Gateway Engineering Education Coalition

Proceedings
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Opening Remarks

Eli Fromm, Gateway Central

Welcome to the home of the 1993 National League champion baseball team! I want to briefly review the purpose of this meeting and the way in which I hope we will function. We wanted to have the meeting as an opportunity for the people who are working on the various projects in Gateway to get together, communicate, present what has been accomplished, and what the plans and thoughts are as we move ahead.

Because of the busy agenda, there will be only a short time for perhaps one or two questions after each presentation. But we have arranged, as you see in the agenda, for a period of time at the end of each day to have an in-depth discussion. I hope that at that point, you will feel comfortable to critique what has been said during the day. I hope that no one feels offended by any critique because the purpose is for us to comment to one another and to benefit from the thoughts that we all have. Critiquing is a critical part of the conference for project investigators and also helps Institutional Activity Leaders (IALs) and Governing Board members, who are here. It is an important ingredient that we have not been able to have yet without this conference.

The time allowed for each presentation is fifteen minutes. We will set a timer for fourteen minutes to signal the speaker to finish and to take a few questions. Discussions will be recorded (tape recording) so that we can include them in the proceedings. Please identify yourself when you pose a question or make a comment. Also, there will be some video-taping and still photos will be taken.

I want to also mention that there are some handouts in the back of the room, including the Gateway Directory. However, the Directory needs continued updating. Therefore, before you leave, please provide the missing information (E-mail address, fax number, etc.) so that we can issue an update. Communication is our most difficult issue. It is the necessary ingredient to get our teams working together and any means that we can use to foster that, including the Directory, is very important. Hopefully, we are all using E-mail to communicate. At Gateway Central, we are investigating desktop video conferencing capability. The technology is here. The biggest problem is the cable highway among the institutions. We cannot afford to establish a dedicated network between all of our institutions but reasonable quality videoconferencing may be available at phone line bandwidth. There will be more on this later.

At the end of each day, you will notice that there is a discussion session and that we have facilitators identified. The idea is that those two facilitators, plus the session chair of the day, will stimulate a discussion. Please don't let those three people be the only discussion participants. The intent is to get you involved.

Finally, during the next two days, please introduce yourselves to Andrea Shumsky and Ed Cotilla who many of you have talked to on the phone but never met. They have been working so hard to get this all together. I want to thank them for their work .

ENGR 143-144, Engineering Concepts and Applications: A New Freshman Engineering Course

W. Sanford Topham, Case Western Reserve University
Mark R. De Guire, Case Western Reserve University
Arthur A. Hucklebridge, Case Western Reserve University

A year long freshman engineering course is being developed based on concepts from the E4 program at Drexel University. The main goals of this course are to introduce freshmen to engineering, show the integration of math, science and engineering, and provide practical laboratory and design experience.

It is important for students who are considering engineering as a career to become familiar with the field, understand what is involved in the practice of engineering and be introduced to some of the professional responsibilities and policies.

These students have been exposed to math and science throughout their secondary education and should understand as early as possible how math and science are used in engineering problem-solving and design. Thus math and science concepts taught in the freshman year will be related to engineering problems throughout the course.

This course provides the opportunity to incorporate new methodology and technology in presenting the course material. The fiber-optics network (CWRUnet) and the development of the electronic library will greatly increase the amount of information available to the students. This will permit the way in which the course is taught to be significantly modified; from the present strict lecture method to an active learning approach. In active learning the students are presented with a problem, question or situation, and they then conduct a search to find related material. While lectures will be used, it is expected that as the course develops the concept of active learning will significantly alter the way the academic material is presented. With information linkages

provided through a electronic library of lecture notes, reference material, science and math concepts, as well as multi-media presentations, the student will have large amounts of organized information available. The process of acquiring the information will not only be more exciting but will enhance the learning process.

Making materials available in the electronic format will allow the lecture materials to be more informative and interesting and will give the student access to the material, via the network, as they study in their dormitory room or other locations on campus.

The laboratory will be an important part of the course. Laboratory experiments will be performed using on-line computers to collect and evaluate data. These computers will provide instructions and information on the experiment and the operation of the laboratory equipment. Open-ended design projects will use the large information base to give the students the capability of using design concepts to a significant depth even at the early stages of their education.

This new freshman course will provide an early, central focus on engineering and will provide a base on which the engineering curriculum can be built in several ways:

- teaching techniques that take advantage of the latest technology will be developed

- an extensive electronic reference base will be established on which other material can be easily added as the student moves through the four year curriculum

- the students will have acquired laboratory experience, have studied engineering concepts and will be familiar with design concepts; all of which will assist them in their upper division courses.

Because the students will have direct access to information that allows them to rapidly recall previously learned principles, a great deal of "re-teaching" of fundamentals will be unnecessary . Thus as new concepts and approaches to engineering education are developed for the freshman course, there will be a natural evaluation of the upper division courses to determine what changes should be made in curricular structure, teaching methodology, multi-disciplinary integration of material, and the introduction of design concepts and team building.

The plan is to continue to develop the freshman course with more involvement of the other coalition schools. Through workshops and other methods of sharing information it is evident that there exists a great deal of material that can be applied directly to course and that much of the material developed at CWU can be used by other schools. An FTP server which will allow the direct transfer of programs, simulations, lecture modules, etc. between schools is being developed. With a stronger coalition effort to make more detailed information available from each of the other schools, shared information should provide a significant amount of the course material.

The long range goal is to offer the freshman course to all new students interested in engineering and perhaps to those interested in applied natural science by the Fall of 1995. The course is being offered on a trial basis in the Fall 1993 to 30 students. After a review, any necessary changes will be made and the course will be offered to about 25% of the incoming engineering freshman (approximately 100 students) in the Fall 1994.

The course was developed by a committee of faculty from each engineering department, math, physics and chemistry. After the basic philosophy and outline of the course was

determined, three faculty were chosen to organize the three sections of the course: computers and computer programming; materials and chemical engineering; mechanical, electrical, systems and biomedical engineering. Approximately twelve faculty members are providing material and/or presenting lectures.

While the course is structured on the main engineering topics, an interdisciplinary theme runs throughout the course.

Computers & Computer Programing

The course begins with an introduction to computer systems and to the computer as a tool which is used in the solution of engineering problems. The students are taught how to use CWRUnet and in the use of network capabilities such as E-mail, electronic bulletin boards and information access.

To provide a strong base on which an engineering student can build an understanding of the computer and its uses, computer programming is taught using PASCAL, a language which allows the student to gain an insight into the structure of computer languages. Programming experience is gained with discussions on input/output, selections using "if", repetition using "for", data structures, control using "while", "repeat" and the use of subprogram procedures and functions. Practice with these programming basics will allow the student to write programs through out the course to collect and analyze data and control the laboratory experiments.

Measurement theory is used early in the course to give the students an introduction to such concepts as precision and accuracy and provides a convenient means for the collection of data from real problems to be used in the basic programs being written.

Materials & Chemical Engineering

The second main section of the course introduces the fields of chemical engineering and materials science and engineering. This choice was partly dictated by what other "basic" courses the engineering freshmen at CWRU will have had by the ninth week of their first semester: some college-level chemistry and calculus, but no physics. That is, the students are prepared for lectures that apply chemistry and some calculus to engineering problems, whereas mechanics and related concepts are slated for the second semester when the physics sequence starts. The second reason for starting the discussion of specific engineering fields with materials and chemical engineering was conceptual: these disciplines supply much of the "stuff" from which other engineers produce their solutions.

This concept — synthesis of useful substances — is a common thread between chemical and materials engineering and serves as the theme of the first few lectures. First, an introductory lecture defines these fields and discusses what they have in common with all engineering disciplines:

- A foundation of basic science: math, chemistry, physics, and biology;
- Application of basic science to meet society's technological challenges;
- Design as a vehicle for meeting those challenges;
- Societal boundaries on technological developments, including economics, environmental impact, and ethical considerations.

The theme of synthesis is developed in two lectures and two laboratory exercises. In the first lecture, materials processing is discussed, that is, the production of useful substances and the fabrication of those substances into useful objects. This starts with a brief survey of some outstanding materials processing achievements from ancient times: Chinese bronze, Damascus steel, Greek pottery, European stained glass, paper, and textiles. Differences and similarities in the process of technological advancement between ancient and modern times are discussed, with respect to reliance on empiricism versus basic science, and the role of technology transfer.

The second "synthesis" lecture uses the fabrication of barium titanate, a ferroelectric and piezoelectric ceramic, to illustrate several chemical and materials-processing concepts: length scales from the atomic to the macroscopic; solid-state reaction rates, with their dependence on temperature and particle size, versus ceramic synthesis from liquid solutions; and meeting the fabrication challenges posed by a device design, in particular that of a multi-layer ceramic capacitor.

The laboratory exercises associated with these lectures consist of two routes to the synthesis of barium titanate. The first is the solid state reaction of barium carbonate and titanium oxide, whose progress is monitored by weight loss (from release of carbon dioxide from the carbonate) as a function of time and temperature. The second route is the coprecipitation of a mixed barium-titanium oxalate from liquid solution, with subsequent heating to form barium titanate at much lower temperatures than is possible with the solid-state route.

At this point, the stage has been set to begin discussing materials applications based on their properties. Two classes of materials properties are described:

- Properties that are defined as the ratio of a material's response to the environmental stimulus that elicited the response.
- Properties that describe a material's behavior during irreversible physical or chemical change, such as hardness and corrosion resistance.

The first category is represented by a matrix of stimulus-response ratios. Not only does this hearken back to the use of arrays in the programming part of the course; it also introduces the concept of “natural” stimulus-response pairs (such as electrical conductivity, the ratio of current density to electric field) that make up the diagonal of the matrix, as opposed to “coupled” properties such as piezoelectricity (the appearance of mechanical strain under an applied electric field) that make up the off-diagonal terms of the matrix.

The dependence of these properties on environmental parameters such as temperature allows the introduction of the topic of materials as sensors or switches, depending on the gradualness or abruptness of their property variation.

RTD temperature sensors, zinc oxide varistors as surge protectors, superconductor switches, and piezoelectric electromechanical transducers are discussed as examples. The associated laboratory exercise measures the resistivity versus temperature of the barium titanate materials made in the preceding labs. These compositions, specially doped to show a several order-of-magnitude increase in resistivity at the Curie temperature, illustrate the use of PTCR (positive temperature coefficient of resistance) thermistors as self-regulating heating elements.

In the second semester, after concepts of mechanical resonance have been discussed, there will be a laboratory exercise on piezoelectric electromechanical transducers. This exercise will illustrate various designs that can be used to amplify the small strains associated with the piezoelectric effect; the efficiency of conversion of electrical work to mechanical and vice-versa in these devices; and the sometimes catastrophic effects of resonance (when the piezoelectric pieces are shattered by being driven near their resonance frequency!)

Four additional lectures are planned in the areas of polymer properties and characterization. The laboratory exercise will include the measurement of polymer viscosity (a “natural” stimulus-response property) as a function of monomer concentration in solution. Two additional lectures and a lab will focus on the chemical engineering of materials processes, including bread making.

Throughout these lectures, several aims have been kept in the forefront:

- To show a continuum from synthesis of a material, to the design of a device, to the production of that device and its eventual use in some electrical, mechanical, or other application;
- To illustrate the basic science behind an engineering solution to a practical need;
- To show areas of intersection between different disciplines of engineering.

In the delivery of the material, emphasis has been placed on the use of electronic presentation tools such as computer slide presentations, video clips, and animations, while the labs are intended to provide hands-on experience with the processes and devices described.

Electrical, Mechanical, Systems & Biomedical Engineering

The second semester of this course in directed toward engineering application of basic math, science and computational skills which the students have been thus far accumulating. Specific areas of application which are presented include circuit theory, mechanics, signal processing, instrumentation, mathematical modelling and simulation.

Within the areas of application enumerated above, a large number of specific topics are discussed. Among these topics are Ohm's Law, Thevenin's Equivalent Circuit, Wheatstone Bridge circuits, alternating current, elasticity, beam theory, resistance strain gages, composite materials, vibrations, LRC circuits, computational complexity, chaos theory, piezo-electric materials, biomedical measurements, digital filters, image and signal processing, control theory, linear programming and optimization.

While these topics appear to be extremely wide-ranging (and are), an underlying theme behind this course is the commonality of the analytical tools that are brought to bear within the various fields of engineering. A second order differential equation, or more specifically its solution, is shown to have application not only in understanding harmonic motion, but also in electrical circuit design, in mechanical vibration analysis and in signal processing. The application of basic circuit theory, along with an understanding of the mechanical-electrical properties of various materials, is shown to have allowed the development and application of a wide range of instrumentation, which has not only added to the understanding of physical phenomena, essential to all fields of engineering, but has also brought about the possibility of active, on-line control of many engineering processes.

An important concept, repeatedly brought up in the course, is the idea that the development of an appropriate mathematical model, and the analysis of that model, is the basis by which all engineers understand, measure and control physical phenomena for the benefit of society. While that model may be more or less complex for a given situation, and its application more or less robust, all but the most simplistic of models typically can be analyzed more efficiently (and often only) with numerical algorithms, carried out on digital computers. The development of efficient algorithms and computational strategies is shown to lend itself to such applications as real-time control, simulation and optimization.

Limitations of mathematical models, such as linearity or stability, are also repeatedly emphasized. The point is made that only by understanding the underlying assumptions behind a mathematical model, its solution algorithm, and the physical phenomenon to which it is being applied, can an engineer define (and respect) the ranges of behavior for which the model is appropriate. Case studies will be utilized to illustrate the positive results of proper application of rigorous engineering analysis, as well as the negative results of not respecting the limitations of mathematical models.

The importance and quantity of interaction which occurs among the various engineering disciplines is also brought out repeatedly in the course. A laboratory experience such as the bike/rider monitoring exercise, carried out by student teams, emphasizes the potential inter-disciplinary nature of many engineering projects. The common language of mathematical modelling, solution algorithms and experimentation is shown to allow ready and effective communication among engineers with varied specializations.

Development of communication skills, verbal, written and graphical, is also an important aspect of the second semester of this course. In addition to the weekly written lab reports, the student are required to research a topic of their choice (with approval), either individually or on small teams, for seminar presentation. The development of audio-visual material for the presentation is strongly encouraged, and appropriate software (PowerPoint, Photoshop, QuickTime, MathLab, etc.) is made available on the laboratory computers (on the students' own time) and over the network, for that purpose.

A Core Curriculum for Engineering Majors at Polytechnic University

Prepared by:
Roger P. Roess, Polytechnic University

Introduction

In Summer of 1992, Polytechnic University undertook to redesign its undergraduate curriculum for all engineering majors. Two global objectives guided the development of the curriculum: (1) to re-establish an appropriate balance between depth and breadth components of the engineering curricula, and (2) to provide a structure within which the objectives and framework of Drexel's E-4 program could be quickly implemented for all Polytechnic students. The second of these responds directly to the objectives of the coalition.

Beyond the two global objectives, the development of the core curriculum was guided by seven more specific objectives:

- Early immersion of engineering majors in the study of engineering;
- Integration of all aspects of engineering curricula;
- Increased use of modern educational technology;
- Improved communications skills for all engineering graduates;
- Enrichment of the curriculum;
- Making engineering the intellectual focus of all portions of engineering curricula; and
- Increasing educational efficiency.

Many of these objectives are borrowed directly or indirectly from those guiding the development of the E-4 program. Others respond to issues more unique to Polytechnic.

While communications skills is a universal problem for many engineering graduates, many of Polytechnic undergraduates come from an ESL background, even though they are native Americans. This complicates the problem, and makes its remedy all the more important. Increasing educational efficiency addresses Polytechnic's unique environment in which bifurcation of programs and duplication of basic subject offerings has led an economically inviable delivery system.

Establishment of core curriculum specifically aimed at engineering majors is an easier task at Polytechnic than at many other universities. Almost 95% of all undergraduates at Polytechnic are enrolled in engineering majors or computer science. Thus, all departments, including those in supporting departments are already comfortable in teaching primarily engineering majors.

Participants

The development of the core curriculum involved a large number of faculty members across all departments of the university. The effort was led by an Ad-Hoc Committee on Core Curriculum, which consisted of:
Dr. Roger Roess, V.P. for Academic Affairs
(Chair)

Dr. Nancy Tooney, Assistant V.P. for Academic Affairs, Assoc. Prof. of Chemistry

Dr. Pamela Kramer, Assistant Provost for Freshman Studies, Assoc. Prof. of Psychology

Dr. William McShane, Head, Dept. of Mechanical and Industrial Engineering

Dr. Len Shaw, Dean, School of Electrical Engineering and Computer Science

Prof. Donald Hunt, Prof. of Electrical Engineering

Dr. Donald Scarl, Prof. of Physics, Chair-Undergraduate Curriculum and Standards Committee of the Faculty

Dr. Ann Eisenberg, Head, Dept. of Humanities and Communications

Dr. Wolhee Choe, Prof. of Humanities, Chair- Educational Policies Committee of the Faculty

Dr. Louis Menashe, Head, Dept. of Social Sciences

Dr. Emeric Deutsch, Prof. of Mathematics

Dr. Henry Ruston, Prof. of Computer Science

Dr. Donald Schleich, Head, Dept. of Chemistry

Dr. Volkan Otugen, Assistant Prof. of Aerospace Engineering

Dr. Walter Zurawski, Associate Prof. of Chemical Engineering

Dr. Shirley Motzkin, Prof. of Biology

Structure of the Core Curriculum

The core curriculum for engineering majors consists of five major components:

- The Liberal Arts Core
- The Mathematics Core
- The Basic Science Core
- The Engineering and Computer Science Core
- Writing Across the Curriculum Program

A. The Liberal Arts Core (27 credits)

The liberal arts core curriculum consists of 27 credits intended to insure minimal general world literacy and communications skills for all engineering graduates. While this portion of the curriculum was one of the most controversial, the final structure included three credits beyond the ABET minimum for this area.

All students are required to take the following courses:

HU 101 Writing and the Humanities I, OR
HU 103 Writing and the Humanities-ESL I

HU 200 Writing and the Humanities II
HU 111 Professional Report Writing
SS 104 Contemporary World History

All courses are 3 credits each. The HU 101/103 sequence is unique in that it combines freshman composition with introductory study of humanities content areas.

Each student completes the 27-credit liberal arts core by selecting one two-course sequence in the humanities and one three-course sequence in the social sciences. Humanities sequences are available in literature, fine arts, and philosophy. Social science sequences are available in history, history and philosophy of technology, economics, psychology, and behavioral sciences. Many of the courses making up these sequences have been revised to reflect an increased emphasis on events related to technology.

B. The Mathematics Core (17 credits)

The mathematics core represents a significant revision of Polytechnic's math sequence for engineering majors. The core consists of four math courses that all engineering students take. Each engineering discipline must specify an additional required mathematics course in probability, probability and statistics, linear algebra, numeric methods, or advanced calculus.

The four common courses required of all engineering majors are:

MA 106 Calculus I (4 cr)
MA 107 Calculus II (4 cr)
MA 108 Differential Equations and Numerical Methods (3 cr)
MA 109 Multidimensional Calculus
(3 cr)

The most significant revision in this curriculum is the adoption of the "Harvard Method" for teaching calculus. This method is strongly computer-based, and focuses on the use of calculus in addition to pure theory. All concepts are demonstrated in three ways: algebraically (the traditional method), graphically, and numerically. The latter two require in-class use of computers and software for illustration purposes. Engineering applications will also be introduced into lectures and recitations.

A 2-credit course, MA 105- Introductory Calculus has also been created for students who are weak in advanced algebra and/or trigonometry preparation. About 75% of all undergraduates are placed in this course (by examination). The high percentage reflects the results of the NYS-mandated "sequential mathematics" high-school curriculum, which leaves most students poorly prepared in these critical areas.

Because of this, the Faculty is now considering a modification which would add two credits to the total degree requirements and MA 105 to the Mathematics Core. Students would be permitted to place out of this course with advanced placement credits or by taking an examination for credit.

C. The Basic Science Core (16 credits)

The basic science core consists of 3 physics courses and 2 chemistry courses with associated laboratories, as follows:

CM 101 General Chemistry I (2.5 cr)
CM 111 General Chemistry Lab I (0.5 cr)
CM 102 General Chemistry II (2.5 cr)
CM 112 General Chemistry Lab II (0.5 cr)
PH 107 Mechanics (3 cr)
PH 108 Electricity, Magnetism, and Fluids (3 cr)

PH 118 Physics Lab for PH 108 (0.5 cr)

PH 109 Waves, Optics, and Thermodynamics (3 cr)
PH 119 Physics Lab for PH 109 (0.5 cr)

The Chemistry sequence has been revised to reflect a greater emphasis on materials chemistry, and to provide overview coverage of all of the major areas of chemistry.
The Physics sequence features greater use of experiential learning in the laboratory, and is using specialized software for self-tutoring and occasional classroom use.

D. The Engineering and Computer Science Core (22 credits)

The centerpiece of the core curriculum is the engineering and computer science core. It is intended to insure that all students understand the underlying principles of engineering in general before being immersed in a disciplinary specialty. This is the principal means by which Polytechnic is restoring a measure of *breadth* to its engineering curricula.

The Accreditation Board for Engineering and Technology (ABET) defines six fundamental areas of engineering:

- Mechanics
- Electric and Electronic Circuits
- Materials Science
- Thermodynamics
- Transport Phenomena
- Computer Science (NOT programming skills)

The engineering core starts with a new freshman engineering program, and includes a common computer course. Thus, all students take three basic courses in their freshman year:

EG 101 Introduction to Engineering (3 cr)
EG 102 Introduction to Engineering Design (3 cr)
CS 200 Programming Methodology (3 cr)

These three courses will expose students to elements of all of the six basic elements of engineering.

EG 101 is structured as follows: a one-hour common lecture (taught to all freshman in a large group), a three-hour laboratory emphasizing observation, measurement, and manipulation of basic phenomena. It is a hands-on, experiential curriculum. One-hour recitations are conducted in groups of 18-20. Many senior engineering are involved in lectures and recitations for the program. Each student makes an oral presentation at least five times during the semester, in addition to submitting formal laboratory reports each week.

EG 102 is similarly structured, except that lectures focus on design methodology and process, and the laboratory consists of simple group and individual design projects and competitions. Recitations revolve around progress reports given by students. Students are urged to use available projectors and graphics packages to enhance their presentations.

CS 200 stresses fundamental programming logic and methodology. The course uses PASCAL, with some FORTRAN included. The choice of a language was a major discussion point. Most faculty preferred "C" as a language for general use. The computer science faculty finds "C" not sufficiently structured for a first course in programming theory. It is likely that this debate will continue for some time.

To complete the engineering core, each engineering discipline must require three courses in its program, each of which focuses on one of the six principal areas of engineering identified by ABET. At least one of these must be taught by an engineering department other than the major department. For these purposes, computer science is treated as an "engineering" department.

The last point was also one which generated significant controversy. The compromise of accepting computer science as an engineering department made it easier for the electrical engineering curriculum to meet the core requirements.

In addition to three courses addressing specific engineering fundamentals, each discipline is required to include 4 credits of senior design project in its curriculum.

This the engineering and computer science core is made up of:

9 credits of common courses.
9 credits of fundamental courses.
4 credits of senior design project.

In practice, many departments will share common fundamental courses, creating even greater breadth in the curriculum.

E. Writing and Speaking Across the Curriculum

In struggling with the pervasive problem of improving the communications skills of engineering graduates, it was quickly determined that constant practice and reinforcement throughout the curriculum would be needed.

In addition to the communications skills component of the liberal arts core, each department is called upon to identify courses as *writing and speaking intensive*. In such courses, explicit significant writing and/or speaking assignments will be included, and the final grade will be based upon both the substance of the presentation and the quality of the presentation.

Every full-time student will have at least one such course in every semester of their undergraduate study.

In practical terms, all humanities and social science electives are designated as "writing and speaking intensive." The freshman engineering sequence, EG 101/102 is also so designated. Engineering departments have identified key junior and senior courses which will also carry this designation. Virtually all senior design projects will be designated as "writing and speaking intensive."

In addition to designated courses for specific writing and speaking content, Polytechnic has opened a "writing/speaking learning center" staffed by professional tutors. Students may access the center for help by scheduling regular visits, or on an occasional drop-in basis, although the latter is discouraged. In addition, freshman classes designated as "writing and speaking intensive" have been assigned specific tutors to work with students as needed.

F. Summary of the Core Curriculum

The core curriculum specified 82 credits of a 136-credit engineering degree program. This leaves 54 credits to be determined by discipline beyond the core requirements. In addition, 9 credits of engineering core courses are defined by discipline, as are the 4 required credits of senior design project. Thus, 67 total credits are specified by discipline.

In practical terms, this represents a reduction in the number of credits traditionally specified by engineering discipline at Polytechnic. To accommodate the core curriculum, most engineering disciplines had to reduce disciplinary credits by from 9 to 12 credits. While this was a difficult procedure, the number of credits previously defined by discipline is a measure of how far the depth component had compromised the breadth component of the curriculum.

The overall balance created is a significant improvement over the immediately preceding curriculum structure. Students now learn that "engineering" is indeed a cohesive profession before jumping into the depths of a particular discipline.

Status and Schedule

This project is essentially complete and in place. The proposal for a core curriculum was developed over the summer and fall of 1992. During spring of 1993, extensive discussions with each department, and with relevant faculty committees took place. Despite what was often a heated debate, the Faculty unanimously approved the curriculum in March of 1993.
Efforts related to the creation of the freshman engineering curriculum are covered in another paper. To accommodate increased computer usage, Polytechnic expanded and updated its laboratories on both of its undergraduate campuses. Mobile computer units with signal transformers and 27-inch monitors

were provided for classroom use, although the option of equipping several classrooms with fixed facilities is still under consideration.

