lab.
- d) List three bad things about the program.  
Locked-in schedule; pre-assigned groups; some unprepared and lowly motivated students hurting team work; rigidity in requirement - being treated like high school students.
- e) What is your overall evaluation of the program so far? Please be objective.



Except two students, the overall evaluations were positive.

Positive Comments: "Enjoy the program very much, ....group work can be very effective....enjoy the set up of the schedule the most", "...enjoyed the program a lot, it gives me a good idea about what engineering is all about," "I think the program has been a success so far.", "My overall evaluation is that it is good. I am on track with classes and enjoy the benefits".

Negative Comments: "It seems to be falling apart because of how the students were chosen. Too many people were picked who cannot handle it.", "I feel that this program could use many improvements. There is too much work."

f) Suggestions for improvement to the program. Please be specific.

Make sure all students in the program are at the same education level; Let students pick their own groups two weeks into the semester; Better coordination among the teachers; More field trips.

## 2) Semester Evaluation

The semester evaluation was long, with questionnaires for the program and individual course. Since it would take too much space to list them all, only the most relevant questions and some representative samples of students' responses are given below. Note the changes for the positive.

a) Are you, in general, happy with the program?

"As happy as I could be. No complaints!", "Yes.", "It is OK - good".

b) Has the program met with your expectation?

"The program has been what I expected and possibly a bit more.", "Yes", "Almost", "Yes, it is successful in my eyes, but it was a lot harder than I expected.", "Not as many projects as I had expected."

c) About the team work, is the current arrangement functioning well?

"Yes.", "The second arrangement is great.", "Yes, but some students do not care, and still expect you to do the work for them.", "Our own chosen groups is running well.", "we work separately."

d) About the design projects, do they help to inspire your interest in engineering?

"I really like the project except for the report, etc.", "The projects are helpful.", "Yes, they made me think I like doing this...", "Yes, working in groups.", "They are very interesting; but it's a little bit too much work to finish them. I've learned a lot about the "real world".", "Yes, but sometimes they are a burden when we have many other projects to do - they can be very stressful.", "I enjoyed working on the design projects the most, out of all the assignments. The hands on work is more interesting than book work.", "They let me use talents and interests for engineering. The projects are one of the best parts.", "The projects are fun. I want to design a robot."

e) What is your overall evaluation of the program so far?

"Good for now.", "Very good.", "I think it helps us develop good social skills for the work environment."

f) Would you recommend this program to your friend? Why?

"Yes, this program made it a whole lot easier to adapt to college and its expectations.", "Yes, because we have learned many things that would not be covered in the regular freshman engineering courses.", "Yes, because it is a great program.", "Only if they are extremely good students.", "Yes, the work is hard, but we are learning.", "Yes, because it encourages and helps you learn more."

## B. Faculty Observation

A variety of things came to light as a result of the past semester's experience. They are as follows:

- 1) Taking several classes together helped them to learn from each other and with making friends
- 2) Since the mathematics and physics teachers worked closely with each other, calculus as a co-requisite instead of pre-requisite was not a serious problem



- 3) Having a common set of rules for all the four classes was a great help
- 4) Most students had taken algebra in the early part of their high school career and had forgotten most of it
- 5) Students lacked good study habits and were poor at time management.
- 6) Having physics at the same time as calculus seemed to have helped the students in understanding “word problems”
- 7) Having the English class in a computer laboratory was very helpful as the students can do their writing on the computer
- 8) Overhead projection equipment connected to the computer was very helpful in teaching different software like Maple, Excel, AutoCAD, etc.

## Discussions

- 1) While it is too premature to draw any definite conclusions, the pilot program seemed to have accomplished some of its objectives. Students are better motivated by early exposure to engineering subjects. They appreciated mathematics more, realizing its applications to physical problems. Students in the pilot program, in general, performed better in the calculus course, especially in “word problems.” By integrating calculus with physics, students in the program not only could succeed in physics without having calculus as a pre-requisite but also scored higher compared to other engineering freshmen in the regular physics class. There could be other factors contributing to this better performance, but it is believed that learning mathematics and physics together does have a positive impact.
- 2) Integrating English with science and engineering was an interesting attempt. There was debate whether it should remain a creative writing course. To have a better understanding of science subjects and engineering requirements, the English instructor voluntarily sat in the physics class and maintained frequent interactions with engineering instructors. Reading assignments were geared more toward the sciences and students were guided to prepare technical reports for the engineering course. Students were required to use word processing to do their writing. The correction of grammar and writing styles by the instructor were demonstrated to the whole class through a projector connected to the instructor’s station. Students’ responses were in general very positive and many became very fond of the English course. The instructors also felt students performed better as compared to other students in regular English classes.
- 3) The Introduction to Engineering course is an exciting experiment. Even though there were some minor problems, such as grouping and scheduling in the beginning, the hands-on experience, early exposure to engineering, and team work definitely had a positive impact on the students. Students were much more enthusiastic about engineering and, by the end of the semester, had a better idea of their objective of study. Experience learned from this first year will be used for more refinement in the future.
- 4) Working closely with a small group of students has helped the faculty discover or confirm many problems encountered by engineering freshmen. One major problem is students’ preparedness for mathematics. It is not that these incoming freshmen did not have the required mathematics subjects in high school. Even students with very high SAT scores have difficulty comprehending the material. A good number of students forgot the mathematics they took as sophomores and juniors in high school and became discouraged. A comprehensive review course before the semester starts seems a necessary remedy.
- 5) A very confusing but frustrating issue is the failure of many seemingly high potential students. Many freshmen who were high achievers in high school and in SAT or other tests, had difficulty in coping with college work. Some students were over-confident and did not put in the effort. A good number of students merely did



not develop good study habits. Many said that that they did not have to put in much effort in high school and simply admitted that they did not know how to study. Study habits, prioritization, and time management are the major problems that these students had to learn. In the next phase of this program, special efforts will be devoted to help students overcome these problems.

6) We were extremely fortunate in having a team of devoted faculty members who believe in this new concept and were willing to put in the special effort needed in its implementation. The leadership from the administration of the University of Miami and whole-hearted support from the department chairmen and faculty of both the College of Arts and Sciences and the College of Engineering were the critical ingredients needed for making the program possible.

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Dr. Ramarathnam Narasimhan is the Director of the Advising Center for the College of Engineering. The advising center does academic advising for all incoming freshmen and sophomore students. He is also a faculty member in the Department of Mechanical Engineering. He has been intimately involved in the development of courses for the IMPaCT program and is one of the people teaching the Introduction to Engineering class. He has his degrees from University of Madras, India, Indian Institute of Technology, Madras, India and the University of Miami.

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Samuel S. Lee received his Ph.D. degree from the University of California, Berkeley and joined the faculty in the department of Mechanical Engineering at the University of Miami in 1965. He became a full Professor in 1973 and served as the department chairman in 1975, prior to being appointed Associate Dean of the College of Engineering in 1978. His research areas are in Fluid Mechanics and Heat Transfer. He was the chairman of a faculty committee which was appointed to develop an innovative curriculum for the College and is responsible in the planning and implementation of the IMPaCT Program.