Pilot offerings of Harvard Mathematics and EG 101 were held in spring of 1993. In fall of 1993, the freshman portion of the core was fully in place, and all incoming freshman were taking this curriculum.

Only through the active participation of a substantial number of faculty was such a large undertaking possible. Active support from the Provost, the President, and the Board also provided impetus.

Following adoption of the core by the Faculty, all engineering departments had to revise their disciplinary curricula to accommodate the core. Despite the short time available, all departments had completed this process, and all engineering curricula were approved by the Faculty at its final meeting in May 1993. Changes in disciplinary curricula will be phased in over four years, as students starting the core in Fall 1993 move through the program.

An unexpected, but happy, byproduct of the core curriculum was the adoption of portions of the core by the mathematics, chemistry, and physics undergraduate curricula, providing a base on commonality between engineering students and their math and science counterparts.

Copies of the full core curriculum (including individual course outlines) were delivered to Gateway Central in Spring of 1993.

Closing Comments

Upon joining Gateway, the Polytechnic stood with a very traditional set of engineering curricula. Virtually all curriculum development took place within individual departments, with Faculty committees acting as reviewers, not iniators of curriculum evaluation and renewal.

To take an active role in Gateway, it was necessary for Polytechnic to quickly re-orient its curriculum to embrace the principles of E-4, and to create a structure within which additional lower and upper division curriculum development could take place with Gateway partners.

Many conditions contribute to making major change possible. Recruitment and retention problems has led to fiscal woes which were apparent to one and all at Polytechnic. While many were uncomfortable with the pace of change, virtually all were ready to accept the need to do so.

The relationship to Gateway was a mutually-reinforcing one. The goals and objectives of Gateway, and the support provided, were evidence that the directions under consideration were in fact the wave of the future, and were not as radical as they first appeared.

Now, with a core curriculum in place, Polytechnic is structured to implement additional lower- and upper-division innovations in concert with Gateway partners.

It is difficult to understate the enormity of change which has taken place at Polytechnic in the course of a single year. The fact that it was accomplished without alienating individual or groups of faculty is even more surprising.

Now, the job is to monitor the progress and success of this new curriculum, and to make changes and revisions as needed. An ad-hoc committee will be established, in coordination with the Undergraduate Curriculum and Standards Committee and the Educational Policies Committee of the Faculty with a specific mandate to do this.

Ultimately, curriculum renewal must not become a once-every-decade event. It must be an ongoing, vibrant process at all times. The world continues to move on, and we must move with it, or be left behind wondering where all of our students went.

Freshman Engineering Courses at
Polytechnic University

Prepared by:
Charles A. Kelly, Polytechnic University

Introduction

During the summer of 1992, in conjunction with it's development of a new core curriculum for all engineering majors, Polytechnic University faculty, administration, and staff undertook the design and development of two new freshman engineering courses. Three strategic objectives were established at the beginning of this activity: (1) To provide entering freshmen with meaningful knowledge and experience pertaining to what engineers do, the problem solving processes they use and some exposure to the modern tools and technology they employ. (2) To provide upper level freshmen with an understanding of the Engineering Design Process, including cost, quality and manufactureability considerations and an opportunity to practice basic skills in practical design and construction projects and (3) To give students in both of these courses the opportunity to work in small interdisciplinary teams to promote the breadth of their understanding, develop interpersonal skills and to practice and hone their writing and verbal capabilities. These strategic objectives are consistent with, and supportive of, the global objectives set out by the new core curriculum and are therefore in turn, responsive to the objectives of the coalition.

Participants

The design, development, pilot testing and full implementation of these new freshman engineering courses involved a large number of faculty across all departments of the university. They are:

Dr. Roger Roess, V.P. for Academic Affairs.

Dr. Nancy Tooney, Assistant V.P. for Academic Affairs and Associate Professor of Chemistry.

Dr. Pamela Kramer, Assistant Provost for Freshman Studies and Associate Professor of Psychology.

Dr. William McShane, Head, Department of Mechanical and Industrial Engineering.

Dr. Len Shaw, Dean, School of Electrical Engineering and Computer Science.

Professor Charles Kelly, Industry Professor of Industrial Engineering and Director of Freshman Engineering.

Professor Frank Cassara, Professor of Electrical Engineering.

Professor Carmine D'Antonio, Professor of Metal and Materials Science.

Professor Donald Hunt, Professor of Electrical Engineering.

Professor Sunil Kumar, Assistant Professor of Mechanical Engineering.

Professor Volkan Otugen, Assistant Professor of Aerospace Engineering.

Professor Sotiris Pagdadis, Assistant Professor of Civil Engineering.

Professor Donald Scarl, Professor of Physics.

Professor Peter Voltz, Assistant Professor of Computer Science.

Professor Walter Zurawsky, Assistant Professor of Chemical Engineering.

Structure Of The Freshman Engineering Courses

All entering (first semester) freshmen are required to take EG101, Introduction to Engineering. It is a three credit, laboratory intensive, multidisciplinary course consisting of a weekly one hour lecture, three hour laboratory and a one hour recitation.
All upper level (second semester) freshmen are required to take EG102, Introduction to Engineering Design. It is a three credit, design intensive, multidisciplinary course consisting of a weekly one hour lecture, three hour project laboratory and a one hour project reporting recitation.
Both courses introduce the student to a variety of computer based tools for their skills development and use in completing their course requirements. They are: 1) Word Perfect for word processing, 2) Excel for spreadsheets, 3) LABview for simulation and 4) Design CAD for design and analysis.

Development Of The Courses

During the summer of 1992, a broad outline of both courses was developed with the involvement of most of the participants heretofore mentioned. In preparation for piloting EG101 (one section of 18 students) in the Spring of 1993, the detailed syllabus and facilities for this course were put in place during the fall of 1992. A similar process was repeated in the Summer of 1993 to 1) develop the details of EG102, for piloting in the fall of 1993 (now) and 2) scale up the pilot version of EG101 to accommodate over 300 entering freshman at two campus locations, also in the Fall of 1993 (now).

Facilities For The Courses

Three identical 700 square foot laboratories have been put in place, at a cost of approximately 150 thousand dollars, to accommodate our anticipated freshman enrollment. Each laboratory is designed to support multiple 18 student sections and provide, for each 2 students, 1) a suitable workbench, 2) a 486 DX computer and network access to all required software, 3) a toolkit used during the course and 4) all of the laboratory and design project materials required for the various semester activities. In addition to the above, each laboratory is equipped with suitable audio/visual equipment, software reference materials, video tapes on engineering and design topics and the required storage facilities for course materials and supplies.

The Introduction To Engineering Course (EG101)

This course consists of 12 one hour lectures on a variety of engineering subjects, 12 three hour laboratories on the same variety of engineering subjects and 12 one hour recitations in which the students periodically verbally present their laboratory experiences. The lecture material provides background for its companion laboratory but is, by design, loosely coupled to it. Students are expected to write and submit a brief laboratory report each week, recite about every other week, take three quizzes (on lecture material), submit three proficiency assignments (on software skills), and take a comprehensive final exam during the semester. Grading for the course is as follows: lab reports 50%, quizzes 15%, proficiency assignments 15%, recitations 10%, and final exam 10%.

A. The EG101 Lecture Sequence

1. Introduction (syllabus and requirements)
2. Presentation of Engineering Data
3. Putting a Robot to Work
4. The Robot Revisited
5. How Things Break
6. Standards and Design
7. Measuring Distances
8. Vibrations, Waves and Spectra
9. Digital Electronics
10. Laser Technology
11. Heat: Problems and Challenges
12. Overall Perspectives (engineering careers)

A thirteenth lecture is also scheduled, to be given by an invited engineer from industry.

B. The EG101 Laboratory Sequence

1. Introduction (computers and software)
2. Take a Device Apart and Describe It
3. Programmable Robot Assembly
4. Programmable Robot Performance
5. Design Failure: Cause and Effect
6. Boom Construction Competition
7. Distance Measurement
8. Vibrations,Waves and Spectra
9. Digital Design
10. Fiber Optics Communications
11. Thermal Insulation Competition
12. Review and Make-up

C. Status And Schedule

The EG101 pilot course was run and completed in the spring semester of 1993. By all measures, it was successful and only minor changes were introduced in its scaled up version, which is now in its innaugural run.

Fourteen students (mostly second semester freshmen) participated in the EG101 pilot course and reported these opinions (on a scale of 1 to 10 at the end of the semester:

Quality of instruction	8.5
Amount of work required	7.0
Interest in lectures	6.3
Interest in laboratories	8.4
Interest in recitations	7.7
Take again or recommend?	9.5

The full, scaled up version of EG101 is now in operation and is providing its intended entry level engineering instruction to over 300 students at two campus locations (total of 19 sections). Students in our electrical, mechanical, aerospace, chemical, civil, metalurgical, computer engineering, computer science mathematics, and physics programs are participating in this course in discripline- mixed sections and laboratory teams, which are changed weekly.

The Introduction to Engineering Design Course (EG102)

This course, in terms of weekly hours and their allottment to lecture, lab and recitation activity, is identically structured to EG101.

However, in its design thrust, it differs markedly from EG101 in content as follows:

	EG101	**EG102**
Lecture	Engineering topics	Design topics
Laboratories	Engineering experiments	Design projects
Recitations	Laboratory summarizations	Design reviews
Skills	Wordprocessor Spread Sheet Simulation Written/Oral	Sketching CAD Analysis Presentation
Textbook	Lab notes and lecture notes	Essentials of Engineering Design
Homework	Lab reports	Assigned from text

After being exposed to and developing basic skills at the begining of the course, the EG102 student is expected to complete two design projects
during the semester as follows:

Project #1

Short in duration (4 weeks)
Limited in scope
Limited in analysis
Opportunity to practice
Instructor assigned

Project #2

Longer in duration (8 weeks)
Broader in scope
Analysis required
Opportunitity to implement
Team selected

Grading for EG102 is as follows:
project #1 20%, project #2 40%, progress reports 10%, CAD proficiency test 15%, and homework assignments 15%. There is no final exam.

A. The EG102 Lecture Sequence

1. Course introduction
2. Library resources
3. Principles of estimating
4. Writing proposals and progress reports
5. Project #2 introduction
6. Time efficiency and mamagement
7. Concurrent engineering and quality by design
8. Thermal analysis
9. Dimensioning and tolerances
10. Finding and filing patents
11. Engineering and the environment
12. Engineering ethics
13. Engineering design careers

B. The EG102 Laboratory Sequence

1. Introduction to project #1
2. Sketching and CAD

3-5. Complete project #1
6-13. Begin and complete project #2

The recitations following these laboratories are used for interactive proposal, status, analysis and final project presentations.

C. The EG102 Project Menu

Project #1
(Instructor Assigned)
A. Design a one-story house
B. Redesign a consumer project
C. Design a writing desk
D. Design a parking lot

Project #2
(Team Selected)
Design and construct:
A. An underwater retrieval system
B. An operating drawbridge
C. An operating winch
D. A moving vehicle
E. An operating windmill

D. Status And Schedule

EG102 is currently being piloted with a section of 12 students grouped into four 3 person design teams, comprised of multiple disciplines. Based on its semester-end evaluation, this course will be adjusted and scaled up for all second semester freshmen in the Spring 1994 term.

We anticipate running sixteen sections of EG102 and four sections of EG101 in the Spring of 1994. The EG101 sections are planned in anticipation of a combined 20% retake and transfer-in rate.

Closing Comments

The development and implementation of freshman engineering courses at Polytechnic University has been accomplished successfully with the tremendous effort and support of faculty, administration and staff. The support of the Gateway coalition was also significant, crucial, and much appreciated.

Our initial success is not without opportunity to fine tune and improve, and we intend to do just that with the constructive feedback we seek and receive from our students, faculty and the engineering education community.

Integration of Engineering Mechanics Examples and Concepts in Mathematics

Prepared by:
Dr. Leonid Vulakh, Cooper Union

One of the goals of the Gateway Coalition is to enhance the curriculum of engineering at the freshman and sophomore levels. To achieve this goal it has been suggested to accompany the mathematical courses with projects consisting of engineering-type problems. While solving problems, students will apply mathematical concepts and theories which they have just learned. The solution to some of the problems should be verified experimentally in the laboratory. The project under consideration is the first step in that direction.

In order to develop the first project, the team was composed of 1 M.E. faculty (Dr. P. Grossman), 1 C.E. faculty (Dr. V. Guido), and 1 Physics faculty (Dr. L. Vulakh). From June to August 1992 the team met on a regular basis to:

1. identify the topics that should be included in the project,
2. review/revise the drafts, and
3. select the group of students for the project.

During the first semester our students take two mathematical courses: Calculus I (MA 111, 4 credits) and Analytic Geometry, Vectors and Matrices (MA 110, 2 credits). Course MA 110 is a prerequisite to such courses as Calculus II (MA 113), Vector Calculus (MA 223), Physics (Ph 112), Vector Mechanics for Engineers (ESC 100), etc.... The attached syllabus for MA 110 details the material that is covered each week in class. In MA 110, as in any standard course in Vector Algebra, vector operations are applied to such mathematical problems as: find equation of a line or plane in space; the angle between two lines; the area of a triangle: the volume of a parallelepiped; etc. The team has developed a project which consists of four problems in Engineering Mechanics. It has been included in course MA 110. Two topics are discussed in the project: Equilibrium and Work. It begins with a short introduction which contains the definitions of equivalent forces, concurrent system of forces, moments of a force about a point and about an axis, and the equations of equilibrium of a rigid body. All the problems except Problem 4 are taken from "Vector Mechanics for Engineers", by F. P. Beer and E. R. Johnston, Jr. (5th Edition). In Problems 1-3, the students apply Vector Algebra to find tension in cables and the reaction at the ball and socket joint.

The Physics Department has designed and is constructing an experimental apparatus which will enable the students to verify their solutions in the Physics Laboratory.

When solving Problem 1 to find the tension in cables, the students use linear operations with vectors and solve a system of linear equations. They verify experimentally in the Physics Laboratory the solution obtained mathematically.

To solve Problem 1, the students use properties of the moment of a force about a point (see Exercise 1), apply linear operations with vectors, cross product, and solve a system of linear equations.

Problem 3 is challenging and should be considered as an extra credit problem. To solve it, the students have to apply the properties of the moment of a force about an axis (see Exercise 2). In addition to operation with vectors applied in Problems 1 and 2, the students should apply the properties of the dot product and mixed triple product.

Finally, when solving Problem 4, the students apply the dot product of the two vectors and its properties to find the work of the weight of a particle which moves in polygonal line.

For the experiment, a group of 24 students was chosen. By the middle of October, when they had learned Vector Algebra and its application to Analytic Geometry, the instructor presented the project and solved a few sample problems similar to those from the project.

The students were able to handle Problems 1, 2 and 4 with relative ease and the results were as good as could be expected. Problem 3 was difficult for most of them. The project constituted 10% of the final grade for course MA 110 and therefore had only a minor influence on it. Out of 10 points for the project, the average grade was 7 points.

In the second semester, the order of presentation of topics for Calculus II (MA 113) and Newtonian Mechanics (Ph 112) has been revised to insure that the students have an initial exposure to the mathematical tools required for the physics course (i.e. an introduction to Vector Calculus prior to studying generalized planar motion).

Besides the fact that the project exposed the students to engineering for the first time, it also provided them with additional training in Vector Algebra which they had to apply to Engineering-type problems and therefore they will be better prepared for other courses in Mathematics, Science, and Engineering.
Solutions to Exercises 1 and 2, Problems 1 - 3, and the C-programs calculating the solutions are attached.

Syllabus

MA 110 (2 Credits) Analytic Geometry, Vectors and Matrices
Text: Elementary Linear Algebra, 3rd Ed., Stewart Venit, Wayne Bishop, PWS-KENT Publ. Co.

1. Vectors. Scalar multiplication.
   Vector addition (Sec. 1.1)

2. Dot product (Sec. 1.2)

3. Cross product.
   Torque (Sec. 1.2)

4. Planes in space (Sec. 1.3)

5. Lines in space (Sec. 1.3)

6. Euclidean m-space (Sec. 1.4)

7. Systems of linear Equations
   (Sec. 2.1)

8. Matrices and row reduction of linear systems (Sec. 2.2)

9. Operations on matrices (Sec. 2.3)

10. Matrix equations. The inverse of a matrix (Sec. 2.4)

11. Theory of linear systems (Sec. 2.1)
12. Determinants (Sec. 3.1)
13. Properties of determinants (Sec. 3.2)
14. Cramer's Rule (Sec. 3.3)

Developing A Computer-Mediated Learning Laboratory For First Year Students

Morton B.Friedman, Columbia University

Introduction

Engineering schools are being compelled by self-interest, competition and increasing pressure from industry and government to "buy into" the notion that undergraduate education is in need of major improvement, some would even say in need of total reform and restructuring. It is surely unrealistic to expect curricula designed in the pre-computer age to continue to serve well engineering education into the 21st century. The tools and practice of engineering are changing at a rapid rate, on a scale and in ways not experienced heretofore, driven by the explosive growth of information and automation in the traditional disciplines, the creation of new disciplines and the pervasive role of computers. Moreover engineering education is now committed to attracting a more diverse student population than in the past and the changing preparation and composition of this population must be taken into account. The students are owed an education which will provide them with the knowledge and tools of modern technology to work in traditional and in evolving new interdisciplinary modes and which will empower them for life-long learning.

Reforming undergraduate education is a complex undertaking that certainly requires commitment of resources within an institution. But an equally essential ingredient is multi-institutional collaboration on a broad front in order to provide the necessary moral imperative for change as well as to support wide-ranging innovation and experiment with curricula, educational technology and methodology, that are beyond the capabilities of a single institution. The Gateway Coalition is providing the stimulus and opportunity for Columbia, in collaboration with other institutions, to embark on a substantive restructuring of its undergraduate curriculum. The aim has been to formulate desired new educational goals and to implement them in ways that are doable, acceptable and attractive to faculty and students and that may serve as paradigms for change for other institutions and for the future.

There has been a variety of well-documented reform efforts in the academic community in recent years employing approaches ranging from Drexel University's total restructuring of its lower division curriculum to the more modest and limited experiments with individual new courses and methodologies being undertaken at other institutions. Some of the basic reforms being explored by the Gateway schools are an outgrowth of the philosophy of the E4 program developed by Drexel. However they are being adapted to lower division curricula by other Coalition schools in ways more compatible with their own institutional cultures and in ways that may be more acceptable to a broader range of institutions. Reform of the lower division curriculum is only one part of an iterative process of change that will eventually encompass the entire curriculum but it is the natural starting point for the process and is the focus of the work reported here.

The present report focuses on the process and content of some of the restructuring and cultural changes being developed and implemented at Columbia for the freshman year of its engineering curriculum. The primary effort in the restructuring so far has been the development of an electronic-driven teaching/learning laboratory and the creation of a concomitant year-long required course called "Introduction to Engineering" that will serve to bring substantive engineering concepts and philosophy into the freshman year. The laboratory and the course will also serve to introduce and integrate into the curriculum the computer as an intellectual and professional tool at the freshman level. The associated electronic teaching and learning modules being developed as parts of the course will be important elements in the implementation; they are discussed more fully in documentation presented elsewhere. An additional element in the reform process has been a Gateway sponsored collaboration with the

Mathematics department at Columbia which has developed a novel computer-mediated approach to the teaching of the calculus. The substantial involvement of mathematicians in the process represents a successful first step in helping to change the institutional culture in ways that encourage the prospects for further meaningful reforms on an institutional basis.

Reinventing the engineering curriculum at Columbia

Background

Serious educational reform always requires some changes in an institution's "culture". Cultural changes are particularly difficult to induce at a comprehensive research university like Columbia where the intellectual dominance of research /graduate education and the dependence of the engineering curriculum on a wide range of disciplines and departments, inside and outside the engineering school, are among the realities that must be dealt with. There has been for decades a common freshman/sophomore program for all engineering students at Columbia, as at many other institutions, given over completely to traditional courses in the calculus, physics, and chemistry, supplemented by a core program in the humanities. A positive consequence has been that engineering students are offered access to a rich and exceptionally broad range of intellectual activities in the arts and sciences. But it has produced a curriculum in which all the engineering disciplines and their technologies are concentrated in the upper division (junior/senior years) creating a technology vacuum in the first two years while the engineering courses are jammed into the upper two years of the program. The result has been a fractured discipline driven curriculum with little room for science or mathematics enrichments or for expansion in new technical directions. This has been abetted by a historical reluctance to invade the lower division with substantive engineering courses and laboratories in order to provide students with maximum flexibility in choosing career paths. Finally, computers play no role in course instruction throughout the lower division curriculum and almost all instruction is in the conventional large-lecture-class mode.

The deficiencies of the existing curricula have led to a movement at Columbia to restructure the undergraduate engineering program. A faculty committee has drafted a report to the Dean which recommends significant reform of the curriculum as a major component of a strategic plan for the School for the next decade. The recommendations included strong support for a number of ideas and developments that are evolving from the Gateway project. The report affirms the need to take advantage of new modes of instructional technology and to explore new teaching and learning methodologies to implement curriculum reform. Equally stressed is the importance of cooperation with the science and humanities faculties on course content and pedagogy in modifying existing courses and in developing new ones as the School moves toward a more integrated curriculum. The challenge is to enhance the curriculum, draw the interest of the students and faculty, but at the same time maintain the full benefits of a comprehensive research university environment. The next sections describe some on-going efforts to meet this challenge.

Bringing engineering into the freshman program

The creation of a computer-mediated learning laboratory for all first year students is a central feature of the proposed reform. The goal is to establish an electronic-driven learning laboratory into which all engineering freshmen are immersed from the day they enter Columbia. The intellectual focus of the laboratory will be a required two-semester course carrying three credit hours each semester, called "Introduction to Engineering" that will take advantage of the rapidly evolving electronic courseware being developed at Columbia and elsewhere. The aim is to break away from the conventional mode of first year curricula with emphasis on science and mathematics and introduce freshmen to engineering in a real-world context to provide some insight into what engineers do and how they work on real projects. The laboratory and the course are being structured to achieve the following:

- make the educational process in the first year an attractive, exciting and fulfilling introduction to engineering and encourage students to learn cooperatively
- provide a mechanism for involving engineering faculty in a substantial way at the freshman level and enable faculty to seriously engage students in engineering from the first day
- encourage students to begin to use and appreciate the computer as an aid to study, as an intellectual and professional tool, and as a communication tool from the day they matriculate
- provide the students with computer tools and experiences that are directly applicable and usable in their regular course work in mathematics, physics, chemistry, engineering and the humanities.
- encourage students to learn to use specific user-oriented software packages, both commercial and internally generated, which will be highly useful in future course work, professional work, and research
- explore the iterative nature of engineering process and design and the importance of multi-dimensional visualization

Electronic learning laboratory

A dedicated electronic facility with multimedia capabilities is under construction and will be completed in time for the Spring 1994 semester. The seeding of the facility has been made possible by an equipment grant from AT&T and a matching grant from Columbia which is providing over 2500 square feet of prime space in the engineering building for the installation . The University has begun a major renovation of existing suites of classrooms and laboratories to create a single facility which will encompass:

- a studio-style electronic classroom equipped with approximately 40 PC's , workstations, graphic and output devices, and servers
- a lecture-style electronic classroom with multimedia display facilities
- an electronic courseware preparation studio with multimedia authoring and rendering capabilities
- electronic network links to all parts of the University and to the outside through an already existing high-speed fiber network including ATM switches

This Gateway facility has been designated as a component of Columbia's high-performance , gigabit multimedia infrastructure which will be in operation at the end of the year. This will enable the laboratory to have real-time access to electronic modules available over academic networks.

Courseware

The contents of the course for the first semester are under design and a pilot version will be in operation in the Spring of 1994. The development of the course, which stresses the integrative interdisciplinary nature of modern engineering and technology, has been a collaborative effort among several of the engineering departments. Development teams are constructing and experimenting with new ways of presenting course material in an environment which utilizes the computer as an intrinsic intellectual tool. The course will be “team taught” but it will emphasize the use of interactive tutorial and learning modules with the instructors serving more as mentors or coaches than lecturers in keeping with the newer methodologies being exploited.

The pilot program will utilize initially in-house software to provide faculty with opportunities to develop experience and expertise with electronic teaching and learning. Several of the engineering faculty have constructed interactive instructional and tutorial computer modules that will form parts of the course and that have the capacity to provide expanded material for extended use throughout the curriculum. Faculty have created a series of lecture/tutorial modules using interactive multimedia to develop a number of basic engineering concepts and to introduce the use of computer software for exploring engineering design. Among the commercial software being exploited are word processors, spreadsheets, drawing/drafting software, analytical software such as Mathematica and Maple and some specialized engineering software as well.

The core of the course is a series of learning modules which provide an introduction to some design concepts of wide application from a few engineering disciplines. The emphasis in all the modules is on visualization as a powerful tool for conveying ideas and stimulating interest. The particular modules developed for the purpose are a consequence of both the interests of a number of faculty and the sense that the areas chosen offer students meaningful introductions to engineering perspectives at the freshman level. The first semester is organized around five teaching/learning modules :

1. The computer as an engineering tool

2. Engineering graphics and computer-aided design

3. Process engineering in the computer age

4. Construction engineering and the management of mega-projects

5. Flood control and fluid engineering

Each subject area is given over a period of 7 .5 hours (two weeks) in which 2.5 hours are in the conventional lecture mode while 5 hours are used in a studio style by the students exploring in the learning laboratory the electronic material introduced by the instructor. The electronic material will be fully supported by written material in the form of manuals and handouts that are being prepared.

A Multimedia Module for Engineering Freshmen: Introduction to the Design of Continuous Processes

Prepared by:

J.L. Spencer, N.C. Otterson, L.C. Mattas
Columbia University in the City of New York

Introduction and Overview

The essential idea behind the module is to:

- Present to the students to the concept of a continuous process, illustrating the concept with a number of diverse examples treated qualitatively.

- Show them at an introductory level how such processes are treated quantitatively.

- Introduce them to a modern software package (ASPEN/MAX) which formulates and solves the material and energy balance equations which describe a very simple example of such a process.

- Provide very detailed step-by-step instructions for using MAX to simulate a flash vaporizer/heat exchanger system. This system is used to separate an ethanol/water mixture.

- Show the students how to use MAX to solve one or more simple design problems related to the vaporizer/exchanger example. The basic design problem is to select the operating temperature of the flash unit so as to produce a condensate stream containing 80% ethanol. A second design problem involves finding the size of the heat exchanger that minimizes the cost of operating the flash unit.

The module will run on 386/486 IBM-compatible personal computers, and is being written using the authoring software ACTION!, produced by Macromedia Inc. The multimedia techniques used appear to have certain important advantages relative to the usual lecture format which might be used for presenting the same material. These are:

The pace at which the material is presented is entirely under the control of the student. The student can skip forward rapidly when relatively familiar material is being presented, or take as much time as needed to understand more difficult concepts. More important, the student can at any time return to earlier material (organized as "scenes") if he/she realizes that a previously covered concept was not fully understood. This is in direct contrast to the lecture format, but is an advantage shared by books.

From any scene there can be access to more detailed information related to that scene. This facility can be used to review basic material which is presumed, often incorrectly, to be well understood by all students. For example, in a certain presentation the inverse of a matrix might be referred to. A button in the scene can be used to trigger the definition of the inverse of a matrix, a definition which refers to matrix multiplication. A second button can then be used to review the definition of matrix multiplication and, if necessary, a third button can be used to review the inner product of vectors. Note that this facility is also available when using a book, but requires the somewhat tedious use of the book index. On the other hand all the material in the book is accessible to the user, while in the simple multimedia presentation discussed here only selected information is linked to a given scene. More complex authorware will allow more complex linkage of information.

The accessing of more basic information referred to above is, in the lecture format, equivalent to asking a question. It is well known, however, that students are often very reluctant to ask questions, perhaps because they feel that they will reveal a level of ignorance not shared by their peers. (According to a Japanese proverb, "To ask is a moment of shame, not to ask is an eternity of shame.") But the barriers to asking an apparently stupid question of a computer do not exist, and this in fact may be an important advantage of a multimedia presentation.

The ability to use images to make concrete what otherwise are relatively abstract concepts. In the usual lecture format it often inconvenient to intersperse high resolution images throughout the presentation. And time permits the drawing of only the most rudimentary structures on a chalkboard. But in many cases the discussion of equipment, for example a heat exchanger, would be much improved if the students could see the equipment in detail, what the internals are, and how the equipment is connected in an overall process. All this is easily possible in a multimedia presentation. It is also possible to include sound in the present-ation, although this may be of less use in most technical areas. (A counterexample might be the display of the spectrum of sound while playing the sound itself.)

The use of animation to illustrate dynamically how certain processes operate. For example the countercurrent flow of liquid and vapor in a distillation column can be illustrated very clearly using even the rudimentary animation facility of authoring software like ACTION25!. With more complex soft-ware real-time video can be used.

The ability to test the student's understanding at any point in the presentation. This can be done easily by incorporating questions, followed by answers, in selected scenes. By monitoring the accuracy of their answers to the questions, students can judge their level of understanding and, more important, adjust their rate of progress through the material to assure a good level of understanding. Such monitoring is almost impossible in the usual lecture format, and this accounts for the common situation that both the students and the instructor feel, incorrectly, that good progress is being made. Only when an exam is given and graded do both realize the real situation.

Module Design

The module will be used with freshmen, and thus will presume only very fundamental knowledge. A strong emphasis will be placed on making sure that the students have a deep physical understanding of the process itself and of the equipment used to carry out the process, and this will be accomplished by heavy use of multimedia techniques, especially the use of images of. The first version of the module will contain all the basic ideas, but will not explore in depth the use of multimedia techniques. Later versions will be richer in multimedia based descriptions of equipment, molecular behavior, etc.

The module will begin with a general description of continuous processes, with as broad a range as possible of examples used to illustrate and make concrete the basic concept. The perhaps more familiar concept of a batch process will be introduced first, as contrast for the introduction of a continuous process. Then the module will describe in detail the sample process to be treated using ASPEN, namely the continuous separation of an ethanol/water mixture using a flash vaporizer and a heat exchanger. This process is simple, important in industry, and pedagogically interesting because it involves strongly coupled material and energy balances, and also vapor-liquid equilibrium relations. Although the corresponding equations will be displayed and explained to the students, the actual formulation and solution of the equations will be handled entirely by ASPEN, so that the mathematical demands on the students are consistent with their freshman status. The object is to have the students understand what a program like ASPEN can do, rather than to teach them in detail how ASPEN works.

Finally, the module will take the students step-by-step through the use of ASPEN (actually a simplified version of ASPEN called MAX), as a basis for letting the students use ASPEN to model the ethanol separation process.

Students finishing the module will be given a 10 to 20 page handout (most pages taken directly from the module) showing in detail how to use MAX, and then will be asked to use MAX to set up and run the continuous process example covered in detail in the module, and to carry out some simple design studies.

As is consistent with the goals of Gateway, the concept of design will be introduced, and the students will use MAX to, in essence, design the ethanol separation process. That is, the students will vary a small number of design variables and attempt to arrive at a process which, for example, minimizes energy consumption or maximizes operating profit, while satisfying certain design constraints. The students will see how a powerful program like MAX permits them to treat quantitatively (i.e. to design) a relatively complex system without having, themselves, to formulate or solve a single equation. They will see how scope can be given to their creativity, as the use of MAX allows them to formulate and answer in a few seconds questions that, in the near past, would have required days of tedious calculations.

Scheduling and Deliverables

A complete first-level version of the module described above will be ready for use by students by January 15, 1994.

As described above, the opportunities for adding additional material (images, questions and answers, background material, etc.) are almost unlimited, but a second level version of the module will be based, first, on the response of the students during the Spring term to the first version in the pilot course. This version will be completed by June 15, 1994, and will contain more material, especially images and sound obtained in the field, and internal self-testing.

The deliverables will be the module itself, in the form of an ACTION! (Version 2.5) file, and the printed notes generated mainly by printing screens from the module.

If the module is successful, additional examples may be added. These examples will be chosen so as to have the broadest impact and familiarity for engineering freshmen, consistent with the capabilities of the ASPEN/MAX software. For example, the simulation of a system for adding chlorine continuously to drinking water, or for humidifying air, might be a good examples.

The problem of choosing examples is worth a brief discussion. One of the goals of the Gateway project is to introduce real engineering quite early in the curriculum. But this implies that abstract principles not be taught in isolation, but instead be illustrated by concrete examples. However each concrete example is inevitably linked more closely to one engineering discipline than to the others. Thus a conflict arises in developing a course for freshmen, most of whom want to retain flexibility in the choice of discipline. The solution, imperfect but workable, seems to be to choose a number of relatively simple examples which are as broadly based as possible. This is the rationale for using the ethanol/water separation in the module described above.

The Learning Lab for Freshman: A Multimedia Approach to Engineering Graphics

Prepared by:
Eden Greig Muir, Columbia University

As part of the Learning Lab for Freshmen, we have begun the process of restructuring the engineering graphics curriculum, incorporating it within a multimedia and computer-aided design (CAD) environment. This report will briefly discuss our goals and our experience in the initial prototyping of a multi-media module for engineering graphics instruction.

In the recent past, our graphics courses have relied on text books, slide shows, blackboard notes, overhead projections, and computer demos, with appropriate variations in the Civil, Industrial and Mechanical Engineering departments. The students were assigned exercises in drawing and descriptive geometry and the work was done with a combination of manual drafting, freehand sketching, and programming-based CAD.

The new approach emphasizes the development of the visual skills and thinking seen in the Renaissance engineer's notebook, combined with the mastery of today's advanced 3D computer modeling. Traditional drafting is out; freehand sketching and computers are in. This change is encouraged by dramatic improvements in user interfaces for complex three-dimensional CAD and faster, inexpensive CPUs, as well as multimedia software which makes it possible to design a virtual learning environment where the several approaches to graphics can coexist.

A multimedia approach to graphics must make use of the computer's ability to handle digital images as well as text, sound, video, database and hypertext features, as well as links to related applications. For our initial investigations, we selected the Macintosh hardware platform, HyperCard multimedia software, and the form•Z CAD program. The hypertext concept is central to the project; the goal is to allow non-linear and individually selected paths through a text and graphics database of course material, so that students are navigating independently with a

sense of exploration. From the point of view of the teacher, this is an opportunity to "compose" class material, to elaborate on ideas without concern for classroom logistics, to reinforce the existing material. and accelerate the pace of learning. This semester the graphics classes began using form•Z, a Macintosh-based solid-modeling CAD software with a "friendly" user-interface. The students now can solve the traditional engineering visualization puzzles (missing views, etc.) by creating 3D models and viewing them in perspective rendered with shading and cast shadows. After only 4 weeks of instruction, the student work is far superior to that of previous years, leading us to the conclusion that the graphics module should be designed as a guide to facilitate this kind of CAD work, and as a window into a wider area of engineering graphics topics.

The existing course notes on such topics as drawing types, projective geometry, and engineering conventions, are being transferred onto HyperCard "cards" which are gathered into "stacks" which can be linked in many different ways. Cards show the text with certain key words highlighted as "buttons", which are scripted links to other cards. This programming capability allow the design of elaborate links to related information and images and to interactive dialogue boxes and video windows as well as to sound. Some examples of engineering graphics topics which we are repackaging in a multimedia format:

- 2D engineering drawing (plan, section, etc.) is presented on cards which can be browsed through or operated as a quiz, with notes at several levels of complexity on issues such as geometry, scale, accuracy, tolerances, line weight, dimensioning, graphical conventions, symbols, etc. An assignment "window" is always available for drawing, and for completing homework using a CAD program.

- The theory and mechanics of 3D projections, including axonometric and perspectives views, are presented with discussion and examples of freehand sketching technique, methods for manual drafting, and CAD. The text deals with issues such as distortion, relation to photography, and offers "sidetrips" into famous examples.

- Classic problems of descriptive geometry such as intersections of solids, shadow casting, etc. are presented with old and new examples. This links to a history of engineering graphics from Leonardo, Descartes, and Monge, to the present, illustrated with digitized color images and short biographies.

Certain features in the selected software came to be recognized as essential for our project. These included flexibility in interface design, repeatability of buttons and cards, scripting capability, interactive features, global variables and unique card id’s which can be stored in these variables, easy linking to other cards or stacks developed by others, modular information storage allowing the addition of new cards and information, as well as sound and video capability.

The limitations of the software included an inconvenient automatic saving feature, a lack of color editing and limited color viewing, poor painting and drawing tools,difficult sound and text importation, and only PICT or PICT2 file-handling capability. In view of these drawbacks, some of which were somewhat mitigated by add-on products, the current multimedia software offerings are being resurveyed.

Software modularity and flexibility are crucial to these multimedia projects, since the digital learning environment is never complete, but is always in a dynamic process of self-criticism, testing, and updating. The system must be able to grow and to link to other larger resources, such as existing on-line encyclopedias and digital image libraries, and must be transferrable to the new hardware platforms and operating systems of the future.

Introduction to Engineering -- No Instructor Needed!?

John Dickerson, University of South Carolina

This paper was presented using experimental software. Below is a summary.

In an attempt to 1) reduce instructional cost, 2) improve problem solving tools, 3) improve communication skills, and 4)test the feasibility of (1,2,and 3), a computer based "Introduction to Engineering" course was offered to 25 USC freshman in the Fall of 1992. The course was module based with each module lasting 1 to 2
weeks. A module typically represented the following activities for each student.

1. Request a problem assignment from the computer (each student would get a similiar but individualized assignment). The assignment is electronically sent to the report room (MathCad).

2. Go to the appropriate laboratory (computer simulated) and experimentally attempt a solution to the assignment. The activity in the lab is electronically sent to the report room (MathCad).

3. Go to the study room (MathCad, same as the report room) and logically attempt a solution to the assignment.

4. Write a report on your solution to the assignment including a discussion of the differences between the experimental and analytical solution. Electronically submit the report to the non-instructor.

The simulated laboratories are available in C.

Creating a Streamlined Gateway Core Course Sequence

Prepared by:
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Vision

The revision of the engineering curriculum for lower division students has been implemented to a very high degree at Drexel University. However, it became apparent to the members of the team at Florida International University that the Drexel model would not serve well the FIU students. Since the purpose of the coalition is to develop variations in the programs, it was decided to pursue a curriculum development plan that differs a great deal from that at Drexel.

FIU is an urban campus with mostly commuting students and many of these pursuing part-time studies. Thus, a fully integrated curriculum would not be appropriate for a significant number of the students since they take less than a full load. In addition, a majority of the engineering students that graduate from FIU (around 75%) transfers from community colleges. Thus it became one of our objectives to develop a program that could be exported to these community colleges, including through the electronic media of distant learning. As a result of this reasoning, it was decided to develop an engineering core sequence that consists of one or two courses in each of the four lower division semesters. These courses could then be coordinated with the non-engineering courses. The degree and level of this coordination could be adjusted to fit the needs of specific groups of students. This approach, it was believed would achieve the flexibility required for the student population being served at FIU.

It was decided that the new core curriculum would have to embody the several features that are important to the basic goals of Gateway. First of all, engineering must be the intellectual centerpiece of the curriculum. This would start with the first semester and would continue throughout the educational experience. Second, learning the process of engineering design would be an important component of the educational experience and would be implemented by way of design projects completed by teams of students. Third, the students must realize the interdiciplinary nature of engineering. This would include the realization that the engineering field encompasses themes and ideas that are traditionally taught in other departments. This could be accomplished by a coordination between the courses rather than by fully integrating them.

Curriculum Planning

The design of the new core curriculum was undertaken with the goal of creating a common sequence that would instill the students of all engineering diciplines with a defined set of skills. Of course, it is also necessary that this sequence is compatable with the existing curricula of the five engineering programs. Another objective was to modernize the educational process in the area of basic sciences. This was implemented by adding a course in the field of biological science and adding material in modern physics. Both of these are perceived as vital skills for the modern engineer.

It was also seen that it would be necessary to eliminate some credit hours from the existing curricula. Since the new first semester course "Introduction To Engineering" substitutes 3 credits for the existing 1 credit course, it is necessary to reduce the credits required somewhere in the new curriculum to compensate for this. This reduction is further indicated by the fact that it was impossible to identify an existing common engineering core. This means that some programs will be subjected to additional credits in the process of adapting the new engineering core.

It was decided to eliminate the duplication of teaching basic mechanics and basic principles of electric circuits both in the physics courses and in the engineering courses. This reduction in physics credits would be offset by substituting an introduction to modern physics for part of the physics that was eliminated. Of course, the area of basic science would be augmented by adding an introductory biological science course to the core curriculum. This would insure that the ABET requirements for the amount of coverage in mathematics and basic sciences was still satisfied.

The specific course sequence for the experimental curriculum is rather difficult to define since there are conflicting criteria that must be considered. For the purposes of the first draft of the program, two different plans were formulated based on the application of two conflicting sets of criteria:

1. Delivering an agreed to set of skills to the students.
2. Developing a sequence that will be acceptable to all five engineering programs.

During the summer of 1993, two separate development plans were pursued. The results of these are documented in Appendix I and Appendix II, included in this paper.

The Present Curriculum at FIU

The experimental curriculum at FIU is entering its second year of implementation. For both years, the program has been applied to pilot groups consisting of the Honors Program students who designate engineering as their field of study. This choice was made after considering several factors. Since these are students with higher levels of academic skills, they are less likely to suffer adverse effects from any errors made in the design of the sequence. Administratively, they are an easily identified group and they are all full-time students. This makes potential problems in course scheduling, registration and other logistical factors be less toublesome. On the other hand, it can be argued that this group does not give an accurate indication of how the program will work when applied to the more general student population. This is a factor that must be taken into consideration in the evaluation of the effectiveness of the program.

The program consists of the core of 4 engineering courses, of which only 3 have been taught so far, and associated courses which are coordinated with the engineering courses. The small numbers of students have made it easier to administer and teach the courses but this has made it impossible to create separate sections in all of the associated courses (such as calculus). The sequence will now be described as it exists in the first three semesters.

In the first semester, the 3 credit Introduction To Engineering course is taught in very close coordination with the English composition course. The coordination is maintained through weekly meetings of the faculty team and by cross-attendance of faculty to the other course meetings. This has proved to work very effectively but is time consuming for the faculty involved and requires paying for release time for this extra effort from the Gateway funding. The first semester engineering course consists of 3 tracks:

Professional issues
Engineering design process
Engineering tools

The manner in which each of these is taught is explained in the following paragraphs.

The engineering professional issues include giving students a view of the different professional societies, especially through talks by the student engineering societies on the campus. They are encouraged to join the societies and to become involved in the ongoing projects. They are also lectured on legal issues regarding ownership of intellectual property such as copyrights, trademarks and patents. This also leads to consideration of how ethics apply in the engineering profession. The topics of economics, marketing and competition are treated and the ethics are also applied to these areas. The engineer as a entrepeneur is discussed by an engineer who has experience in this endeavor. The student teams are encouraged to form "corporations" for the completion of their design projects and this activity includes creating company logos and corporate structures.

The engineering design process is instilled by having the students form teams and select projects to be developed. The process includes first writing requests for proposals and then writing the proposals to define their project plans. The faculty responsible for this track of the course works closely with the students during the definition of the project and then during the following phases. They are instilled with an appreciation of the recursive nature of the design process and the necessity to communicate clearly their results. The final reports are both written documents as well as oral presentations with demonstrations of the prototypes.

The engineering tools are largely computer-based skills. These include the use of the computer network and electronic mail. They are forced to use E-MAIL to communicate with each other and with the faculty of this course. They are also introduced to the word processor and must apply it by their electronic journals which are reviewed weekly by the course coordinator. They are also introduced to the EXCEL spreadsheet program and are assigned exercises in which the results are reported with spreadsheet printouts. They are also assigned electrical laboratory projects in which the concepts of measurement techniques, accuracy, value tolerances and the keeping of engineering notebooks are introduced.

In the second implementation of this first freshman semester, a coordination with the Calculus I course was also implemented. Since the number of students was too small to constitute a separate section of the course, a compromise was tried. The section of the course in which all of the pilot students were placed was filled mostly by other engineering freshmen students. The instructor of this section attends the weekly meetings of the faculty team and he is emphasizing engineering applications in his examples and in the problems he assigns.

During the second semester, a 4-credit course in applied mechanics is taught which combines traditional statics with dynamics. During this course, the project track is continued as the designs are enhanced to reflect the application of the material learned in the new course. The computer skills track is continued through the application of MATHCAD to solve mechanics problems and create reports on the results.

The communications skills are developed further as the second English course is coordinated with the engineering course as was done during the first semester. As was the case in the first semester, a project report is required and must be both written and orally presented to the class audience.

For the third semester, a 3-credit course titled System Dynamics covers the unified modeling approach to mechanical, electrical, fluidic and thermal systems. The team projects are continued during this course and the principles of modeling are applied to enhance the designs. Since the English sequence has been finished by this time, coordination is transferred to other courses including calculus and computer programming. For the first implementation being taught this semester, only the calculus coordination is being tried.

The first semester course pair of Introduction To Engineering and English composition have been implemented at Miami Dade Community College, the largest feeder of lower division students to FIU's engineering programs. The coordination of the courses at MDCC with those at FIU is maintained through monthly meetings of the faculty teams and through frequent telephone conversations between the facilitators of the programs at the two institutions.

Future Developments

The curriculum development program at FIU will be expanded and enhanced in several aspects over the remaining 3 years of the funded activity. These aspects include expanding the number of students participating in the program, expanding the faculty participation within the college of engineering, resolving the uncertainty of the two plans, increasing the level of participation by the community colleges and increasing the number of non-engineering courses coordinated with the program courses.

There are many problems to be solved in order to achieve the goals stated above for the future developments. These problems relate primarily to procuring the cooperation of the many faculty members that will be necessary to implement the expansions envisioned for the next few years. In order for this cooperation to occur, there are several factors that must be arranged.

1. Arrange compensation for extra faculty effort.
2. Ensure that these activities are recognized as valid for earning tenure and for salary increases.
3. Convince the faculty in general that the Gateway goals are important and worthwhile.

In addition to these, there are issues with the students involved in the program that must be addressed. The program must be made more flexible so that students entering with deficiencies (such as in calculus) may have an avenue to phase into the program. Also, a program of testing and evaluation must be implemented in order to validate the effectiveness of the new course sequence.

To increase the level at which the program is exported to the community colleges, it will be necessary to establish a mechanism by which courses recognized as engineering courses can be taught at non-accredited institutions. This could be done if ABET agrees to establish a monitoring procedure through which an ABET accredited university such as FIU could take responsibility for the courses being taught at the local community colleges.

The common denominator to solving many of these problems is the need for additional funds. If funds are available to compensate faculty for team meetings and for attending other class meetings, then it should be no problem to get their participation. For the short term, it may be possible to procure additional funding for these activities by getting grants from other funding agencies. However, in the long run, the program must be self-sustaining and the revenues must all come from sources within the university.

Appendix I

We believe that Gateway's promise lies in what it wishes to accomplish, namely, to redirect the engineering program so that its graduates may have an immediate impact on the economy with minimum retraining.

Previously, engineering programs were designed to teach blocks of instruction with the intent of providing the basics to students who could then go on to graduate school. It was posited that the student who left after receiving the BS degree would be trained by the company that did the hiring to fulfill its goals. Students going on to graduate school were trained to do basic research, an area where many companies had given up claim because of the prohibitive costs involved. Professors who had been in industry always warned their undergraduates that they would be lucky to see 5-10% of what was taught in school. Feedback from companies to engineering programs always included the rejoinder that students need to be better prepared to tackle projects and in a much sooner time frame. In other words, universities were asked to provide a graduate ready to do the job thus indicating that 1) in-house training of graduates was becoming less attractive and that 2) universities and industry should not think of themselves as two separate entities.

With the problems of the economy, engineering programs are being required to be more adaptable and are being forced to become more involved in creating the proper student to meet the economy's needs. The gap between what we previously taught engineering students and what is needed to be taught is being forced shut by economic considerations. Enter the Gateway project.

Gateway's philosophy, in our view, is to provide students who have integrated all the blocks of instruction, who are knowledgeable about how companies operate, and who can jump into a job and become productive as soon as possible.

Several FIU Gateway members met to brainstorm how to carry out this philosophy. Our first meeting centered on creating a set of common courses that all students should take. These common courses were to be designed to meet the requirements of the basic EIT examination, the first step in obtaining the Professional Engineer's License. In order to create these courses, we needed to redesign the basic natural science core within the engineering programs.

In our discussion we determined that, in order to meet the ABET and University Core Curriculum requirements and still maintain course credit limits at 128, that:

1. The first Physics course would be dropped and in its place the first Engineering Systems course and a lower division Human Physiology + Lab would be taken;

2. The second course in Physics would be kept or we would ask the Physics department to create 2 courses of 3 credits each--one in modern physics and one to cover the areas of physics 1&2 not covered by the other courses to be created.

These changes would only add one credit to the curriculum and reduce the number of math and science credits from 34 to 32 -- 17 math credits and 15 science credits as opposed to 17 math and 17 science in the present curriculum. These changes would still meet ABET and University core requirements.

Along with these changes, we also determined that we had to develop an "Introduction to Engineering" course at the freshman level to immerse the student in the integrated design approach, the team concept and the different aspects that must be dealt with when putting a product to market.

The second freshman level class to be developed was an Engineering Systems course to provide the students with an understanding of the analogies of linear mechanical, torsional mechanical, electrical, fluidic and thermal systems when viewed from a lumped parameter approach.

The follow-on Gateway courses to the freshman-level Gateway Engineering Science courses were derived using the following matrix AND the need to meet the minimum areas required to pass the EIT, irrespective of one's major.

COURSE	CE	IE	EE	CPTR	ME
FLUIDS	X	--	--	--	X
THERMODYNAMICS	--	X	--	--	X
STATICS	X	X	X	X	X
DYNAMICS	X	X	X	--	X
STRENGTH OF MATERIALS	X	--	--	--	X
MATERIALS	X*	X	X	--	X
EE I	X	X	X*	X*	X
MANUFACTURING PROCESSES	--	X	--	--	X
ENGINEERING ECONOMY	X	X	X	X	--
PRESENT PROGRAM--TOTAL CREDITS	21	21	15	9	24

In the previous graph an "X" means that the course is in the particular program while an "--" means it is not. An "X*" means the subject area is taught but only covers material directed to that particular discipline. The areas listed above are on the EIT examination except for "manufacturing processes". Based on this, it was suggested that 4 other courses above the freshman level Gateway Engineering Science courses would be created to meet the minimum requirements for the EIT.

The first course created is a combination of statics and dynamics (subareas to be determined) similar to an applied mechanics
course taught by a sister state university. This course would be for 4 credit hours. A follow-on upper division course would have to be generated by ME to cover certain topics of dynamics in more detail.

The second course to be created would be a combination of thermodynamics and fluid dynamics (subareas to be determined) and would also include a lab component. This course would be similar to the heat/mass/momentum transfer course taught

at a sister state university. This course would be for 4 credit hours. A follow- on, upper division course would be generated by ME and CE to cover specific areas of their concern.

The third course to be created is a combination strength of materials, materials engineering and certain topics in manufacturing processes. This course would be for 4 credit hours. Follow-on, upper division courses taught by CE and ME would be generated to cover their specific areas of concern.

The final course to be created would be a course combining EE I and EE II (for non-EE majors). This new course would cover, *at the very least*, the material that normally appears on the EIT. The courses Circuits I and II (for EE and Computer Engineering majors) would be reconfigured into one course to cover the material not covered by the new course. The new course created for the Gateway program would be for 3 credit hours.

Engineering Economy, a three credit course, would be required for all disciplines. This course is in existence and is taught by the IE Department.

The Impact on Each Program

The following benefits have been inferred for each of the programs.

The CE student would receive instruction in thermodynamics, and learn about other materials as well as manufacturing processes, instruction he/she does not get now. The CE program would change by adding these follow-on Engineering courses (18 credits), and by possibly adding two courses (CE materials/strength follow-on - 3 credits, and if necessary, fluids II - 3 credits). These changes would replace the 21 credits shown in the preceding table by the 24 credits discussed here.

The IE student would receive instruction in fluid dynamics and strength of materials which is not part of their existing curriculum. The IE program would replace the courses in the preceding table by the follow-on Engineering courses and Engineering Economy WITHOUT change in the number of credits taken.

The EE student would receive instruction in fluid dynamics, thermodynamics, strength of materials and manufacturing processes while reducing their load in the areas of statics and dynamics. The EE program would replace the courses in the preceding table by adding the 18 credits of the follow-on Gateway Engineering courses and reconfiguring one course. The changes would replace the 15 credits in the table by the 18 credits discussed here.

The Computer Engineering student would apparently be the most impacted by these changes. Because they have very little of the normal engineering program, they will receive instruction in fluid dynamics, thermodynamics, dynamics, strength of materials, materials engineering and manufacturing. They would need the reconfigured course given to EE students and would take the 18 credits of the follow-on courses. Thus they would replace the 9 credits found in the preceding table by 18 credits.

The ME student is basically taking all these areas. However, they will need to take the Engineering Economy course and two follow-on courses, one in Fluid/Thermo and one in Dynamics. Thus they would replace the 24 credits of the present program (shown in the preceding table) with 24 credits of the new program (18 credits + follow-on [6 credits]). Thus NO increase would be incurred in the number of credits by the program.

These changes have been implemented as follows: The Introduction to Engineering course was offered in Fall 92 and is being taught in Fall 93. The Engineering Systems course was taught in Spring 93 and will be taught in Fall 94. The statics/dynamics course is being taught in Fall 93 and will be taught in Spring 94. The thermal/fluids course and the EE course are scheduled to be taught in Spring 94 with the strength/materials/manufacturing course in Fall 95. The second teaching of the Engineering Systems and statics/dynamics courses have been interchanged in the schedule so that the students will receive more mathematics and engineering science instruction prior to entering the Engineering Systems course.

Appendix II

Overview

The Gateway Coalition is an NSF-funded project with 10 universities participating in a program to enhance engineering education. With Gordon Hopkins, Dean of the School of Engineering as prinicpal investigator the program at FIU has several activities, including the curriculum revision which is headed by Dr. Heimer. NSF is funding 4 coalitions altogether for a period of 5 years with a goal to revise engineering education in this country. There is a strong likelihood that changes will be made and our activity here gives us the opportunity to help define those changes rather than to be forced later to follow what other universities have accomplished.

The revised curricula at some institutions in our coalition, including Drexel University the leader in this activity, are being completely integrated to encompass all courses. Because of our situation in which many students study only part time and many do their lower division studies at community colleges, we decided to create a more flexible curriculum. This is taking the form of an engineering core sequence which is then coordinated with the other courses. This, we believe, will allow the part time students to participate in the revised curriculum and that also this format can be "exported" to MDCC and other local community colleges. This form may be implemented through video, multimedia, ISDN computer links and/or other forms of distant learning technologies.

The plan outlined below will implement a core sequence of 4 engineering courses (one per semester during lower division study) that can be taken by students in all engineering programs. The curriculum is designed to meet the basic goals of the Gateway Coalition Program with minimal impact on the existing curriculum plans. The program was planned to meet the following objectives:

- Create an engineering-centered core for the lower division
- Enhance the learning of the current engineering material
- Expand the engineering content in selected areas
- Eliminate teaching of the same material twice
- Coordinate these courses with non-engineering courses
- Use design projects to provide focus and continuity
- Maintain compatability with changing ABET requirements

Contents of the New Engineering Core Courses

The new core proposed below was composed by surveying the existing requirements for the 5 engineering programs (Civil, Computer, Electrical, Industrial and Mechanical) to find the common content. This was then rearranged to form a new lower division "core" which satisfies many of the Gateway goals. While it was not possible to accomplish this fully, a compromise was found as listed below, with the exceptions noted.

Existing Common Requirements in Engineering

Course	CR	Exceptions and Comments
INTRO TO ENG	1	IE does not require this
STATICS	3	
DYNAMICS	3	Comp E does not require this
ECONOMICS	3	CE requires a Soc Sci econ course
ETHICS	3	ME and IE do not require this but there is room for it as an elective
TOTAL	*13*	

Proposed New "Engineering Core"

Course	CR	Contents of the Course
INTRO TO ENG	3	Project design, professionalism, ethics, economics & communications.
ENG MECHANICS	4	Statics, dynamics, project design & communications.
SYSTEM DYNAMICS	4	Modeling mechanical, electrical, luidic, & thermal systems. Project design & communications.
EC0N & ETHICS	3	Economics, ethics, legal issues, project design & communications.
TOTAL	*14*	

Credit Hours Comparison
The increase of 1 credit hour is offset by the net gain in physics vs biology (-5 in physics and +3 in biology). However, there are increased hours in some programs; Comp E adds 2 hours, IE and ME add 3 credits in Ethics which should be countable as one of the electives already in the curriculum.

Philosophy of the New Core
The structure of this new core was designed to create a logical sequence of material that is applied to projects which the student teams originate and carry out over the course of the 4 semesters. It was considered making the fourth course be an engineering materials course but this was rejected since this is an additional course not required by Computer Engineering. (Since there is already a 3 credit deficit in Comp E due to Dynamics, this would have been too much to overcome.)

The project progression during the 4 courses will be as follows

Core Course	**Project Accomplishments**
INTRO TO ENGIN	Define project, build & test first prototype

MECHANICS	Apply principles of mechanics to design
SYSTEM DYNAMICS	Use system modeling to analyze design and improve its performance
ECON & ETHICS	Expand economic, ethical & legal aspects as manufacturing plan is developed for product

The use of computer tools and the emphasis on communications will be stressed throughout the course sequence by way of assignments.
Final reports (both written and oral) will be required each term as the projects are refined.

Impact on Engineering Science and Design

Engineering Mechanics: The 6 hours of the old Statics + Dynamics sequence is now distributed between the two new 4-credit courses taken in the second and third semesters. Most of the traditional material is covered in the first course while more advanced topics are treated in the second course which deals with system modeling.

Electrical Engineering: The basics of electrical theory are still covered in the new physics course and the concepts of circuits are introduced in the systems modeling course of the new core. The more advanced treatment of circuit theory and electronics systems is still done in EE 1 or in the circuits-electronics course sequence, depending of the major of the student.

Thermodynamics Fluids and Materials: The modeling of thermal and fluidic systems will be covered in the systems modeling core course. However, the majority of this material will still be taught in the existing engineering courses in those programs which require them. Since some students do not presently take engineering courses in these areas, the new curriculum will offer them a broader education in these engineering sciences.

Engineering Economics and Ethics: The presentation of this material will be greatly enhanced by the new format. The concepts will be introduced in the first course and will be a required part of the project reports at the end of every term. When this material is covered in depth in the fourth course, the students will have already had significant experience with them so they will find them much easier to absorb and apply. This context - interdiciplinary team projects- should also prove to be a valuable preparation to their final application of these in the capstone design courses.

ABET Impact

Since ABET is requiring all programs to conform to the new guidelines in the future, the rules for curriculum content will be different. It will now be necessary to show that curriculum content in engineering science and engineering design combined conforms to objectives established within the program rather than to fixed numbers from ABET. Of course, the program administrators will be required to justify these objectives and show that they conform with the stated goals of the university. The ABET guidelines strongly recommend that topics such as the design process, ethics, economic factors and social impact are taught.

The design process itself is an important component of the engineering design curriculum. The ABET guidelines stress this as the following quotes illustrate. "Design cannot be taught in one course; it is an experience that must grow with the student's development." ... "In particular, the institution must describe how the design experience is developed and integrated throughout the curriculum, ..." We believe that this approach of combining this lower division design experience with the senior capstone design project is an excellent way of meeting the ABET objectives in this area. The lower division design project has advantages in that it is interdiciplinary in nature and is undertaken by teams rather than individuals, both of which are important experiences in engineering design. Also, these projects are intended to span all four semesters of the lower division so they provide a continued focus for application as new material is learned.

The new curriculum also offers improved adherence to the ABET criteria in non-technical areas. Again quoting from the ABET Accreditation Criteria: "Competence in written communication in the English language is essential for the engineering graduate."
"An understanding of the ethical, social, economic and safety considerations in engineering practice is essential for a successful engineering career." The manner in which the new core stresses the communication skills as applied to engineering assignments (as described in the following section) clearly fits these guidelines. Also, the use of the design projects to apply principles of engineering economics and ethics in two of these courses gives the students a much better appreciation of them, again in accordance with ABET.

Changes in Other Areas of the Curriculum

Impact in Mathematics and the Basic Sciences _

Mathematics: The mathematics course sequences have not been changed in any of the programs. However, as the program develops there will be increasing coordination between the new engineering courses and the special sections of the calculus courses created for engineering students.

Physics: The physics sequence will be enhanced by adding material in modern physics. It will also be modified by eliminating the material that is duplicated in engineering courses. The specific changes are:

- Reduce Physics I from 6 credits to 3 credits by eliminating the Newtonian mechanics material. This new Physics I course will cover acoustics, gravitation, temperature and gas kinetics.

- Reduce Physics II from 6 credits to 4 credits by eliminating electrical circuits concepts which are taught in EE 1 and in EE circuits courses. Keep the basic theory of electrical elements, field theory and optics. Add an introduction to modern physics.

These new physics courses will be developed to coordinate with the engineering and mathematics courses.

Chemistry: Maintain the chemistry course requirements as they presently are. In the future, the chemistry course will have special sections for engineering students which will be coordinated with the new engineering courses.

Biology: Add a 3 credit course in biology to the curriculum. This is done based on the widely held belief that technology in the life sciences area is rapidly emerging in importance and will have increased impact on all branches of engineering in the near future.

ABET Impact: There is a net decrease of 2 credit hours in the area of basic science with 5 less hours of physics compensated by 3 added hours in biology. However, all programs still have enough total hours in mathematics and basic science to meet the ABET requirement of 32 total hours.

Impact in Humanities and Social Sciences

English: From the first year of the program, a very strong coordination has been established between the engineering courses and the 2 freshman composition courses. The application of the critical thinking process, presented in the writing courses, to the engineering design process is stressed. The importance of both written and oral communications is stressed through the many assignments made in the engineering courses. Then the skills for completing these assignments are developed in the English courses.

There is no change in the course requirements in English but the two freshman composition courses have special sections consisting only of the engineering students and close coordination of the assignments is maintained.

Other Humanities and Social Science Courses: There will be an effort made to create special sections in courses such as Historical Analysis and Philosophical Analysis which will be composed of engineering students. The material in these courses can then be presented in such a way so as to demonstrate its pertinence to engineering issues.

Objective: The goal is not to dilute the humanistic and social science content of the engineering curriculum. Instead, by having the students learn this material with some emphasis on the context of engineering, it will enhance their appreciation of it. It is perceived that they will place more importance on this material while they are students and also that they will be more apt to retain it and use it when practicing their profession.

Course Coordination

The coordination of courses requires close communications between the faculty teaching the individual courses. At the time this document is being written, this has been applied only to the freshmen engineering courses and the freshmen English composition courses. It has been implemented through weekly meetings between the faculty involved and through attendance by faculty of the classes in the other dicipline.

There is concern that this practice will be difficult to maintain as the program expands. It is time consuming for faculty to attend the weekly meetings (usually 1 hour in length) and especially time consuming to attend the other class meetings. If this practice is to continue, it will be necessary to compensate faculty for the extra time spent on these activities. Also, there is concern over the effects of expanding the coordination to more than 2 courses. It may prove difficult to hold meetings among faculty from courses in engineering, English, mathematics and physics who are all attempting to discuss course assignments and coordination. This could lead to the necessity of either holding much longer meetings or holding meetings of sub-groups. Either situation would lead to greater time demands on the faculty involved and exacerbate the problem of compensation for the extra time.

Bootstrap Meeting

Prepared by:
Elizabeth Pittenger, Florida International University

Presented by:
Malcolm Heimer, Elizabeth Pittenger, and David Pittenger
Florida International University

In an effort to give the attendees to the Gateway Conference a taste of how we actually create the curriculum for our freshman and sophomore engineering students who participate in the Gateway Program at Florida International University, the following "play" was scripted.

Those of you who were present in the audience may have noticed that what you saw then is not necessarily what you get herein. That's because, you will remember, the performance created itself before your eyes much like our actual Bootstrap Meetings evolve in "real life."

We hope you enjoyed the meta-Bootstrapping presentation. And we hope you will view this script as an *aide de memoir*.

Malcolm: Well, we've got this Gateway annual conference in Philly. What are we going to do?

Liz: I've got two questions: What <u>are</u> we doing? And how does what we're doing make us different?

David: I think we can brainstorm some answers. But whatever we decide, let's not bore them to death once we get there.

Malcolm: Before we get too crazy, here's the agenda for the upcoming week.

Liz: I don't know why I'm so dependent on your agendas. After all, we keep making everything up as we go along.

Malcolm: Yes, but you know how we engineers like to think.

David: Yeah! I sat in on your introduction to engineering course the whole year, taking the class along with all our new Gateway freshmen, and I still don't know how you engineers think.

Malcolm: That's okay. I still haven't figured out how Liz thinks. And it still feels strange to be in a class teaching freshmen students. I hadn't seen a freshman in ten years.

Liz: This all seems perfectly normal to me. Let's see ... what's *numero uno* on this list?
Oh, the Gateway conference. Hey! I had this idea. . .what if we just show them what we do on a weekly basis?

David: How can we do that when <u>we</u> don't even know what we're going to come up with at these meetings?

Malcolm: At least it won't be the ususal "stand up in front of the room and talk at them" kind of thing. We could begin talking about our plans for the class the following week, carry that on through and then go to an evaluation. Move through time. Flash a sign that says "Time Passes" to let the audience know what's going on.

Liz: Right! Sort of a meta-bootstrapping session. But I think we need to get back to our questions. What are we doing this for?

David: Well, I suggest we base the whole thing on the same central pillar we base the Gateway Program on ... the design Project.

Liz: ... And the idea of Process. You know, show them how we're figuring out what to do when the paradigm shifts.
Malcolm: Yes! It's important to demonstrate how we make the students take responsibility for their own education with the grading committee.

David: Right. That reminds me, don't let me forget to tell the "Three Amigos" about the internship with Coulter Electronics.

Malcolm: Ah, yes. How's that going?

David: [AD LIB about the internship]

Liz: Let's mention this to Annette, too. She's a non-traditional freshman. Did you know that she's already got several years experience working for IBM?

Malcolm: Yes, that surprised me. When I mentioned that about 50% of the freshman Gateway class was girls to the sophomore class, they all perked up their ears.

Liz: Guess they're pretty normal. This year's freshmen students are already showing an interest in their sophomore counterparts. I think it's important that we bring them together. Let them know they're not alone. We've got to begin to give the program a feeling of being continuous, having some traditions.

David: Exactly. Have a mixer. We can do it in either the intro to engineering class or in their English class. You know us English people ... always ready to party.

Malcolm: That would be perfect. Remind me to mention it when we go to Professor Radin's class Friday to tell the sophomores to prepare their Baja experience presentation for the freshman class.

Liz: That's the taping, right? The day I'm supposed to bring the camera to take slides in case we can't find the old video in time for the Philadelphia meeting.

Malcolm: Yes. We meet in the studio for another go at the always unpredictable role-playing project proposal.

David: I love these taping sessions. They're just like our meetings. You never know what's going to happen next.

Liz: Just like us the students have their own agenda, but things always end up being impromptu. Good quality in an engineer ... think creatively on your feet.

Malcolm: Well, we've still got the old-fashioned kind. Let me show you this article by Bob Pease. I want to give it to our freshmen and see what they have to say about it.

[The **article** is projected onto the screen.]

David: "What's All This Spreadsheet Stuff, Anyway?" Sounds exactly like what our students are doing in the computer lab with Excel. They should be experts.

Malcolm: They are. That's why I wanted to have their reactions. He's a sort of curmudgeon in favor of going back to the old way of doing things.

Liz: I'd love to see what this computer generation will do when they get hold of this. Why don't you let me show this to them in English, and I'll give them an assignment to react to this article with letters to Robert Pease? It could be fun.

[Published **student letters** are projected onto the screen.]

David: Who knows, he may print them and our students will have national publishing credits.

Malcolm: Right! They'll be entering into a dialog with a real engineer.

Liz: Yes, I think that's one of the things Gateway should do ... provide students with opportunities to think of themselves as budding engineers.

Malcolm: It's important that they no longer have that old feeling of, "Well, I'm taking all this math and physics, and English, and someday I'll be an engineer." They should begin doing and being engineers now.

David: Speaking of which . . . How are the student projects going? Are they in their teams yet?

Malcolm: They grouped in fours and already elected the group captain as well as a person to represent them on the grading committee. And they're brainstorming their own projects.

Liz: It's great. I got to sort of float from group to group. Listen to their ideas: an oncoming headlight detector that automatically adjusts your beams from high to low; a pendulum guided submarine capable of diving and resurfacing; a doorbell answering machine.

David: All those ideas already? They understand that they're supposed to design and build a prototype by the end of the semester, right?

Malcolm: No question about that. We decided to let the sophomores change their projects if they wanted to.

Liz: I'm glad. Sticking with a project that gets to be disappointing after a year's work could alienate the students.

David: No more temperature controlled hat? What'll I do when the Phillies come to play the Marlins and I'm sitting on the sunny side of the stadium?

Malcolm: I'm afraid the students discovered that the Peltier unit attached to a metal conducting plate just wasn't efficient.

David: Okay. I had a hard time imagining myself with a car battery on my hip, operating my cooling device.

Liz: And the Water Whacker?

Malcolm: Oh! That group is considering applying for a patent for their device.

Liz: I could have used the Water Whacker after Hurricane Andrew.

David: No more hover cars in the works?

Malcolm: The Mini-Baja competition vehicle seems to have their attention. Apparently some of last year's freshmen got to drive it over the summer and had lot's of fun.

Liz: It seems to be the kind of engineering project that has everything.

Malcolm: We've got some great pictures of the students and their car.

[**Malcolm** *ad libs* as the slides are projected.]

David: So this is essentially what the sophomores are going to show in their presentation to the freshmen in two weeks?

Liz: I wonder if we should involve the speech department in giving some "hot tips" to the freshmen about giving oral presentations?

David: I can contact Professor Karsh; she'll be happy to help out with our Gateway group. But it might be a better idea to let the first presentation be done "cold Turkey" so that there's less pressure on the students to have to do their first presentation a right way.

[**Freshman presentation** slides are projected during following bit.]

Liz: How are we going to grade these presentations?

Malcolm: I thought we could let the student grading committee meet and decide. Nothing too complicated, just select several criteria, such as content, organization, and maybe imaginativeness of delivery.

Liz: Good. That jives nicely with some of the main considerations they have to keep in mind when doing essays for the English class. This way they'll see how the skills of one discipline are required by others.

David: Have you noticed the student evaluators are always harder on their peers than we are?

Malcolm: Yes, I'd be inclined to just hold up a card with "5" or "3," like judging an event in the Olympics.

Liz: That takes care of the oral presentations. What about the written ones?

David: Maybe both the English and engineering departments can evaluate those.

Malcolm: I'd like that. I still feel uncomfortable grading formal writing asignments.

Liz: Sure, I'd be happy to help. Only I think it ought to be made clear that the writing of this engineering project is your assignment. So, I'm not going to use English class time for any drafting.

Malcolm: No. They have to be able to take responsibility for their own work.

David: In that case, Malcolm, maybe we should give you some guidelines for grading written assignments and let you take over the grading of the papers yourself.

Malcolm: Thanks a lot!

Liz: Just write down a "5" or a "3." The students will catch on.

David: Seriously, this does raise some issues. The Gateway Program requires extra work by the teachers involved in it. If it's going to continue, the faculty has to be compensated for their time.

Malcolm: True. We're supplying funds to the community college to underwrite the time of the people over there trying to implement a Gateway Program so that their graduates integrate seamlessly when they come to F.I.U. after two years.

Liz: Great. But what happens at the end of four years when the N. S. F. funding dries up? I don't like the idea of being involved in an experiment that has little likelihood of becoming the new paradigm. It's an empty exercise.

Malcolm: And there are so many different approaches we could take. Do we create a liberal arts education for the engineering students or do we prepare them for the engineer-in-training exam that all graduates have to take?

David: And the students tell me they want some kind of acknowledgment by the university, recognizing that they've been through a special program.

Liz: And we want the university to accept the changes we've made in the engineering curriculum and adapt to the project design approach.

Malcolm: Besides those issues, there's the whole issue of ABET. There seems to be little real sense in changing the engineering education paradigm if the accrediting organization doesn't go along.

David: There's a real isssue here of cross-disciplinary education. Even the dean of Arts & Sciences has questions about what we're doing with engineering as English instructors. He doesn't want the perception to be that we're a service to another college.

Liz: Well, I, for one, do have this "vision thing" -- if I can quote our former President. I think if the Federal government is funding a nationwide project to change engineering education, then some real changes have to be effected. Otherwise, we've squandered the money.

Malcolm: The truth is, at F.I.U. we're luckier than some schools because we have our dean on board.

David: It's a truism that colleges and universities are just like any other bureaucracy ...territorial and resistant.

Liz: One day this introduction to engineering course should become a core requirement for all entering freshmen.
Malcolm: That's true, this is an Age of Technology.

Liz: Exactly! We have to address verbal, numerical, and technological literacy for the next century.

David: Whew! That's a tall order. Maybe we can get some help with these concerns from our colleagues at the Gateway convention.

Malcolm: Well, that brings us right back to item one on our agenda. Let's see . . . as usual we didn't stick to the formalized program.

Liz: What did you expect?

Malcolm and David: The usual!

Finis

Restructuring Applied Thermodynamics - Exploratory Thermodynamics

Prepared by:
John S. Morse, University of South Carolina

Applied Thermodynamics is a staple course in the Mechanical Engineering curriculum. Although there is probably not a universally accepted canon, most offerings include power and refrigeration cycles, mixtures with particular attention to air conditioning, combustion, and equilibrium. Normally the course involves a great deal of analysis work, with some design placed in. Usually the design is not high level, that is, optimization is rarely a goal. Design is normally a matter of picking the appropriate process and developing parameters that result in a workable model.

It is desirable to improve the design process, but the cost of working thermodynamic analyses is high. In thermodynamics, almost all property models are very complex, so complex in fact, that look-up tables are required to contain all the data. Thus there are very few analytical solutions in thermodynamic analyses for use in optimization procedures. The look-up nature of property values discourages repeated solutions of the same problem under slightly different conditions, and it also leads to frustration on the part of the student. If such look-up work ("drudge work") could be eliminated, more effort could be focused on thermodynamics and design. One obvious solution is to obtain equations of state and provide computer look-up mechanisms. This has been done by a number of firms that market property value software, such as ThermoWare (Stanford University) and the American Society of Mechanical Engineers Steam Tables, 6th edition (Fairfield, NJ). However, the inputs to these must be done manually, and then the student writes down the resulting numbers and then works out the first and second laws, and so forth. This shortens up the time spent on working a problem, but does not necessarily mean the student would gladly do an optimization study.

The next step up is equations of state that can be called as subroutines. One such set is by

Sonntag, Park, and Park (John Wiley and Sons, NY, NY). It contains FORTRAN subroutines for several substances that provide all property values for any set of two inputs that include temperature and/or pressure. There are eight sets of input pairs. I have used this software extensively in my classes, having students write programs that analyze Rankine cycles, air conditioners, and adiabatic saturators (swamp coolers). They have also written programs to optimize reheat pressures in Rankine power plants. However, the drawback here is they must write the program.

The next logical step is to eliminate the programming and replace it with a visual environment. This transition is why spreadsheets are often preferred over user-written programs to perform simple (and complex) engineering calculations.

The vehicle I have chosen to replace user-written programs is VisSim, by Visual Solutions (Westford, MA). It is a simulated analog computer that runs under Windows. It allows user-defined functions, which are programs in the form of dynamic linked libraries (DLLs). The current DLLs include butane and water. I obtained equations of state from "Thermodynamic Properties in SI" by W. C. Reynolds (Depart-ment of Mechanical Engineering, Stanford University). Each DLL is attached to a user-defined block bearing the name of the substance. The two current DLLs each have three inputs and seven outputs. The inputs are two independent variables, plus a third input that stands for the type of input pair, i.e. temperature and pressure is input pair number one. The seven outputs are pressure, specific volume, temperature, specific internal energy, specific enthalpy, specific entropy, and quality, and they appear in that order from top to bottom. Pressure is in MPa, temperature is in K, and the other variables are in kJ/kg, kJ/kg K, or m^3/kg. A series of other DLLs to perform other property value functions is planned. These will include specific enthalpy as a function of temperature for gases, and combustion properties such as enthalpy of formation and stoichiometric requirements.

In order to analyze a thermodynamic problem in VisSim, the student must write out the necessary mass and energy conservation equations, plus the second law if applicable. These are then translated into on-screen elements ("blocks") representing algebraic operations. Property values are looked up with user-defined blocks placed where needed. The easiest way to describe a VisSim solution is to view Figure 1, which is a simple ideal Rankine power plant. It requires three property value calls, one of pressure and quality (pump inlet), one of temperature and pressure (boiler exit), and one of pressure and entropy (turbine exit). Note that butane is being used as a working fluid as the water DLL is not complete yet. Three input blocks are needed to define the cycle, namely, the condenser and boiler pressures and the boiler exit temperature. Note that the first law and pump work equation are used together to provide the pump work and the enthalpy at the pump exit. The block with 1000 in it is a gain block, which simply multiplies the input signal by the gain (1000 in this case) to provide the output signal. This is a units conversion from MPa to kPa. Note that several display blocks show the boiler heat transfer, turbine work, and efficiency, among others.

The beauty of VisSim is that it removes the work of looking up the property values, but still forces the student to work out the conservation equations. It does not provide any magic formulas. Further, it can be graded visually, rather than by going over lines of code in a program. The real power of this approach is that innumerable what-if scenarios can be explored with very little effort. For example, suppose that I wish to have the students observe the effect of increasing boiler exit temperature on both efficiency and the turbine exit state. They can place a ramp function on the boiler exit temperature, to vary it as a function of time. Then they can place a plot block on the diagram and monitor efficiency and turbine exit quality as functions of time (Figure 2). Figure 3 is an enlarged view of the resulting plot. Note that the quality returned by the DLL jumps to 99 when the superheat region is reached. This is to hammer home the fact that quality is meaningless outside the two-phase region.

The VisSim approach is much more powerful than working one or two problems in class and then extrapolating the results verbally. With this diagram, it is a simple matter to assign as homework the exploration of changing boiler pressure, condenser pressure, and boiler exit temperature. This can be done on the first day the Rankine cycle is covered, since the student need only understand the hand analysis to build the VisSim model.

The next step with the Rankine cycle is to introduce the reheater, which is readily done after the students report the results of the first homework and the teacher explains about the deleterious effects of too much moisture on the turbine exit. The second assignment could involve adding a reheater at arbitrary pressure to the Rankine cycle and reporting on the impact on efficiency and turbine exit conditions (Figure 4). Now the stage is ripe for some design work that is often squeezed out of Applied Thermodynamics, that of optimal reheat pressure. It is simple to program reheater pressure as a function of time and plot it and efficiency as functions of time (Figure 5). Figure 6 shows an expanded view of the plot. Note that the optimum reheater pressure lies below 1 MPa. If each student uses a different base cycle, the class can see that the optimum depends on the other parameters.

The next area of cycle improvement is the regenerative cycle. Since adding feedwater heaters makes the hand solution of Rankine cycles even longer, very few instructors assign enough problems for students to really get a feel for how the regenerative cycle improves efficiency. This problem can be overcome with the use of VisSim. It is relatively easy to add a feedwater heater to a simple Rankine cycle. Adding one or two more can be mostly accomplished with copy and paste operations. After the student grasps the effects of feedwater heaters on efficiency, then one could tackle a design problem of optimizing the pressure distribution of each feedwater heater. However, this may require more time than can be allotted. One might fall back on the equal enthalpy drops simplification model and perturb it to show it is close to ideal. One can also explore the difference between using open and closed feedwater heaters. Note that some of these problems might be better classified as open-ended design problems.

Another major subject area in Applied Thermodynamics is air conditioning problems that involve air-water vapor mixtures. There are of course two major classifications: cooling with condensation, which necessarily involves an external refrigeration device, and adiabatic saturation cooling, or swamp cooling. Either of these systems is easily set-up in VisSim. Figure 7 illustrates a condensing type air conditioner. The user can set the inlet and outlet air temperatures and relative humidity levels. The model calculates the condensate flowrate per mass of dry air flowing through the unit, and the required heat transfer per mass of dry air. It also calculates the temperature the air must reach as it passes through the evaporator coils in order to achieve the desired exit specific humidity. This temperature is designated T evaporator on the diagram. The student can explore changing the inlet and outlet conditions and can note that removing water vapor takes a lot of energy compared to cooling the air down.

The swamp cooler can also be investigated. Figure 8 illustrates a swamp cooler. The model is virtually identical to the air conditioner. In the swamp cooler, the outlet temperature is unknown. Therefore the first law is solved using a constraint block, and an unknown block is placed in front of the output temperature variable block. An initial guess is fed into the unknown, and then VisSim uses the Newton method to vary the outlet temperature until the constraint block reaches zero. Thus the user does not have to write any code for finding the correct outlet temperature. The student can explore the effects of changing the inlet relative humidity, which has a tremendous impact on the change in temperature across the adiabatic saturator. The swamp cooler can be extended to an indirect cooling unit as shown in Figure 9. This allows the student to explore the diminishing returns effect of using swamp cooling in high humidity areas. They observe that as the inlet relative humidity approaches 100%, the heat transfer per mass of dry air falls to zero. The indirect cooling unit modeled here has equal heat capacities on both sides of the heat exchanger.

Current state of exploratory thermodynamics:
This project is currently a work in progress. The models pictured in this communication have been built. The ones that have answers shown in the display blocks (1's are default values) have been tested and work correctly (except the evaporator temperature in Figure 7). The butane DLL is completed (all eight input pairs work). The water DLL is not completed. It has enough input types enabled to do most of the air conditioning applications. For reasons that are not clear right now the swamp cooler is not working. The working diagrams are now ready to be put in the hands of the students. They will use and evaluate the concept of exploratory thermodynamics, and will determine if it is a success.

Summary

The concept of exploratory learning is to give students an environment in which they can rapidly solve thermodynamic analyses, opening the possibility of high level design work. This can be done with a product such as VisSim, where the drudge work of looking up property values is eliminated, but the thermodynamic analysis (conservation equations) must still be used. Once a model is constructed, the student can run numerous variations to perform parametric design studies.

Work is nearing completion on air conditioning applications and on a Rankine cycle with butane as a working fluid. More work remains in finishing the water DLL and testing and validating the models shown here. It is my intent to also do work with adiabatic flame temperature and equilibrium in the future.

Freshman Engineering Design - The First Two Years

Prepared by:
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Presented by:
George Pincus, New Jersey Institute of Technology

The New Jersey Institute of Technology is a member of the NSF sponsored engineering education "Gateway" Coalition. NJIT working with other Gateway partners, planned and developed a new freshman engineering design course: Fundamentals of Engineering Design within the Coalition focus area of Curriculum Innovation and Development. The process of course development and implementation, details of the course, teaching methodologies, course philosophy and valuable lessons learned are described below.

Introduction

Initial planning sessions of the ten Gateway Coalition partner schools during 1991 identified Curriculum Innovation and Development as a principal area of interest to all partners. Thus, NJIT placed a high priority on curricular innovations and specifically, within the freshman engineering program. This priority is motivated by desires to alleviate retention problems identified at many engineering schools.

Improvement of engineering design throughout the curriculum has been a popular topic in many engineering education meetings and other interested groups. In particular, the Manufacturing Studies Board of the National Research Council issued a timely report "Improving Engineering Education," National Research Council, Washington, D.C., 1991. The Manufacturing Studies Board includes industrial leaders and academicians and several recommendations and comments are most appropriate for development of engineering design courses. For example:

"Design education is clearly weak; it must receive increased emphasis and introduce modern design practices if it is to educate engineers who will contribute to the drive towards greater industrial competitiveness."

"Undergraduate engineering design education must:

- show how the fundamental engineering science background is relevant to engineering design;
- teach students what the design process entails and familiarize them with the basic tools of the process;
- demonstrate that design involves not just function but also producibility, cost, customer preference, and a variety of life cycle issues; and
- convey the importance of other subjects such as mathematics, economics and manufacturing.

To achieve these goals, design must be distributed throughout the engineering curriculum, beginning with introductory design courses, which serve the dual purpose of introducing the design process and demonstrating the relevance of the engineering courses to design, and continuing as part of the more advanced engineering courses."

Many engineering educators describe the need for incorporating design in the freshman year. For example: "The eternal questions for freshmen engineering programs must be, how do we foster enthusiasm and motivation while trying to develop skills, encourage creativity, and instill discipline?" from T.A. Blasingame, in Computer Aided Problem Solving: Experience in a Freshman Class, Preprint, Fourth Conference on Undergraduate Engineering Education, Santa Barbara, CA, July 26-31, 1992.

or:

"The course involves a project-driven approach that groups students in teams to participate in the design activities associated with the product realization process. They gain a conceptual understanding of the engineering design process through an active learning experience....Reaction to teaching design so early in the engineering curriculum has been extremely favorable. Students are highly motivated by the design approach and, as a result, learn engineering fundamentals, develop critical thinking skills, learn to cooperate as teams members and gain practical hands-on experience." from J.W.Dally and G.M. Zhang, A Freshman Engineering Design Course, Journal of Engineering Education, Vol. 82, No. 2, April 1993, pp. 83-91.

or:

"Design integrated throughout the entire curriculum can stimulate and motivate students in all of their sometimes daunting studies. Tying together and justifying the many disciplines of modern engineering practice, design integrated across the curriculum and throughout the educational sequence can provide students with a clearly visible, unbroken path that starts with the freshman year and leads to a rewarding professional career. Early and continuing practice in design, in the broad sense of original thinking intended here, can dramatically improve the entire engineering education experience," from C.R. Peterson, in Why Integrate Design, ASEE Prism, Vol. 2 No. 9, April 1993, pp. 26-29.
or the following three quotes from the recent paper by Bordogna, Fromm and Ernst: Engineering Education: Innovation Through Integration, Journal of Engineering Education, Vol. 82, No. 1, January 1993, pp.3-8:

"There is a growing need to influence academe to educate students to see the world whole, to help them sense the coupling among seemingly disparate fields of endeavor, to teach synthesis in balance with analysis, and to enhance their capabilities to build connections between the world of learning and the world beyond,"

"This new construct of the curriculum has an integrated core in which the basic science fundamentals are developed 'just-in-time' with engineering concepts while the engineering purposefulness of the entire enterprise becomes apparent,"

"Student interest and excitement is high, leadership qualities and personal professional development emerge, while retention rates are increased by double digit percentages and pedagogy is 'robust.' This construct, developed with significant structural and cultural change, relates to the first two years in a single specific institutional environment. Bold experiments which address these challenges across the nation's many forms of institutional settings and extend throughout the duration of the baccalaureate experience must be undertaken."

The efforts for the first year of the Gateway Coalition focused on planning the freshman course and included exploration of the various modalities used to teach freshman engineering design at other schools. In particular, parts of other partner's freshman engineering curricula were reviewed, and where appropriate, adapted for use in the NJIT freshman design course.

Similarities among NSF Engineering Education Coalitions funded since 1990 indicate high priority for activities dealing with engineering design, and in particular, freshman engineering design, as shown in Figure 1:

Engineering Education Coalitions
NSF Funded for 5 Years for $15,000,000 Each

- SYNTHESIS (1990) California Polytechnic State at San Luis Obispo, Cornell, Hampton, Iowa State, Southern, Stanford, Tuskegee, UC Berkeley
  - Prototype of a new multimedia electronic database and network
  - 5 model courses and courseware prototypes
  - * Freshman design experience

- ECSEL (1990) Howard University, University of Washington, University of Maryland, Penn State, MIT, Morgan State, CCNY
  - ***** Integrate design into the entire engineering curriculum
  - Students to become active learners through emphasis on hands-on projects, teamwork and communications

- SUCCEED (1992) Clemson, Florida A&M/Florida State, University of Florida, Georgia Tech, North Carolina A&T, North Carolina State, University of North Carolina-Charlotte, Virginia Polytechnic Institute
  - * Curriculum restructuring to integrate all subjects with engineering design and practice
  - Eliminate course and infrastructure barriers to curriculum innovation
  - Focus on engineering as a process and system
  - Total quality management

- **GATEWAY** (1992) Case Western, Columbia, Cooper Union, Drexel, Florida International, **NJIT**, Ohio State, University of Pennsylvania, Polytechnic University, University of South Carolina
  - ***** Emphasize design and teamwork throughout curriculum
  - * Focus on teaching the core of engineering "up front"
  - Quality assurance and outcomes measurement

Figure 1: Existing NSF Engineering Education Coalitions.

Planning

A faculty committee with representation of all engineering programs was formed and began considering possible incorporation of an engineering design experience in the freshman year (the freshman year is common to all NJIT engineering students). The existing course EG 101 Engineering Graphics was selected as an appropriate candidate for revision and upgrading. The Committee considered several Gateway models and after careful deliberations proposed a replacement course FED 101 Fundamentals of Engineering Design which would retain key features of EG 101. However, course teaching methodology was modified to provide learning of "skills" during the process of working through "modules." Instead of following chapters in a text for the purpose of learning a specific body of knowledge and testing students to determine how well the information was retained, a different (for NJIT) approach was developed. Thus, freshmen students are part of a design team working on deliverables. In developing a solution to the design problem, a variety of skills are learned "just in time," often termed "concurrent engineering." Thus, when students need to produce drawings, a CAD program is learned and used. Or, if students need to collect data and arrive at some conclusions, simple principles of statistics are learned and used. The faculty committee prepared the "modules" in order to provide real team design learning experiences.

Course Description and Organization

Fundamentals of Engineering Design is now required in the freshman year in all engineering programs offered at the New Jersey Institute of Technology. The course meets three times per week and includes lecture, recitation and laboratory. Volunteer faculty from several engineering disciplines participate as members of teaching teams.

The course consists of learning modules addressing carefully selected open ended engineering design problems. The assignments are selected to illustrate a multitude of engineering design tools, for example: software applications across engineering disciplines; computer aided design and drafting; sketching, dimensioning and blueprint reading; graphical analysis and presentation; spreadsheet use; data collection, processing, and statistical analysis. Modules also include relevant modern methodologies such as total quality management and pollution prevention and control.

Students are grouped in interdisciplinary teams and are expected to learn specific skills as they progress through each module as shown on Figure 1. Each module focuses on a specific area of engineering, for example, one module includes design of a part for a machine. Students in the module learn computer graphics, dimensioning, material behavior, elementary mechanical design, a software design tool, and actual physical production of the part using a Stereo Lithography Apparatus (SLA). The students may collect dimensional data and perform a statistical analysis and thus, learn concepts such as median, standard deviation, and distributions.

Modules in traditional engineering fields of chemical engineering, civil engineering, electrical engineering, industrial engineering, and mechanical engineering as well as interdisciplinary biomedical, transportation, environmental and manufacturing engineering are included or will be included in the future. Students spend at least 7 weeks on each module, depending on the complexity of the problem. NJIT's resources are available to students. Laboratories containing testing equipment, chemical analysis equipment, machine shops, robotics labs, wood shops, among others, may be used. Also, recently built computer rooms have been equipped and use priority assigned for freshmen. State-of-the-art design tools and other software are available to freshmen in the lab.

Student teams of four members each work together in solving a design problem, and presenting a deliverable. Thus, oral and written presentation skills are developed. Each course section completes one module and then the section is assigned another module. The modules are under the direction of one or several professors with other faculty participation as required by the module contents. For example, the module may address a problem in chemical/environmental engineering. The lead professor may be a volunteer chemical engineering faculty but may be assisted by a mechanical engineering faculty member, humanities faculty, and others.

First Year Deliverables

The first freshman design course is now in operation and appears to be successful. Laboratories to serve the needs of the course(s) were prepared and are operating. These include a 20 workstation room used as a teaching classroom and as an open computing laboratory plus a 1,000 sq. ft. room adjacent to the "Factory of the Future" equipped with tables, lockers and chairs for use of the student teams. Four sections of FED 101 Fundamentals of Freshman Design are running in the 1993 fall term. The FED 101 course includes 3 modules: A Manufacturing/Mechanical/Industrial Engineering module lasting the full 14 weeks of the semester plus two other modules: the Electrical Engineering/Physics module lasting 7 weeks and the Civil/Environmental Engineering module lasting 7 weeks. Students in all four sections of the course meet for 3 hours per week for the Manufacturing/Mechanical/Industrial Engineering module and cycle through the other two modules which also meet 3 hours per week. Thus, students meet for a total of 6 class hours per week. Figures 4 to 6 describe the 3 modules developed for use in the Fall 1993 semester.

An expansion of the freshman design experience has been proposed. The proposal, which has a target initiation date of fall 1994 (that is, the 1994-1995 academic year) has two parts: The first part is a change in title of course FED 101 Fundamentals of Engineering Design to FEDM 101 Fundamentals of Engineering Design and Manufacturing I. The change is a reflection of the significant course content in "manufacturing" related activities. For example: computer aided design, tolerances, dimensioning, manufacturability, production of the actual design in the Stereo Lithography Apparatus (SLA) are all included in FED 101. The second part of the proposal is to introduce a new course FEDM 102 Fundamentals of Engineering Design and Manufacturing II. This course, similar in organization to FEDM 101, will replace an introductory course in computer and information science taken by all engineering students (CIS 101). Programming and other computing skills will then be learned by students as they worked through the modules in the two courses FEDM 101 and FEDM 102. Thus, the freshman design experience will include both semesters of the freshman year. These changes are being proposed and are subject to approval by the Undergraduate Curriculum Committee, the Engineering Chairpersons Council and the NJIT engineering faculty.

Evaluation Plan

Student attitudes towards engineering will be evaluated using written and oral instruments. The data will be compared among sections and groups of students each year. The impact of having the freshman design experience will also be measured by retention, a quantitative amount, as well as number of times students change their major. Also, written teaching evaluations are performed in each section of the course. These student evaluations help identify course impact upon the students, and serve to assess other significant factors such as: the materials being taught, the facilities, and the instructor. Faculty at other Gateway Coalition schools may be asked to help evaluate the NJIT freshman design course(s). In addition, the English/Humanities course in the freshman year is closely linked to the Fundamentals of Engineering Design and Manufacturing course and evaluation instruments are being developed for that specific linkage. During presentation of the deliverables, panels of industrial experts may be asked to help judge and evaluated student work.

NJIT/GATEWAY Coalition and Future Plans

Several of the NSF-sponsored ngineering Education Gateway Coalition schools have developed similar freshmen courses. For example, the E4 program at Drexel university uses an integrated modular approach to learning and students are expected to learn skills as they complete design assignments. Relevant material developed in the E4 program was adapted for use in the Fundamentals of Engineering courses at NJIT. Other schools are in the process of developing teaching modules. NJIT will exchange and compare freshman design modules with other Gateway Coalition schools (Case Western Reserve University, Columbia University, Cooper Union, Drexel University, Florida International University, Ohio State University, Polytechnic University, University of Pennsylvania, University of South Carolina).

Plans for the future include having a group of lead freshmen design professors from other Gateway Coalition schools visit NJIT for the purpose of reviewing and advising NJIT on possible improvements in the freshman design courses. Also, proposals will be made for the second and third year of the Gateway project (1993-1995) to form student and teaching teams across Gateway Coalition schools to work on common modules. State-of-the-art communications technologies will be incorporated into these activities to bring the world of the future to the classroom environment. NJIT will identify community colleges, one in south New Jersey and another in north New Jersey to expand offering of the freshman design courses to community colleges (1993-1994). By the last year of the Gateway project (1996-1997), student competitions will be organized and held. Also, the balance of community colleges in New Jersey will be provided with the opportunity to offer their students NJIT's freshman design courses.

The Freshman Engineering Design Project Experience at F.I.U.

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Abstract

This paper presents a different vision for the engineering education process. Based on this vision a sequence of pilot team-Taught courses, with emphasis on the product realization process, were introduced to the freshmen in the honor program at Florida International University College of Engineering. The design process teaching experience in the first of these courses is discussed.

Introduction

Engineering design has long been recognized as one of the most critical components of the industrial product realization process. Within the past two decades, the effective use of engineering design has allowed foreign firms to improve quality, reduce cost, and speed time to market. The result has been a steady decline of U.S. competitiveness in the global marketplace. Improving design methodology has been recognized as the single most essential step to industrial excellence and national competitiveness of U. S. products.

Unfortunately, the overall quality of engineering design in the United States is regarded by many as quite low. The partnership that exists to enhance engineering design - industries, universities and the government - has not always worked to the advantage of the product realization process. Linked to this situation is the widespread opinion that engineering curricula do not adequately prepare young engineers to become creative design professionals.

To address this concern, one of the key objectives of the GATEWAY Coalition is to make design a focal point in engineering education. As member of the GATEWAY Coalition, Florida International University (FIU), has introduced a sequence of pilot team-taught courses, with emphasis on the design process, to the freshmen in the honor program. These courses are based on a different vision for engineering education. In the following, the vision and teaching experience in the first of these courses are discussed.

Current Engineering Curricula

Recent engineering curricula revisions have been characterized by two major trends: (1) a continually increasing emphasis on courses concerned with teaching theoretical techniques or concepts; and (2) an overall reduction in the total number of courses required for graduation. Partially as a result of these changes, a very important aspect of basic engineering has been slighted, specifically that part of the curriculum integrating theory and experiment through engineering design projects. Undoubtedly, these new curricula adequately prepare young engineers for analytical work. However, graduates of such programs often lack the techniques necessary for dealing successfully with complex practical problems which characterize both industrial operations and research.

Curricular developments in many institutions have also been influenced significantly by increasing stricter enforcement of compliance with the EAT/ABET design requirements since the late seventies. In many curricula, the depth of engineering science has been reduced to accommodate additional "design." While the intent of broadening the design experience may have been good, specific implementations have often led to an overall weakening of the curricula, particularly when the design projects were not well integrated with the general engineering science topic at hand.

Industrial managers indicate that many of today's graduating engineers, although well qualified as far as theoretical understanding is concerned, do not appear to be prepared for planning and implementing engineering projects involving the prediction of the performance of complex systems. Further, these students do not appear to have sufficient exposure to realistic modeling, analysis, and synthesis. Projects require a familiarity with engineering hardware and experimental measurement techniques, as well as an ability to contribute to group problem solutions. These managers further indicate that most industries provide training programs for young engineers covering material which they feel should have been offered as part of their undergraduate education.

In an attempt to provide a meaningful education in engineering, within the framework of present-day curricula, an increasing number of colleges and universities have evolved some type of capstone design course, partly due to accreditation pressure. These courses range in length from part of a semester to one academic year, with some extending over a longer period of time. The structures of these courses range from individual study research to group projects, and may involve engineering design, feasibility, application studies, and prototype development. Course supervision varies from weekly meetings to periodic reviews of the students' work.

A majority of the engineering problems of today are complex and may involve such diverse disciplines as psychology, economics, biology, chemistry, physics, and sociology, as well as the many fields of engineering. How can an engineer design systems that minimize air pollution or global weather impact, for example, without being concerned about chemical processes, atmospheric properties, weather phenomena, safety, financial limitations, and perhaps even politics? In order to analyze such problems adequately, the young engineer should be prepared to interact effectively with other disciplines, in addition to engineering, which may be associated with the project. Group dynamics, team-work and communication skills are essential to a successful project and should be practiced in project activity. Most important engineering design projects of today are multidisciplinary in nature and require a multidisciplinary group solution.

Vision for Engineering Education

From the previous section it is clear that a paradigm shift in engineering education is needed. The sequence of new courses introduced to the freshmen in the honor program at FIU College of engineering is a step in that direction. The sequence of team-taught courses are designed with a different vision for engineering education. The basic philosophy behind these courses is the following:

Since product realization is the heart of the engineering profession, product realization process should be the heart of any engineering education from its starting point.

In other words, one of the main objectives of any engineering education process is to expose students to a realistic engineering product realization situations which, upon satisfactory completion, should enhance their ability to assume responsibilities and to optimize their decision-making and team working skills. This type of experience is increasingly important because practicing engineers continually need to find, accept, and apply new ideas, methods, and materials. Such experience will provide the young engineer with a background in engineering hardware, group dynamics, and experimental measurement techniques, and better prepare him or her for a career in engineering.

To implement this vision at FIU, a sequence of multidisciplinary project type courses were introduced to the freshman honor program. Benefits from the multidisciplinary projects type course are many. These projects foster a logical and orderly approach to group problem solving. In order to achieve the problem's solution, the students must analyze the project in its entirety prior to its initiation. This requires the definition of the importance of the project and compromises the ideal and practical approaches. The projects encourage planning and efficiency, since the project must be completed in a finite amount of time. Design projects emphasize the need for application of critical path techniques. Further, emphasis should be placed on continuous improvement and total quality- that is, meeting stated objectives at a reasonable, competitive cost.

The design projects, at the freshman level, foster ingenuity and creativity as the students apply the basic engineering knowledge as they learn it to practical projects. Students are encouraged to use the equipment available in the laboratories with modifications as necessary, since financial resources for the projects are generally limited.

The projects also promote technical responsibility and professional ethics. The students are obliged to defend the technical recommendation which they have derived on completion of their project. Students benefit from the mentoring activities that invariably will occur because students typically acquire technical strength in different areas. This is particularly true in the practice of interdisciplinary situations.

The design projects help to broaden the students' outlook and capabilities, as they mature, during the educational process. Discussions with faculty and library research, using the various sources of scientific information, and discussions with peers, all become useful and valuable resources as the student analyzes and conducts the project. Especially valuable in multidisciplinary teams is the experience of dealing with differing viewpoints.

The design project also develops team effort, where not all students perform all tasks, but a group effort to complete a project. Organization and working together are essential to a successful project. If design goals and "product" objectives are well defined and identified, the ultimate outcome, in the form of a prototype, can be evaluated. The team as a group is accountable. If properly organized, individual team members are also accountable to the team. for maximum effectiveness, teams should expect and demand such accountability of each of its members. To that end, students should participate in evaluation of individual contributions to the overall effort.

It is, of course, true that all projects do not meet all of these expectations for all students involved. However, the experience to date indicates that students who have participated in such a design project course are better able to meet the challenge of today's technology.

Freshman Engineering Design Experience

The first freshman course in the FIU sequence included lectures on the design process, and team-oriented design projects requiring both oral and written proposals and reports. Half of the class time is devoted to the projects. During the first month of the semester, lectures are devoted exclusively to the design process. Ways in which a design team may be formed and organized are discussed. Techniques on individual and team brain storming are presented.

By the end of the first month teams of 4-6 students are formed. Interactive discussions on the problem identification process with each team are conducted. The lectures then focus on the importance of communication, including oral and written proposals, progress and final reports. The importance of high quality working drawings and prototypes are also discussed.

The remainder of the first half of the course deals with brain storming until a project is selected by each team. The project is selected, by consulting with the instructor, from a final list prepared by the team based on the feasibility of building a prototype or a model. During the fall of 1992, there were three teams working on three different projects.

By the end of the first half of the semester a written proposal and an oral presentation is made by each team. While each team must meet regularly outside the classroom in order to complete their project and build their prototype, halfperiods of class-time are regularly set aside during the second half of the semester to allow the teams to discuss and to consult with the instructor as needed. Progress reports and oral presentations are made by each team one month before the end of the semester. At the end of the semester a final report is submitted and a prototype or scaled model is demonstrated during the final presentation.

The design project receives grades, by the instructor and the other teams for the oral presentations. The written proposal and final report are graded by the instructor. After group project grades have been determined individual grades are determined by the instructors based upon student input of each team member's contribution.

The three design projects were new and innovative ideas that were conceived by the students. One particularly creative project was "The S-Hat", which will cool the head in the hot weather and warm it in the cold weather. Students used a semiconductor junction and an electric battery. The prototype was demonstrated for the heating effect during the final presentation. Additional development was needed for the cooling effect and finding the proper size battery for packaging.

Another creative design was the "Water Whacker". By connecting a small container with intake pipe and helical blade to a conventional hedger it can be transformed to a portable pump. The prototype demonstrated the concept but needed further development.

The third project dealt with a concept "Hover Car". A scaled model of the car was built using fiberglass and a layout was presented using AutoCad.

In general, the oral presentations were well-rehearsed and the technical reports were well written. Some engineering analyses were attempted by two teams. Also, some market and cost analyses were made by one of the teams.

Conclusion

During the semester it was very clear that students enjoyed the creativity aspect of the course and the open ended projects. They also felt the importance of communication skills and the effort of other team members in the success of the project. As the course progressed student seemed to get a better understanding about engineering.

Judging from the level of maturity and ability of the students in the following course it is clear that students have learned a great deal about the design process. They also seem to realize the importance and the proper place of the engineering analysis tools taught in other courses.

References

T. E. Shoup " Innovations in Engineering Design Education Resource Guide" Proceedings of the ASME Design Education Conference, Orlando, Florida, 1993.

L. S. Fletcher, *et al*. " The Role of Design Projects in Engineering Education" Proceedings of the ASME Design Education Conference, Orlando, Florida, 1993.

R. Reiss, *et al*. " The Freshman Design Experience at Howard University" Proceedings of the ASME Design Education Conference, Orlando, Florida, 1993.

G. Glegg " The Design of Design" Cambridge Engineering Series, Cambridge University Press, Cambridge 1969.

Freshman Design II

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Goals

The goals are to emphasize creativity, intuition and the cultivation of engineering common sense. This project course could serve both as an introduction to a particular discipline and to the interdisciplinary nature of engineering design.

Discussion

The Cooper Union has been requiring their senior engineering students to take a capstone design course in the four major engineering disciplines (chemical, civil, electrical, and mechanical) for over a decade. Although the students learn that there is often multiple correct solutions their design is often focused to a narrow field of engineering (bridge design, pump/turbine construction, computer networking etc.) and often limited methodology. These is far too much important material to be learned for design education to be focused in a single capstone course. Much of this material can be successfully taught early in the curriculum, thus freeing time in capstone course for more substantial projects (plus giving students a highly motivating taste of some of the creative aspects of
engineering). With this in mind The Cooper Union instituted a freshmen design course.

This first freshman design course introduces the students to the design process. Each student group must state and define their problem, the scope, formulate constraints, evaluate solutions and by synthesizing the facts develop a design. Each student group has a final oral and written report detailing their design. Due to the limitation in the student background and time the projects are limited to a narrow discipline and generally reduced methods of analysis. By continuing the design course to the second semester of the freshman year the students can be introduced to the essence of engineering, i.e., the application of mathematics and science (including the engineering sciences) to real-life problems before they get too deeply involved in studying the more theoretical side of engineering at the beginning of the undergraduate curriculum. It will also help the students develop greater appreciation of the utility of the more theoretical courses they will take later in their program. The development of this second term freshman design course will emphasize creativity in the students chosen discipline within an interdisciplinary context. Interdisciplinary design allows students to interact across disciplines. The course will be divided into two parts. The first part of the course will be "Assemble" where students learn by building a portion of an implemented design module. The importance here, at the assemble stage, is accessibility, repair or replacement, choice of materials, recycling, etc.; where they develop the ability to observe and describe graphically, verbally and in writing (e.g. by writing a manual for building their piece of equipment). Since we do not require freshmen to take a formal engineering lab this projects will entail construction or manufacture and testing of these simple devices. This first part will take about 3 - 4 weeks to complete which includes a final oral (demonstrations of device) and written report. The construction of each device will be a student team effort. The design and construction of the device will teach each student a specific methodology that can be used to refine an assembly design relative to a construction issue. The professor will closely monitor the progress of the device and act as an extended member of the group. This will not only focus the students in the first phase of the project but build a closer relationship between the team and the professor for the second design part of the course. Also, the team will build confidence during the shorter more structured phase of the course.

The second part of the course will consist of a design module. Ideally each group (consisting of 4 to 5 students) will work on different modules. This will insure that there will be no copying of ideas and during the period of oral class presentations there will be a larger body of engineering projects to be discussed. The devices built by each group will have a direct bearing on the design, possibly displaying a physical principle (a small pumping/generating system displaying power).

It is important to note that because the design projects are interdisciplinary the team will consist of students, faculty and practicing engineers from all engineering disciplines. The Cooper Union has been very successful in recruiting practicing engineers to assist the students in their senior projects. Due to the large number of engineering companies in the New York City area near Cooper Union the recruitment of these engineers has never posed a serious problem. The students visit these engineers at their offices and have a first hand knowledge of the design engineers working environment. The practicing engineers have a hands-on knowledge of the project and can relate design details that the professor will not be able to. Therefore, each team will have the sense that they are a small private consulting company and they are working on a contract to design and build a specific module.

Design Team

- 4 to 5 Freshman
- Professor
- Practicing Engineer
- Speech and Writing Experts
- Senior Engineering student

Therefore, each module will have a clear recognition of need. The practicing engineer is often invaluable during this early phase of the design. The next step is to define or formulate the design. Here the students must describe the exact nature of the problem by selecting functional requirements, constraints, and design parameters. Since any good design is an interactive process these requirements will change and probably grow during the data gathering phase. Note, that the major role of the designer is to coordinate inputs from the pertinent specialties, evaluating tradeoff, and guiding convergence to a final design. During this phase of the project the team will emphasize the purpose served by the design and what is to be achieved when the new design is in place.

No matter how well defined a problem may be if the information gathered is incomplete or not accurate the design will be in serious trouble. Therefore, each team will have to retrieve enough information to insure that the data can be interpreted, synthesized, and analyzed. Here the students can be introduced to different sources of information not found in a text or technical journal. This will serve as a first progress report (both oral and written) and as an introduction to the function of a proposal as a device to secure a bid for a design project. The practicing engineer will be instrumental in judging this phase of the design.

First Oral and Written Presentation

- Recognition of need
- Definition of Problem
- Gathering Information

This first report will serve as an engineering proposal.

The next phase of the design has already begun when the information is synthesized (conceptualization). In the conceptualization phase the team has an opportunity to use their inventiveness and creativity. Through these preliminary designs they will develop options for the design. It is likely that the design task is complicated and the project will be subdivided into a number of smaller projects. During this phase the formulation of either or both physical and mathematic models will begin. A ranking matrix will be useful here to determine the best one or two solutions to be carried into the next phase. Note, that the students were introduced to the ranking matrix in their first term. The students will be encouraged to express new ideas. These ideas will be without analysis, that is, deferred judgment. The students will have brainstorming sessions where judgment is suspended until a later screening or evaluation session, that is, no criticism. Note, the wilder the idea the better. Offbeat and impractical suggestions may trigger practical suggestions, The professor will encourage a great number of ideas. It will be easier to pare down a long list in future sessions. The students will accept all ideas and suggest how ideas of others can be turned into better ideas or combined.

The determination and analysis of the final design is often the most rewarding phase of the design project for the student (evaluation). Here the student has selected the most feasible solution based on physical reliability, economics, performance, environmental factors, legal, social, etc. Here the students learn the importance of a sensitivity analysis. By looking at the maximum and minimum realistic extremes of the key design parameters the final design is tested or its sensitivity is determined. Again since the freshman has a limited background the depth of the analysis must be carefully guided by the faculty advisor.

Second Oral and Written Presentation

- Conceptualization
- Evaluation - Design and Test
  design with a sensitivity analysis.

The final phase of the design will be an oral and written report (communication of the design). By the time the students have reached this phase of the design they will have experience in delivering oral and written presentations. The reports will be necessary at selected milestones in the design. Here the team will learn to justify and defend their decisions. They will also have to sell these ideas to the class as a whole. The other teams will learn about different projects and be required to critique each team's design. As in the first term freshmen design course the presentations will be video taped and both speech and writing laboratory will be available. Also, by the time of the final presentation the students have received feedback on their presentation by their classmates, faculty and the professional engineer and have the opportunity to see seniors give presentations. The faculty member will also be guiding each member of the team in sketching, drawing, and drafting. The graphing of the data and acceptable presentation of this data will be carefully reviewed. Each design will have final drawings that have been completed with input from all the members of the team.

Third Oral and Written Presentation

- Communication of Design
  Students will justify and defend
  their design.

The goals outlined above for this second design freshman course is obviously ambitious. Therefore, it is imperative to develop a series of assemblies and design modules that can be completed in a term. A series of handouts will be developed for both the assemblies and design modules. The faculty members must gain the confidence of the team so they are not afraid to question them for information and guidance. There will be the obvious times when the faculty member will take charge of the team's activities to focus their efforts. Each module will be a design of a real engineering project (see the description of a typical module) with interdisciplinary elements. Therefore, the students will not only learn design but they will be introduced to different engineering disciplines and thereby different scientific, mathematic, and engineering principles. That is, there will be a learning experience independent of the design portion of the course. Each project will have to be subdivided into small design projects. These divisions will often be along a discipline line. The joining of these smaller projects into a final design is (probably) the first time the student will learn the nature of interdisciplinary practical engineering projects. The periodic oral presentation and critiques of other teams modules will only broaden the students knowledge of interdisciplinary engineering projects.

In the following section a typical assembly and design module is presented. Note, there may be different solutions than the expected faculty design. This is not only expected but should be encouraged to instill a spirit of creativity in each team.

I Power Plant Design

Assembly

The team will be asked to design, construct, demonstrate and report (oral and written) on a hydroelectric turbine system. The team will be given the following requirements:

1. Maximum and minimum height of fall of the water,
2. Maximum and minimum volume of upper reservoir,
3. Maximum and minimum volume of lower reservoir, and
4. Duration of the operation of the system

Power Plant Assembly Design

In the summer of 1993 a group of high school students conducted experiments on the pump storage project at Cooper Union. A total of 11 students formed three groups and designed constructed and tested a physical model of a pump storage model in the Cooper Union hydraulics laboratory. This experiment consisted of an upper and lower reservoir. A vertical pipe ran from the upper reservoir to a small turbine. This turbine was secured in the lower reservoir. The water was pumped from the lower reservoir to the upper reservoir forming a continuously recirculating water system. A string was attached to the turbine and passed through an elevated pulley. This string was attached to a weight that was lifted by the turbine. The time it took the weight to travel a predetermined distance was measured by the students to determine the output horse power of the system. This project consisting of design, construction analysis, and report writing was completed in less than one week. Two civil engineering senior college students and a professor directed the students.

Communication

Each team will present their assembly during a final demonstration (oral report) and be required to submit a final written report. This report will be complete with graphs and drafted drawings of the final design.

Design Module

The design steps have been outlined above (Dieter's Text). The presentation here will follow the outline.

Recognition of Need

An analysis of the power load by the Power Authority of the State of New York, (PASNY) capacity and generation proposed for service in New York State indicate a need for additional peaking type capacity.

Definition of Problem

Since the Prattsville Site is an ideal location for a pump storage power this design module will be directed to this type of plant. Also, from the recognition of need, that is, peak loading is required, the pump storage facility is well suited. The pump storage plant will be compared to other forms of power generation as a necessary requirement of the project.

Gathering of Information
There is a large body of data on this design module. Since the project was proposed over 10 years ago, Power Authority State New York (PASNY) commissioned a number of studies to be conducted. There is also an existing pump storage plant approximately five miles north of the proposed site, Blemheim-Gilboa Power Plant.

Conceptualization
Clearly there is a large volume of information on this project. The professor must guide the team to arrange this information to conduct analysis, selection of alternatives, and final design evaluation.
Note! There will be at least three options considered here:

1. Pump Storage at the Prattsville site, using the natural topography and geology as lower and upper reservoirs
2. Thermal peaking plant consisting of oil-fired units capable of being cycled to follow hourly changes in the load pattern and,
3. A large number (about 50) of gas turbines located throughout the existing distribution system.

A ranking matrix will be used to determine the best alternative with criteria on one side of the matrix and the alternatives on the other side.

Evaluation
After the best alternative has been selected and a preliminary design has been conducted a sensitivity analysis (as described above) will be run with a final design of the components.

The main criteria for this final design of the Prattsville project follows (the team will be guided to come up with the criteria):

-Adopt solutions which minimize construction time and cost without reducing reliability
-incorporate available up-to-date information
-use field investigation and model test data where necessary to define design parameters.

The team members will have a unique experience for undergraduate students because there were a number of field and model studies conducted for this project (MIT, Worcester Polytechnic, Lamont-Doherty, etc.)

Communication
Final oral and written reports will be necessary. There will be a number of figures describing the data, supporting and clarifying the text, and drafting plates of the final design. The final report may be one of the easier tasks for the team since the students will have delivered reports during the study and therefore, will have completed a large percent of the final report well before the schedule due date.

This design module is obviously too complicated for the team to develop, even a back of the envelope solution, in 12 weeks. But the main point is that a team of freshmen can take a complex interdisciplinary engineering project and subdivide it into specific disciplines, synthesize the information, analyze and evaluate this information to a final design.

To improve the student evaluation process, a list of criteria will be developed. All the professors teaching the freshman design course will have the same criteria, so the students will be evaluated against a given base line. The professor in charge will head up a jury made up of an outside engineer (as outlined above), oral and writing experts from the school, and senior and graduate students. There will be a number of clearly defined milestones where each student will give an oral and written report (at the end of each phase, outlined above). the student will be evaluated at the end of each presentation with feedback at a personal conference. This evaluation criteria may include, but not be limited to: oral and written presentations, ability to work in groups, formation of assumptions, following directions, selection of ideas, setting goals, setting objectives, ability to clarify essential elements, etc. Therefore, the aim of the evaluation process is to have enough clearly defined criteria to assess a student's performance in a routine manner.

Project Schedule

The freshman design II course is scheduled for the spring term, 1994.

Project Deliverables

A series of student handouts is presently being developed for different assemblies and design modules.

Design and Engineering Fundamentals

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Freshman engineering students at The Ohio State University have traditionally taken mathematics, physics, chemistry, and English while being permitted to take only one engineering series - Engineering Graphics. For many years, the objective of the Engineering Graphics courses was to teach the students the fundamentals of engineering drawing, problem solving, and computer programming. Recently, the objective has been broadened to include teaching the fundamentals of design and use of existing computer software. This paper discusses the changes in the Engineering Graphics courses at The Ohio State University (OSU) over the past decade and the motivations for them.

Ten years ago, beginning engineering students at OSU were required to take two Engineering Graphics courses, EG 110 (General Engineering Graphics) and EG 200 (Computer Utilization with Introduction to Engineering Analysis). EG 110 was primarily a drawing course, and students earned 5 credit hours for taking it. EG 200 was a 3-hour course. All drawing in EG 110 was done manually, and the computer programming in EG 200 was done in the batch mode. But major changes in computer technology led to a significant restructuring of the Engineering Graphics courses.

In the early 1980's a new Engineering Graphics sequence was introduced to replace the EG 110/200 series. It consisted of three 3-hour courses. Since Ohio State is on a quarter system, this new series allowed students to take an Engineering Graphics Course each quarter of their freshman year. The series was numbered EG 141, 142, and 143. EG 141 introduced students to drawing (sketching, orthographic views, isometric representations) and to the computer (algorithm development, simple programming, problem solving) with the last two or three weeks of the course devoted to using simple computer programs to produce drawings.

EG 142 focused on manual drawing with some time spent on CADD. EG 143 was a computer-oriented course with emphasis on problem solving and some time spent on programming interactive computer graphics. This new sequence of Engineering Graphics courses taught the fundamentals of engineering drawing, problem solving, and computer programming, but it also provided students with an opportunity to use and create interactive graphics software.

More changes in computer technology and industry's rapid adoption of those changes required constant revision of the Engineering Graphics courses if the students were to be prepared for their life's work. The EG 141, 142, 143 series was updated annually, but by the early 1990's a complete restructuring was necessary.

A new sequence consisting of two 4-hour courses, EG 166 and EG 167, was introduced in 1991 to replace the EG 141-143 series. EG 166 focused on drawing with heavy emphasis on CADD while EG 167 was primarily a computer programming and problem solving course. In the spring of 1992, a design project was piloted in three sections of EG 166. The project was included to give the students an opportunity to learn the design process, experience the excitement of solving a "real" problem, work in teams, and see the practical application of the skills they had learned throughout the course. In addition, students were required to write a report on their design and to make an oral presentation to the class.

Student response to inclusion of the project was overwhelmingly favorable, and the Engineering Graphics faculty tentatively decided to include a design project in all sections of EG 166 in Autumn Quarter 1992.

In an effort to keep abreast of the fundamental engineering skills required for employment in industry and to ensure that the Engineering Graphics courses included as many of those key skills as possible, three members of the Engineering Graphics faculty conducted a survey of OSU Engineering College graduates and their employers during the Summer of 1992. The survey was done in conjunction with the NSF funded Gateway Engineering Education Coalition which was then underway at Ohio State. In the survey, graduates who completed their degrees in the years 1987 - 1991 and their employers were asked to evaluate the importance of several skills to job performance and the graduates' preparation in those skills. The four categories of skills included in the survey were (1) basic engineering skills, (2) graphics skills, (3) computer skills, and (4) communications and problem solving skills. The results indicated that most engineering skills and graphics skills were at least adequate. However, both graduates and employers indicated that computer, communications, and problem solving skills were of utmost importance and that preparation in those areas was quite inadequate with respect to current technology.

Findings of the survey confirmed the Engineering Graphics Faculty's assessment of the types of skills that needed to be included in the beginning Engineering Graphics courses. In Autumn Quarter 1992, the team design project was incorporated into the EG 166 course and written and oral presentations received additional emphasis. Two days were devoted to using a spreadsheet package, Microsoft Excel, to produce tables and graphs that could be incorporated into reports. Plans were made to increase the number of class days devoted to Cadkey Light, the CADD software available for the course, and work began on a new set of drawing exercises to be done on CADD.

EG 167, the computer programming course, uses HP workstations instead of the VAX cluster used for EG 143. The workstations are Unix boxes with Motif window management. The first week is spent on problem solving. The students learn to analyze a problem and create an algorithm for its solution. In the second week they learn to create a logic diagram from the algorithm for its solution. In the second week they learn to create a logic diagram from the algorithm, and then to create FORTRAN computer code from the logic diagram. By the end of the fifth week, they have learned most of the basics of FORTRAN. They then spend two days on an introduction to a symbolic math computation package, MAPLE. They will further develop their MAPLE skills by using the package to do sample calculations to check the accuracy of their computer programs. The final 4+ weeks are spent learning to use a FORTRAN-callable library of graphics subroutines and creating programs that have graphical as well as numerical output.

The most recent changes in the Engineering Graphics courses at OSU have come about as a result of our work with the Gateway Coalition. In an effort to better prepare students to perform the jobs awaiting them when they graduate and to improve retention of those students who select an engineering major as freshmen, an experimental series of Engineering courses has been developed. It is being offered for the first time in Autumn Quarter 1993. The experimental series, numbered ENG 194 A, B, and C, is a three quarter series entitled Fundamentals of Engineering (FE). It is being presented to only one section of carefully selected students with strong mathematics backgrounds. (OSU typically offers 10 to 14 sections of EG 166 and a similar number of EG 167 sections each quarter.) These same students are taking an integrated calculus/engineering mechanics course MSFE I (Mathematical & Scientific Foundations of Engineering) which will be described in another paper presented at this conference. The students are also taking a third course entitled Engineering Laboratory which will be described at a later time. This course is focused on measurements and how things work.

FEI, Autumn Quarter, (4 credit hours) is primarily a graphics course with an introduction to a variety of computer software, including some that will be useful in the calculus/mechanics course and the Engineering Lab course. Graphics include sketching, manual drawing, and computer graphics using Cadkey Light. The other computer software packages being introduced this quarter are a word processor (Microsoft Word), a spreadsheet (Microsoft Excel), and a mathematics package (Maple).

FE I, Winter Quarter, (3 credit hours) will be a computer programming and engineering problem solving course. It will be similar in nature to EG 167, but will be modified to relate more closely to the other FE and MSFE courses. The students will be introduced to C++ as well as FORTRAN.

FE I, Spring Quarter, (2 credit hours) will be a strength of materials and engineering design course. The first five weeks of the quarter will focus on Strength of Engineering Materials. The final five weeks will be devoted to team projects in which each team will be required to create a new design to solve an assigned engineering problem. The completed report of each team must define the problem and present alternative solutions considered the final solution. It must include analyses of weight, strength, durability, cost, and practicality. It must also include manufacturing drawings as appropriate. The students will be
expected to apply the knowledge and skills developed in previous and current courses.

Insights gained from the experimental courses will be used to improve future Engineering Graphics courses. The faculty will continue their close ties with industry, monitoring the skills needed by engineering graduates and modifying the courses as required to keep them up to date. Results of efforts by other members of the Gateway Coalition are eagerly awaited and will be used as appropriate to modify the OSU courses so that we may offer our students the best possible educational experience.

Friday, October 15, 1993

Session I Discussion

Edward Ernst, University of South Carolina & Nihat Bilgutay, Drexel University- Facilitators

Edward Ernst, USC: I am sure that you have many questions but first, I have made some notes and have some broad observations. You have heard thirteen presentations today. One of the things I have noticed is that they reflect the fact that institutional environments differ and institutions are unique. I see much focus on individual courses in terms of content, organization and delivery. The content I have seen before; it is all very traditional, but there is some new packaging. Organization is very strong. There are variations in the degree of integration of math, science and engineering, and in the use of engineering early on in the program. There is much about getting the student to understand better the context of engineering. As to delivery, we are still depending on traditional delivery modes but foresee the use of more laboratories and the integration of new technology such as multi-media.

Nihat Bilgutay, Drexel: I think that Dr. Ernst summed up this session quite well. I would like to encourage feedback to each other and the Gateway administration. We also must think about some of the Gateway challenges that we face. Do you find any impediments? Do you find difficulties working within departments at your colleges? What can you tell us about solutions and perhaps needed resources? Ideas on cross-coalition collaboration are important. This meeting is one way to strengthen that. I think we need a different approach in the lower division but I think it is important to think about how we can enhance cross-coalition cooperation. Also, if you have any observations on major effects of Gateway activities on students, faculty and administration we would like to hear them. What are the desirable outputs not yet accomplished? What do you see as the major challenges for the coalition?

Sam Hilborn, USC: I would like to make an observation which deals with communication and the design aspects of some of the developments that we have heard this afternoon. I think communication is not just a problem within engineering school. I think it is a problem with society in general including English teaching colleagues. What we are trying to communicate at this time in history is somewhat more abstract and complex than what we have done in the past. So it is more difficult to communicate in a way so that you know what I'm trying to say and vice versa. In a design course, one of the things I found which I have not seen in engineering, is an ingredient called "customer satisfaction". When a customer has given you a design job to do he thinks he has told you what he wants you to do. But, are you sure you understood what he told you? So, when students in my class respond to RFPs from throughout the university, such as the English department wanting some kind of computer program, I have the students go and talk to the person and then have them write up what they think they are supposed to do. This document is then sent back to the person who originated the RFP. Ninety percent of the time the students have not gotten it right. There is then an iteration process back and forth between the person who initiated the RFP and the student until an agreement is reached. Frequently, the task changes over time because students will invariably recommend something that the customer had not thought of but would like to incorporate. So that is added to the original aspect of the design and keeps extending the problem, sometimes beyond a reasonable limit. But that is a way of bringing communications into the design process because your ability to be able to understand what the other person wants you to understand is a test of communication.

James E. Mitchell, Drexel: I have two comments. One is about this issue of design definition. I come from an architectural background. For anyone who is interested, there is a well developed discipline called architectural programming which deals with exactly how you elicit what it is that a customer wants and get them to agree to it. So it is not something that you have to start from nowhere on. Second, I would like to anticipate my talk for tomorrow and point out that one of the major experiences that comes out of looking at the evaluation of Drexel's E^4 program is the extraordinary importance of the humanities faculty in the success of the program at Drexel. So much so, that one is among the three team leaders for this year's 300 student program. This person will contribute to the communications aspect and the built-in evaluation. In the formative evaluation process, these faculty were found to be extraordinarily important. Their inputs are very useful and much appreciated by the Engineering faculty.

Eli Fromm, Gateway Central: I would like to offer a few observations to elicit responses. One of the things that caught my attention was the fact that the place where the students get involved/engrossed in the material presented here was usually in the laboratory. The rest seems to be lecturing to the students rather than involving them. I would like to hear some response about that from people that gave presentations today. It is natural in the laboratory (it's essentially a requirement) to involve the student unless doing demonstrations. But the place where the real culture has to change is the way in which we get students to buy-in, have a sense of ownership and become engrossed in the material. What we have traditionally done is just lecturing and I must say I think I heard much of that same routine today. The other comment is with regard to the group from Columbia with the slide about serial vs. parallel port loading the computer. Our experiences at Drexel and, over the past year at other institutions that have begun the process of delivering the curriculum modifications, have shown that we have underestimated what the students can do if given the right environment. In fact, they can handle a significant amount of parallel input. I think it is the parallel input, bringing the pieces together concurrently and not serially, that they enjoy. Again, that is the fundamental kind of change that is required.

Charles Kelly, Polytechnic: I probably did not spend enough time on it but I feel that the recitation content in addition to the laboratory content that we are doing is extremely useful and interesting to a student. The students are asked in different combinations and settings to speak about their experiences, the difficulties they encounter, the help they may need and the different approaches that they take. It is quite spontaneous. There is a teamwork feeling that comes out of it. The students help each other. They do the talking. There is limited interaction with the faculty member. That is a very useful addition to the laboratory. Furthermore, the lecture content that we have is one hour out of a total of five. I believe that a lecture content dwelling on one subject or a continuum over a semester can get tedious and boring. This is not that. This a one hour lecture on a quite different subject although bound to the engineering theme which gives the student a taste of many different things. I think we must work to keep them interesting. And, as you can see from student data, they felt it was the least interesting part. We have improved that and we hope to keep their interest.

Mohamed El-Sayed, FIU: With regard to RFPs, this year with the honors program we are doing it differently. We are asking different teams to write an RFP for another team. After this, they communicate with each other. It shows the student another aspect. Also, in working with students, we found that working with a small group, even though it takes a lot of time, is best. We will usually have office hours set aside to sit down and communicate.

Elizabeth Pittenger, FIU: I want to keep it very short but I'd be happy to talk to any of you on how I have abdicated responsibility in the English classroom. Students have actually selected the kinds of supplementary reading materials that they will study. They lead the group discussion. I am outside the circle. My job is merely to jot their ideas down on the blackboard. I invented this thing that I call "questing", where students go out just for the sake of an "AHA!" experience to discover something around campus. Also, we keep journals both written and electronic with 150 words a day. I want to tell you that it is very hard work not to do any work at all.

Robert Mills, OSU: I am peripheral to the Gateway project. But, I am very excited about what I am hearing and my general attitude is very positive. I have a few concerns that I would like some response to. I polled the audience for an estimate of which institutions are integrating physics in a team-teaching kind of way into Introductory Physics or are planning to do so. The small response leads to another concern. Physics to us stands on its own feet. It is an end in itself. What happens when you teach it as a means towards some other end? Namely, serving the needs of engineering students who get a different perspective on Physics which is not at all the same as the perspective you get from the Physics Department itself. Is that a fear or a danger?

My second concern, and the biggest one, is that a large part of our department's teaching mission is teaching Introductory Physics to engineers. Since OSU engineering students are taught Physics in the context of introductory mathematical, scientific fundamentals of engineering, team teaching, and so on, how does Physics fit in? This applies to math too, I am sure, but I am taking it from the perspective of a physicist. Can I conceive of our Physics Department retooling to the degree that it could do a large part of teaching in the context of this kind of program? Maybe so, maybe not. I am very open to comments.

James E. Mitchell, Drexel: I chaired the group at Drexel University that was responsible for evaluating the E^4 experiment to decide whether or not it would become the entire curriculum for the College of Engineering which means that the Physics Department had to adopt this model, because they were very much affected by it, as were the mathematics people. The actual work was done by Dr. Woodring (I should give him credit for this). What I can say is that exactly the concerns that were just expressed by Bob Mills were expressed during that process. The reality has been that as the Physics and Mathematics professors have become involved in what is actually going on, they have gotten excited about what it allows them to do to improve their own discipline of teaching. There is not universal happiness by any means, but the result has been a pleasure for most of the faculty who come in contact with this because they have found that it gives them ideas on what they can do better in Physics and Mathematics.

Robert Mills, OSU: There is a little difference in the sense that our Physics Department is quite large and already has quite a heavy commitment to Physics education and there is much exploration and experimentation within the context of the department. The Physics educators have a great deal of interest in the Gateway projects and it may be that there will be a serendipitous blending.

Mark DeGuire, CWRU: One thing that became clear to me in my work on our Freshman Engineering course is that society right now really is not supporting multi-disciplinary engineering. I have gotten used to the idea of my expertise being just one component of what is needed to solve environmental problems, or biomedical processes, and I have found it intellectually satisfying. I am actually not afraid to realize that no one type of engineer or scientist is sufficient to solve the problems that are facing society.

Nihat Bilgutay, Drexel: I want to make a comment which perhaps is related to what Mark is saying. Today we essentially covered the lower-division courses for the first year. I think as a complement to that we have to do the inversion process which also encompasses the Gateway objective. I think that balance should be retained in a better distribution across the curriculum.

Jacob Abel, U. of Penn: I notice today that the cornstarch of engineering curriculum is statics (you blend it with physics; you blend it with mathematics, graphics, etc.) We are all realizing that first year physics, 300 year old mechanics, is not the physics that we really need now to move ahead and enable students. Calculus and mechanics are united in the minds of students; the university separates them. There are problems with departmental territories and so on. Physicists have to look at our desire to liberate the Physics Department to really teach Physics. By that I mean modern Physics.

Eli Fromm, Gateway Central: When we started the E^4 project, the same reservations were raised by many people. At Drexel it was because of the culture of our institution. Every one is different. Of the science departments, the one with the least resistance was the Physics Department. Because at Drexel a good part of it is a very applied department. But over time, my comment to everyone, specifically in Math and Chemistry, was that the way to address the concern was to join in the development of the curriculum. The issue of having engineering as the intellectual centerpiece should not be looked on as a road-block. Let us make sure that other disciplines are appropriately covered. They may be covered in different ways. The order in which the topics have been covered over the years is not sacrosanct. Some certainly makes sense but not all of it needs to follow the traditional order. I remember several individuals from our Physics Department commenting that as the result of the process that we began with E^4 they began to look at what was happening in Physics more seriously and concluded that they were doing the same things as their own teachers did when they were in school. Maybe it is time for some change. I think that as the faculty have found what the students accomplish, they themselves have become much more interested in recognizing what the students will do. After all that is what our reward is. We have to give it time. This is now the fifth year at Drexel. It is a slow evolutionary process. Each year a few more faculty become interested and involved as they begin to see what can be done.

Om Agrawal, Cooper: Relative to Jacob Abel's comments, I understand that Shakespeare wrote in circa 1500 AD and, still, people teach Shakespeare. I believe it is for aesthetic reasons. Similarly, static mechanics is about 220 years old but the ideas are not dead. They are still very useful and exciting.

Recently I read that there is a new technology called SPM (Scanning Probe Microscope) which is used to view single atoms from the surface. To me, this is exciting even if I do not understand all of it. I try my best to comprehend some of it and to communicate this to my students. So I do not feel that because a subject is 200 or 300 years old we should simply stop teaching it.

Mort Friedman, Columbia: Eli made a point which is correct: it takes many years. So how come we have to have a review in two or three months? (Laughter)

Nihat Bilgutay, Drexel: As I was sitting here listening to all of you, I noticed how many times the student perspective and our interest in how they perceive their education was brought up. I thought that maybe in the future, we could consider ways of including them in a forum like this. It just occurred to me that we don't have any students here. Perhaps, we could think about having them as co-authors or hold a panel discussion for students or include them in some other way.

John Demel, OSU: A final comment is about tonight's dinner. I hear this on-going discussion and there should be interesting discussions at the dinner table. When I sat down this noon and watched people at various tables, I noticed that we tended to cluster in the same groups that we arrived in. Tonight as you sit down at the tables, check to see if there is more than one of your cohorts from your institution there. If so, find another table and continue these discussions but with a different group of people.

A Contextual Introduction to Transport Phenomena: Manufacturing Fundamentals

Prepared by:
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Goal

The goal of this project is to develop a new approach to teaching of transport phenomena fundamentals through the study of manufacturing processes. Foundations of momentum, heat and mass transport phenomena and, where appropriate, chemical reactions, are to be introduced in the context of materials processing and product manufacturing. A total of two lecture based courses using this approach are to be developed. In the first year, the focus of effort is on the first lecture course.

Course Audience

The proposed course is expected to be one of the cross-disciplinary electives offered to all engineering pre-juniors and juniors in the Drexel Curriculum.

Rationale & Approach

Almost all engineers deal with transformation or processing of solids, liquids or vapors in batch or continuous processes. The proposed course provides a new way for students to gain a fundamental understanding of the engineering sciences that form the basis for design and operation of manufacturing processes. This technique capitalizes on the experience gained in the E^4 program which tells us that increased 'relevancy' holds the students' interests

The engineering science concepts discussed in this course are typically covered in four chemical engineering courses (a total of 16 quarter credits). Clearly, the level of detail and completeness in the present course will be less, but the method of presentation will be conducive to learning. Whereas the traditional transport phenomena include mathematical formalism, with frequent fundamental derivation of equations, this

course will introduce rate concepts and design relationships using a "case-method" approach. Whereas conventional courses cover the transport topics sequentially, this course will treat them simultaneously, or laterally, within the context of manufacturing processes. One readily finds examples of heat and mass transfer and fluid mechanics within areas such as manufacture of aluminum (cans and foils), textile fibers, breakfast cereals, vaccines, waste water treatment, cooling, heating and ventilation of building systems and others can be included. Central to each manufacturing example will be at least two of the basic four branches of transport phenomena. This approach of introducing fundamental rate laws <u>in the context of manufacturing processes</u> offers the advantage of improved learning opportunities and thus better retention of the underlying concepts by the student.

Course Content

A number of manufacturing processes will be studied as case models. See Table 1. Questions of how such processes are designed will be raised. First-order design criteria will be developed from material balance constraints, second-order design criteria from a thermodynamic perspective, and third-order design refinement will be made using rate law concepts. The manufacturing processes will be used to illustrate such principles as transient heat conduction, mass diffusion, interfacial mass transfer, mechanical energy balance, piping and pumping systems design, heat transfer coefficient, chemical and metallurgical reactor design and others. Example of specific examples that is planned is given in Table 1.

The course will be organized into several one week modules [3 to 4 instructional hours]. Each module will include written outline of lectures, questions, discussion points, illustrative problems, homework problems and suggested further reading. Background concepts needed to learn a module and the new concepts illustrated in a module will be included. It is expected that each module will deal with a specific process while sub-modules within it will illustrate one or several processing concepts. The sub-modules will be organized as much as possible in a lateral order rather than sequential. A suggested order of selecting the modules (or sub-modules) in increasing order of difficulty will also be prepared.

Discussion: A Sample Course Module

The Case of Manufacture of Aluminum Cans. The example of soft drink aluminum can was selected as a topic of discussion because of its *omni presence*. The presentation style will emphasize the practical need for a fundamental understanding of transport processes in producing such simple products as an aluminum can. An outline of discussion leading up to the definition of mass transfer coefficient and correlating it to process variables will be introduced via the aluminum can story. The aluminum can is a common experience for all students and detailed knowledge needed to produce a commonly used object is expected to provide motivation and relevance to the transport phenomena concept being discussed.

Outline of connecting discussion topics leading to mass transfer coefficient can be summarized as follows: mechanical design of a coke can - peculiar nicked topside - sides thinner than top - wall - end can thickness - alloy composition [why Mg?] - thickness of can body - process for drawing cans - inclusion & porosity sensitivity of drawing process - need for process to remove hydrogen - process equipment for degassing - analogy with stripping operation - desorption - rate of desorption - interfacial transfer rate - controlling resistance - stirring and small bubble advantage - analogy with aeration of an aquarium - continuous degasser - [batch degassers in steel production] - residence time of melt in degasser and mass transfer coefficient - stirrer selection - purpose - effect of stirrer peed - issues of scale-up - mass transfer correlations - degasser optimization.

Pedagogy.

All engineering students currently take a course in *Fundamentals of Materials* which is concerned with structure-property relationships of materials. The proposed course will deal with how these materials are produced or processed, and hence should follow the materials course taught during the sophomore year.

Current Collaboration

The proposed developments are part of a larger project dealing with the theme Materials: Structure-Property-Processing-Performance Relationships. There are a total of nine projects that deal with various sub segments of these important relationships. The current project emphasizes the processing. Segments of the proposed course, namely the aluminum can story, is expected to be imported by University of Pennsylvania for their materials processing course (Professor McMahan).

Future Collaborations & Developments:

In the coming year, we expect to develop interaction and ties with other Gateway universities for collaboration on processing aspect of materials. Collaborations are sought from those who would develop modules compatible with the goals of the program, especially related to the nanoscale processing, biomolecular processing and others.

Project Schedule

This project was started in Spring AY 92/93. The first edition of this course will be offered as a 3 credit course in Spring 93/94 to all senior students. Outline and selection of material are currently under development. During Summer AY 93/94, an initial documentation of the course lecture modules will be completed.

Evaluation Methodology

We are planning to use course evaluation forms that are currently used in the department, and personal interviews of representative students to obtain information on effectiveness of the proposed course and its methodology. The authors are not knowledgeable in designing questionnaires and interview methodology to elicit the data needed for evaluation. We seek assistance and guidance so that the methodology that will be used this winter will be the same as that used in other Gateway courses.

Deliverables.

First Year 7/1/93 - 8/31/94

- Outline of ten one week modules will be written during 7/93 to 3/94.
- A 3-credit course will be offered in Spring AY 93/94 .
- Document student reviews and instructor experiences.

Second Year 7/1/934- 8/31/95

- Outline of ten one week modules for a second course in processing science.
- Refinement and detailed documentation of modules of the first course will be completed during the second year.
- Two 3-credit course will be offered in Winter and Spring of 94/95.
- Document student reviews and instructor experience.
- Preparation of a paper for presentation at ASEE conference.

Third Year 7/1/936- 8/31/97

- The two 3-credit courses will be revised and offered in Winter and Spring of 94/95.
- Refinement and detailed documentation of both course modules.
- Document student reviews and instructor experience.
- Preparation of a paper for presentation at ASEE conference.

Accomplishments

Outline of some of the modules (see Table 1) have been developed. Collection of teaching aids and problem sets are in progress.

Integration in the Study of Engineering Materials

Dr. Jed S. Lyons, University of South Carolina

Abstract

In order for mechanical engineers to select materials from the rapidly increasing number of choices, they need a solid understanding of the relationships between material structures, properties, and processing. To accomplish this, our undergraduate *Engineering Materials* course has been restructured and student-conducted laboratory experiments have been added. The unique approach taken for the laboratory is first to select representative materials from each of the three basic classes of materials (metals, ceramics, and polymers), and then concurrently characterize these materials with a series of experiments which include microstructure morphology determination, microconstituent properties, bulk mechanical properties and the effects of processing on structure and properties. By following the same set of materials through the same sequence of experiments, the students will easily grasp and retain the concepts of structure-property interrelationships. The result will be graduates who are capable of making intelligent materials selection decisions for design applications.

Background

Because all systems are designed based upon a material's response to mechanical and thermal loadings, a thorough understanding of materials is essential for mechanical engineers. At the University of South Carolina, this knowledge is made available to mechanical engineering undergraduate students in a required, junior level *Engineering Materials* course and three elective courses: *Manufacturing Processes*, *Mechanical Behavior of Materials,* and *Physical Metallurgy*. Historically, the *Engineering Materials* course has evolved from a course in metallurgy. Topics on polymers and ceramics were appended as commercial applications for these materials increased. Prior to the beginning of this project, the course dealt with each of the three basic classes of materials separately, with about 12 weeks spent on metals, 1 week on ceramics and 2 weeks on polymers. Many other mechanical engineering departments in the United States offer a similar educational experience, with the focus being on metals. This format does allow for detailed studies of the science aspects of these materials. However, practicing mechanical engineers need better materials selection skills which are based on a fundamental understanding of the underlying sciences, and advanced material science topics should be reserved for elective courses.

The Revised Course

The outline for the revised course is presented in Figure 1. The lecture topics are arranged in three basic sections: Structures of Materials, Mechanical Behavior of Materials, and Processes for Controlling Structure and Properties. Metals, polymers and ceramics are considered simultaneously in each section, so that the similarities and differences between the classes of materials are emphasized.

Since students retain more information by doing as opposed to listening, an integral part of the revised course is a sequence of student-conducted experiments to be performed concurrently with the lecture. In a "traditional" material's lab, students polish microstructural samples of one material and perform mechanical property tests on others. These labs are ineffective, as there is no relation between the experiments, and the students often don't understand why they are performing them.

STRUCTURES OF MATERIALS
Atomic Bonding
Crystals and Crystal Imperfections
Amorphous Materials
Polymer Crystals
Diffusion

MECHANICAL BEHAVIOR OF MATERIALS
Mechanical Property Measurements
Deformation and Strengthening of Crystals
Deformation and Strengthening of Amorphi
Fracture

PROCESSES FOR CONTROLLING
STRUCTURES AND PROPERTIES
Annealing and Hot Working
Equilibrium Phase Diagrams
Phase Transformations
CORROSION AND DEGRADATION

Figure 1. Revised course outline.

In the *Engineering Materials* laboratory, representative materials from each of the three basic classes of engineering materials (metals, ceramics, and polymers) are concurrently characterized with the series of experiments. The materials chosen as representatives of their class are changed each semester to maximize the learning experience of each lab group. The initial selections were a low carbon steel, a cast aluminum-silicon alloy, polypropylene, polystyrene, and silicon nitride. By following the same set of materials through the same sequence of experiments, the students can grasp and retain the concepts of structure-property inter-relationships.

The experiments, the titles of which are listed in Figure 2, were chosen not only to measure material properties, but to elucidate the fundamental differences between metals, ceramics and polymers. For example, the *Tensile Deformation* experiment conducted in this course does more than teach how to determine properties from a stress-strain diagram. Tests on metal and Thermoplastic samples are interrupted and held at constant strain. The students plot stress versus time, and observe that metals retain their load bearing capabilities at ambient temperature, but plastics exhibit stress relaxation due to molecular displacement. The difference between elastic and permanent deformation is shown by unloading samples after yielding. Ceramic specimens are not tested in tension due to the expense of the required self-aligning grips. Instead, a *Flexure Deformation* experiment is performed which compares ceramics to the same metals tested in tension. The importance of surface finish for structural ceramic parts is made evident by testing specimens with and without surface flaws. The Appendix contains summary descriptions of many of the experiments and also indicates how each of the representative test materials are included.

1. Creep Deformation I (runs all semester)

MATERIAL STRUCTURE LABS
2. Atomic Bonding and Crystal Structure
3. Characterization of Microstructures
4. Polymer Morphology
5. Microconstituent Properties

MECHANICAL BEHAVIOR LABS
6. Tensile Deformation
7. Stress Relaxation
8. Flexure Deformation

PROCESSING LABS
9. Casting and Phase Diagrams
10. Thermal Processing

1. Creep Deformation II

Figure 2. The experiment series.

The Developmental Plan

The *Engineering Materials* course's lectures were restructured and lab procedures for five experiments were drafted during the Summer 1992 semesters. The revised course was offered for the first time in Fall 1992. Since that time, three additional experiments have been successfully added to the lab series and all procedures have undergone revision. Specific milestones to be met during the period that this project is supported by the Gateway Coalition are summarized in Figure 3.

The following strategy is used to develop each experiment. A graduate assistant performs a literature search to find example experiments on the appropriate topics. Experimental procedures for which no examples can be found are based on faculty experience. Draft procedures are then prepared with the help of the professor. All materials and supplies are procured with departmental funds. The assistant then assembles the instrumentation, performs the experiment, analyzes the results, forms conclusions about the effectiveness of the lab, and offers suggestions for improvement. Since reproduction of "textbook" results is often difficult, some experiments require design iteration.

Student Perceptions

A student survey has been conducted at the end of each semester that the revised *Engineering Materials* course is offered. Students comment on what they learned from each experiment and from the entire sequence, the relevancy of the labs to the lecture part of the course, the clarity of the procedures, and the overall benefit of the lab for improving their understanding of the relationship between material structures, properties, and processing. Some results of the survey conducted after the first two semesters are shown in Figure 4. These results give direction for laboratory improvement. For example, over two semesters at least 30% of the students thought that the "Density" lab had no influence on their understanding of atomic bonding and arrangement. This lab is being modified to include electrical conductivity measurements which will provide an additional physical example of different bond types.

FALL 1992.
Implement restructured course with draft labs.
Draft a lab and lecture effectiveness exit survey.

SPRING 1993.
Draft and offer one additional experiment.

SUMMER 1993.
Analyze survey results and revise experiments.
Draft procedures for two additional experiments.

FALL 1993.
Analyze survey results and revise experiments.
Offer two additional experiments.

SPRING 1994.
Draft and offer two additional experiments.

SUMMER 1994
Analyze survey results and revise experiments.
Disseminate the results.

Figure 3. Timetable and Milestones.

Impact on Undergraduate Education

Because most Mechanical Engineering curricula are very structured and often crowded, many students will only take one course in materials. We want to give the broadest possible coverage of all materials that mechanical engineers may be involved with. It is our belief that the educational experience provided by the restructured *Engineering Materials* course is superior to the traditional metallurgy-founded approach to teaching materials science. The addition of the student-conducted experiments will greatly improve the students' understanding and increase the retention of the interrelationships between structure, properties, and processing in all three basic classes of materials. The result will be graduates who are capable of making informed materials selection decisions for design applications.

The unique experience provided by this experiment sequence will serve as a model materials lab for other mechanical engineering departments. Furthermore, the concept of following the same set of materials through similar experiments to elucidate structure-property relationships is equally applicable to other disciplines.

Acknowledgements

The National Science Foundation's Gateway Coalition and Instrumentation and Laboratory Improvement Program and the University of South Carolina's Instructional Development Fund are acknowledged for supporting this project.

Appendix: Summaries of Planned Experiments

Material Structure Labs

Atomic Bonding and Crystal Structure: Differences in atomic bond type and crystal structure are revealed by measuring the electrical conductivity and the mass density of pure metals, alloys, ceramics and polymers. Measured densities are compared to theoretical calculations based on the crystal's unit cell.

Characterization of Microstructures: The microconstituents of cast and wrought metals and crystalline ceramics are identified and measured with quantitative metallography techniques. Manual point counting and computerized image analysis techniques are used and their results are compared. Materials include a cast metal, cold worked and annealed wrought metals, and a ceramic.

Polymer Morphology: The effect of polymer structure on the kinetics of polymer crystallization is studied by heating samples to the melt phase between glass slides followed by slow cooling. During the cooling, embedded thermocouples connected to a chart recorder are used to record time-temperature data during the crystallization transformation. visual inspection using the transmitted polarized light microscope is performed and the spherulite size and volume fraction are measured.

Microconstituent Properties: The non-homogeneous nature of engineering materials is revealed by performing microhardness tests on the microconstituents of cast and wrought metal alloys and on semicrystalline polymers. Also, the hardness gradient in a carburized steel gear is measured to provide an example of case hardening by diffusion.

Mechanical Behavior Labs

Tensile Deformation: The behaviors of metals and polymers are contrasted by performing constant strain-rate tension tests on a cast metal, a wrought metal, a brittle polymer and a ductile polymer. The mechanical properties are related the microstructural measurements obtained in a previous lab.

Flexure Deformation: The behaviors of ceramics and metals under bending loads are contrasted by performing constant strain-rate bending beam tests on the cast metal and the ceramic. The effect of surface flaws on the failure stress of the brittle ceramic is demonstrated by creating a surface indentation on samples before flexure testing.

Time-Dependent Deformation: The creep properties of semicrystalline and amorphous polymers are measured under constant tensile load. The behavior is related to polymer structure and crystallinity. This lab starts week one and runs all semester.

Processing Labs

Solidification Processing: Sand casting is demonstrated with an Al-Si alloy. Thermocouples embedded in thick and thin sections of each mold are used to generate direct cooling curves. The temperature-time data obtained is related to the equilibrium phase diagram for the alloy system.

Thermal Processing: The variation of properties with aging time is studied by performing Rockwell hardness tests on samples of the cast aluminum alloy which has been solutionized and artificially aged to create transition precipitates, coherent precipitates, and incoherent over-aged particles. Also, the affect of alloy composition on the hardenability of steels is determined.

Quantum Structure of Materials
and
Scanning Tunneling Microscopy in the Undergraduate Laboratory

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Introduction

Over the past several years, it has become increasingly evident that new solid-state materials and the application of their unique properties are driving a wide range of new technologies. While the bulk aspects of solids may be understood in great detail, many current applications involve exploiting the properties of the surface or interface. As the electrical and materials engineering disciplines have made major contributions to materials used for microelectronics, advanced materials are also contributing to rapid advances in all engineering professions. As a result, it is important that upper-division undergraduate students be introduced to the theoretical and practical aspects of advanced materials at an appropriate level because this background will certainly be relevant as they enter industry or commence with post-baccalaureate study. This naturally includes the need to introduce the principles of quantum mechanics and applications to solid state physics as well as to consider two-dimensional systems, i.e., surfaces and interfaces. To broaden students' understanding of advanced materials, the background of specific applications should be explored and fabrication, processing, and characterization methods (including vacuum technology) should be introduced in the classroom and the laboratory.

At Drexel University, the goal of the project entitled *Quantum Structure of Materials* is to reformulate courses in engineering on solid state materials to include the study of surfaces and interfaces, to introduce current and future applications, and to provide state-of-the-art laboratory experiences for undergraduates. At the University of Pennsylvania, this project will provide materials to embellish existing courses in materials science and in advanced characterization techniques. The crucial connection to real-world applied science and engineering is the development of hands-on *laboratory modules* in which the students study materials properties of metals, semiconductors, ceramics, polymers, and composites with state-of-the-art experimental probes including Scanning Tunneling Microscopy, Auger Electron Spectroscopy, and Rutherford Backscattering Spectrometry. In addition, an introduction to thin films and thin film growth techniques will be included as a means of sample fabrication. The novel aspect of the experimental component is that it will go far beyond the usual analysis of the results of various experiments. First, the modules will include in-depth consideration of the *theoretical aspects of the problem.* Some modules will contain a *design component* where students will actually design the experiments and build the apparatus. Students will be expected to build several major and minor pieces of experimental apparatus, including chambers, electronics, environmental cells, sample holders, heating and cooling devices, and detectors for *sample analysis.* Finally, students will proceed with the appropriate steps in *materials characterization* of structure and composition. *Presentation of the results* in both written and oral formats will be expected.

For training purposes, only the first experiments in any module will have well-defined results. The expectation is that each module will allow students freedom to formulate their own experiments based on what they learn in class and on their own preliminary research under the guidance of faculty members and staff. This will result in rather open-ended problems that will stimulate students' creativity; some original student projects might actually be expected to lead to publishable results in scientific journals.

This progression will proceed under the supervision of faculty, teaching/research assistants, and laboratory personnel. These courses and experimental modules will be available to upper division undergraduate engineering students at both Drexel University and the University of Pennsylvania. We note that several of the faculty who are involved in this project are also collaborators in research in surface and interface science. Elements of this material will be exported to the Engineering School of The Cooper Union for incorporation into their curriculum.

While the main focus of this paper is to describe the Scanning Tunneling Microscope as the centerpiece of one laboratory module, we will briefly mention the planned classroom components and other laboratory modules that are being developed.

Courses

Drexel University

The *Quantum Structure of Materials* course is being introduced as a two-quarter Junior-level course where quantum theory and applications will be treated in the context of solid state physics. The curriculum will include the following major topics: Quantum Mechanics, Solid State Physics, Surface Science, Materials Science, and Solid State Devices. Laboratory experiments, initially focusing on Scanning Tunneling Microscopy as described below, will be an integral component of this course. The course will be offered to upper-division students, primarily majors in Engineering, Physics, and Chemistry.

University of Pennsylvania

This project will primarily impact two courses – *Quantum Physics of Materials* and *Modern Materials Analysis Techniques.* The former is a Sophomore-level course required for Materials Science and Engineering and for Electrical Engineering majors; in addition, the course may be selected by other Engineering majors. The latter course is offered as an upper-division elective.

Laboratory Modules

Scanning Tunneling Microscopy

The ability to image surface geometric and electronic structure with atomic resolution in real-space was made possible by the invention of the Scanning Tunneling Microscope (STM) which was first reported in 1982.[1,2] This exciting materials characterization technique has captured the imagination of many scientists and engineers throughout the world and has led to new discoveries and capabilities which include imaging complex surface reconstructions[3] and the controlled manipulation of individual atoms on surfaces.[4,5] The STM technique, as depicted in Figure 1, is based on the physical principle of electron tunneling between an atomically-sharp metal tip and the surface of a conducting sample. Tips can be prepared by standard techniques with a good probability of success. In order to achieve electron tunneling, the gap between the tip and sample (which are biased with an appropriate potential difference) must be <10Å (1Å = 10^{-10} m) so that excellent vibration isolation of the tunneling gap from the environment must be ensured. The tunneling current can vary by a factor of ~10 for every 1 Å increase in tip-sample separation (an exponential functional dependence), so, by scanning the tip over the surface, an image of the "electron corrugation" of the surface can be produced. The tip is rastered over the surface with piezoelectric transducers controlled by a computer and the tip-sample current or the z-height required to maintain a constant current (through electronic feedback) is returned to the computer memory producing a three-dimensional image of z-height vs. x- and y-coordinates.

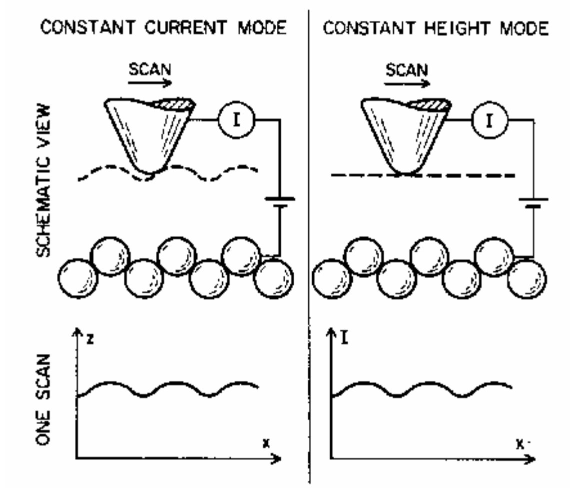

Figure 1: Schematic of STM Operation[6]

After the STM technique was first demonstrated, its relative simplicity and potential for a wide-range of applications extending from surface science experiments performed in ultrahigh vacuum to biological imaging in liquid environments resulted in further refinement and the proliferation of STM in laboratories throughout the world. In addition, several STM-based spin-off techniques have been invented and commercialized, most notably the Atomic Force Microscope (AFM).[7] The STM technique is unique in the sense that within less than a ten-year period of its invention, several commercial instruments of various designs and capabilities were already available. Very recently, an instructional STM (Burleigh ARIS/2200E[8]), which operates in air, was offered for an affordable cost, and this instrument along with associated hardware and software was procured for the project. The STM will also be used for the Gateway course entitled *Improved Materials Engineering and Science Courses: Integrating Experimental Techniques with Computer-aided Design*.

Besides the novelty of exposing undergraduate students to state-of-the-art instrumentation that typically resides in scientific and industrial research laboratories, STM exhibits several characteristics that make it especially suitable for a course that discusses quantum mechanics and the quantum mechanical basis of solids. In addition, engineering design aspects of the instrumentation are indeed fascinating and applicable to many other fields. These include electron tunneling, which can be demonstrated by measuring current vs. tip-sample separation; surface structure (from sub-nanometer to micrometer) of layered compounds, evaporated thin films, conducting polymers, etc.; microactuation; vibration isolation; analog and digital feedback systems; and, computer-based data acquisition and image/signal processing.

We have made excellent progress in implementing the STM for the planned undergraduate laboratory module. In Figures 2 and 3, we present actual images acquired with our instrument. Figure 2 shows an atomic resolution current image of a highly-ordered pyrolytic graphite surface. This image was obtained after processing with a noise filter that resides in the STM system software package. In this two-dimensional view, the atomic corrugation is depicted by the shade of gray. The atoms, which are resolved best in the center of the image are separated by ~2.2 Å. Figure 3 shows a wide-scan image of a gold-coated holographic grating. These figures contrast the size scales and the range of problems that can be addressed with this technique.

The first test of the use of the equipment for an upper-division undergraduate course was made recently. The STM was used over a two-week period by a Physics major in the required Advanced Laboratory course. The student proceeded well through tip preparation, sample preparation, imaging, and analysis after a discussion on the technique and instrumentation, individual reading, and guidance by the Research Assistant assigned to this project. Both graphite and liquid crystal surface were imaged and were presented in the written laboratory report.

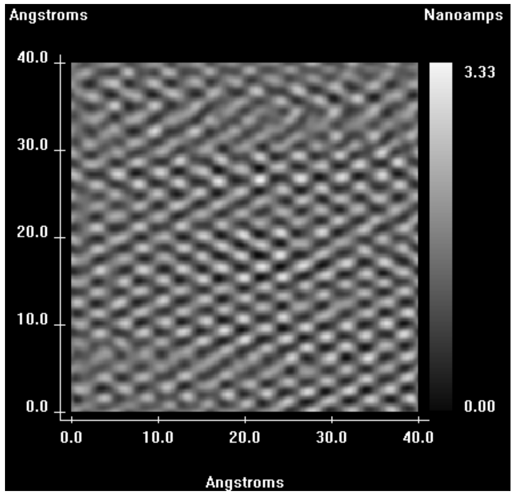

Figure 2: Graphite Surface

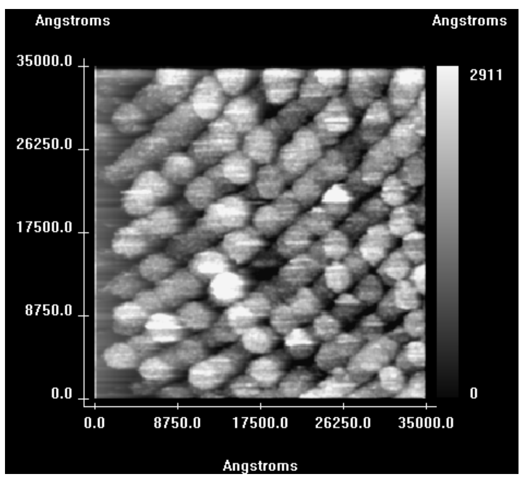

Figure 3: Holographic Grating

Rutherford Backscattering Spectrometry

Ion scattering techniques provide non-destructive analysis of composition structure, and defects in solid state materials. In this module, students will learn the theory of ion-solid interactions. Because these interactions are described by "billiard ball" collisions, theory will apply classical mechanics concepts learned in earlier courses. On the experimental side, students will use computer models to help optimize their experiments. Experimental techniques will include Rutherford backscattering for depth profiling elements at and near the surface of the sample, channeling to determine the structure of crystals and the location of dopants, and particle-induced x-ray emission for trace element analysis.

The experiments will include the study of polymer diffusion, the characterization of a PN junctions, analysis of the interface between ceramics and fibers, and ion beam modification of materials. The facilities are located in the Laboratory for Research on the Structure of Matter at the University of Pennsylvania. These facilities are currently used by undergraduates for independent study and by the materials science community in general. A novel aspect of the ion beam studies is the designation of an instructional sample chamber, which will be incrementally modified by sequential classes in design projects. Initial plans call for the machining of the chamber and sample holder, followed by design and interfacing of the detector and electronics.

Auger Electron Spectroscopy

Auger Electron Spectroscopy (AES) is a powerful technique for studying the composition of the surface region of solids. In AES, the surface of interest is irradiated with a high-energy electron beam (1-3 keV) which results in the emission of secondary electrons. The kinetic energies of these emitted electrons are characteristic of specific atoms. In an Auger spectrometer, the energy of the emitted electrons is measured using an electrostatic energy analyzer. AES provides a sensitive measure of the composition of a surface, and, coupled with an ion gun, AES can be used to measure composition as a function of depth below the surface. This latter use makes it ideal for the characterization of layered materials such as those commonly encountered in the electronics industry.

In this project, a laboratory module aimed at introducing undergraduates to the theory and practice of AES for materials characterization will be developed. This laboratory will make use of the scanning Auger spectrometer which is located in the Laboratory for Research on the Structure of Matter at the University of Pennsylvania. The specific experiments will focus an the use of this technique as an analysis tool in the electronics industry. Specific concepts to be studied will include the electronic structure of materials, analysis of surface composition, measurement of the thickness of thin films, and characterization of the structure of solid-solid interfaces.

Instrumentation Development and Fabrication

Experimental design begins with the development and improvement of instrumentation dedicated to making the desired measurements. There are an array of design concerns associated with the types of instrumentation required for the types of measurements we will perform, and these can, in themselves, be designated as short-term projects. Under the proper supervision, the equipment generated from such projects will essentially build the battery of experiments that will be available for future generations of students. As part of this project, students who design new experimental systems will be introduced to vacuum technologies, electronics, computer-aided design, mechanical, machining and fabrication, design of charged particle accelerators and energy analyzers, safety, writing specifications and interacting with vendors, and budgeting. Students will work in *teams* under a *faculty mentor* to perform this segment of their research which will culminate in the testing and operation of the completed systems on which to perform their measurements.

Concluding Remarks

Status

At Drexel University and at the University of Pennsylvania, we are in the process of developing and coordinating our respective course syllabi with the planned laboratory modules. The laboratory modules are in various stages of development. As noted previously, the STM is already being used on a limited basis for undergraduate instruction as the modules are being developed with the assistance of a graduate assistant. We are prepared to begin student design projects to adapt the thin film processing, RBS, and AES facilities for undergraduate work.

Dissemination

The unique aspects of this project taken as a whole as well as in its individual components will be reported in appropriate science and engineering education conference papers and journals. In addition, it may be expected that original projects within the realm of undergraduate students under the supervision of faculty may be publishable separately. In those cases, the thrust of the project will be discussed and appropriate acknowledgments will be made.

Evaluation

The project will be evaluated on several bases including student input, the effectiveness of inter-departmental and inter-university collaborations, the ease and effectiveness of export, and tracking subsequent performance of students in advanced design and research projects.

Acknowledgments

We wish to acknowledge the expert assistance of Mr. Thomas Mercer (Research Assistant, Drexel University) for acquiring the images reproduced in Figure 2. We also thank Mr. Bruce Rothman (Research Specialist, University of Pennsylvania) for his contributions to the formulation of the *Instrumentation Development and Fabrication Module.*

References

1. G. Binnig, H. Rohrer, Ch. Gerber and E. Weibel, Appl. Phys. Lett. **40**, 178 (1982).
2. G. Binnig, H. Rohrer, Ch. Gerber and E. Weibel, Phys. Rev. Lett. **49**, 57 (1982).
3. G. Binnig, H. Rohrer, Ch. Gerber and E. Weibel, Phys. Rev. Lett. **50**, 120 (1983).
4. D. M. Eigler and E. K. Schweizer, Nature **344**, 524 (1990).
5. In-Whan Lyo and Phaedon Avouris, Science **253**, 173 (1991).
6. Paul K. Hansma and Jerry Tersoff, J. Appl. Phys. **61**, R1 (1987).
7. G. Binnig, C. F. Quate and C. Gerber, Phys. Rev. Lett. **56**, 930 (1986).
8. Burleigh Instruments, Inc., Fishers, NY.

Solid-State Materials

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The standard first course in materials science for engineers concentrates on mechanical properties of materials, such as stress-strain relations, and, to a lesser extent, thermal properties. Certain aspects of metallurgy, such as steel production, and mechanical properties of polymers, ceramics, metals and composite materials are also discussed. The treatment of crystal structures tends to emphasize physical deformation, cracks, granularity and similar mechanical properties. Thermal, electrical and optical properties, especially those based upon the principles of solid-state physics, are hardly treated, if at all.

However, recent advances in the design of semiconductor integrated electronics and integrated optics and related manufacturing processes, including the design of surface structures and solid-state devices operating at high frequencies have had tremendous impact on the fields of electrical engineering, manufacturing process engineering and chemical engineering. This suggests that the classical introduction to materials science for engineers should be modified and made more relevant and current for students studying these vital technologies. The goal of this project is to develop a course on solid-state materials to serve as a first course on materials science with emphasis on electrical, optical and related properties of semiconductors and metals.

This course will be developed in modular form, so that portions of it could be presented in a more classical first materials science course. It is also possible for certain modules to be included in physics, electronics or manufacturing courses. Several suggested projects utilizing facilities of a materials laboratory, a semiconductor manufacturing laboratory or an electronics laboratory will also be developed, and can be adapted for use in various colleges according to the available facilities.

A good example that illustrates the difference between this course and a standard first course in materials science is the presentation of diffusion. The diffusion equation is usually first presented to students in the context of heat flow as they study thermal conductivity in materials. However, in the solid-state materials course, students will be exposed to the diffusion equation first in the context of the flow of charged carriers across homojunctions and heterojunctions in biased semiconductors. Thus, the fundamental concept of diffusion is presented in a context that is both interesting and relevant to the students. Those students who wish to obtain a deeper knowledge of materials science would then take more advanced materials courses, which would cover mechanical and thermal properties in greater depth. Whichever materials course is taken first, though, the students will understand diffusion and be able to solve diffusion problems in engineering. Of course, the material on diffusion of charged carriers can be lifted from the solid-state materials course as a module and presented in a strength of materials course as an illustration of the broad scope of diffusion phenomena.

The solid-state materials course will assume quantum mechanics at the level covered in a typical physics course for engineers at the Sophomore level, as well as a first course in electronic circuits, either one taken by electrical engineers or one taken by those majoring in other engineering fields. Thus, this course will be intended primarily for Juniors. Students will therefore very likely take this course concurrently with advanced electronics courses in the electrical engineering curriculum, or photolithography or other integrated circuit manufacturing courses for manufacturing process engineers.

Requiring prior knowledge of quantum mechanics allows this course to be a bridge between the standard required curriculum in physics for engineers, which usually ends with quantum mechanics, and more advanced physics courses. The course will thus motivate students and inform them as to the important role played by physics in engineering. Similarly, requiring a first electronics course as a prerequisite relieves the instructor of the solid-state materials course from covering basic functional operations of diodes, transistors and other solid-state devices. The solid-state materials course will extend and generalize the principles underlying the behavior of these basic devices, and thereby lay the groundwork for the study of more complicated devices and systems, such as very large scaled integrated circuits (VLSI), integrated optics or integrated microwave circuits.

The course will begin with a discussion of crystals, crystal symmetry and imperfections. Afterwards, the primary topics to be covered include bonding in metals and semiconductors, energy levels and band structure, photons and phonons, carrier distributions and carrier flow across homojunctions and heterojunctions, and thermal, electrical and optical properties of metals and semiconductors. Manufacturing methods, such as photolithography, will also be discussed. Examples will be drawn primarily from VLSI and electro-optics (such as solid-state lasers and integrated optics). In addition to basic problem solving, students will undertake design problems, case studies, laboratory experiments or projects.

Another issue that needs to be addressed is how this course will differ from a solid-state physics course, typically offered by physics departments, sometimes intended for engineers or other non-physics majors. The difference is that this is a true engineering course. Problem solving skills and the relation of physical phenomena to the design of real devices and systems will be emphasized. Indeed, this course may also be taken by physics students who wish to understand how the subjects they study are applied by engineers. Similarly, engineering students taking this course may be motivated to take physics courses that cover the theoretical and experimental aspects of the subject at a more advanced level.

This course is an engineering course, which may be taken by non-engineering majors, not a physics course. It lays the foundations of materials science in an interdisciplinary way, but in a fashion that is more relevant to electrical and chemical or manufacturing engineering students, just as the classical strength of materials course is a proper first course in materials for civil or mechanical engineers. It is hoped that this will produce electrical and chemical engineers who will have a greater appreciation and interest in materials science and its applications.

Structure Property Relationships in Materials: Integrating Experimental Techniques With Computer-Aided Instruction

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Abstract

In light of the importance of materials in all levels of experience, it is essential that students be familiar with material properties, as dictated by processing and microstructure. The 'Gateway' course described here builds on the core sophomore level materials course and consists of closely integrated lecture and laboratory topics to demonstrate design, processing, application and manufacturing It is a two-quarter course involving team teaching from several departments in engineering and science. Objectives and philosophy are outlined, followed by a detailed description of the treatment of fracture mechanics and the optical properties of materials.

Introduction

Materials play an important role in all fields of engineering. Advanced technologies reflect the development of new materials or are limited by the lack of materials with suitable properties. Thus, an understanding of the properties of materials and the dependence of properties on processing and microstructure is an important component of all engineering curricula.

This "Gateway" course is intended to provide a coverage of materials issues relevant to all engineers beyond the Sophomore E4 experience. Specifically, the two-quarter course focuses on the mechanical, electrical, and optical properties of solids. A key feature is team teaching involving faculty from Materials Engineering, Mechanical Engineering and Mechanics, and Physics. The topics are taught around design, processing, application, and manufacturing, with a strong integration of course material and laboratories.

It is the intent of the authors in this presentation to highlight the objectives, methodology and content of the 'Gateway' course integrating experimental techniques with computer-aided instruction. For completeness, details of the core (Sophomore) course are also given since the advanced level course uses the core course as a student prerequisite. The core course laboratories are being developed with investigators at The Ohio State University (J. Demel, B. Breedon, G. Stabb, D. Dickinson) and The University of Pennsylvania (C. McMahon).

The five primary objectives of the two-quarter course, and the pervasive philosophy with respect to students are:

- A broad exposure to polymers, metals, and ceramics with a particular emphasis on optical, electrical and mechanical properties.

- Development of laboratories with three components: a set of preparatory (pre-laboratory) exercises, a hands on experiment, and the use of measured parameters in an engineering design problem.

- Integration of experimental techniques with computer aided instruction. Pre-laboratory exercises will include software modules that demonstrate macroscopic and atomic level material behavior using animation and/or video.

- Application of the parameters that are measured in laboratory. Students will first perform standard tests to characterize a material property, perform suitable design exercises involving realistic applications, and evaluate the accuracy of their predictions by comparison with experiment.

- Development of a multimedia approach to teaching including CAI software simulating test methods. Examples will include fracture and fatigue, typical engineering design applications, and physical phenomenon such as diffusion, electrical conductivity, and solidification.

We first review an example of the laboratories integrated into the lower level course because the upper level gateway course will be based on the Sophomore level Materials course. This is the only prerequisite.

The Lower Level Course

When the Drexel curriculum is fully implemented, about 250 students will take the lower level course each term. Four hands on laboratories and some computer-based laboratories will be included. The modules that are being developed will be compatible with the many syllabi and textbooks currently in use for the teaching of materials. The laboratories associated with the lower level course will include: tensile testing, impact testing, the determination of electrical conductivity, and materials degradation. Multi-media teaching modules using computer animation and videos will cover atomic-scale mechanical deformation, diffusion, electrical conductivity, corrosion, and experimental techniques. The modules will also include lessons in how strain gages and other relevant testing tools work. To illustrate the type of reform that is occurring, we outline the example of the tensile testing laboratory.

The complete laboratory manual begins with a preparatory section outlining the important knowledge necessary to complete the laboratory and a set of questions that students must complete and bring to class; emphasis is on atomic scale explanations of macroscopic behavior, but will also include an animation screen similar to the one shown in Figure 1. The pre-laboratory diskette will have lessons in the workings of strain gages, load cells, chart recorders, and screw and hydraulic tensile machines. A description of some of the topics that will be taught, and the media implementation that will be used to teach them is given in Table I. The hands on portion includes the testing of several metals and polymers and the acquisition of force and elongation data. After calculating stress strain behavior, yield strength, and strain hardening, the measured parameters will be used in the solution of two engineering design problems. The first problem is to consider a bridge capable of carrying specified loads and the second problem is to determine the force required to draw a wire through a die to smaller diameter. The concepts of elastic behavior, yield strength, and strain hardening are all necessary to complete the two problems. Each problem will require a discussion of the changes that could be made to the material to improve on the initial design solution.

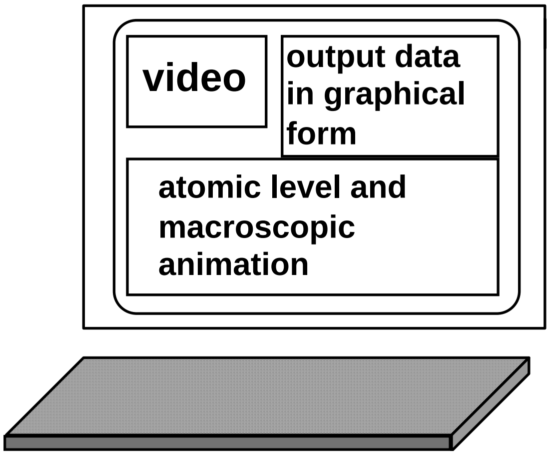

Figure 1. Schematic of the various components that will be portrayed in the computer aided teaching modules.

Table I: Topics and Method of Implementation - Lower Level Course *

Topics	Implementation
1. Elastic Behavior	Animation of elastic deformation to illustrate the relationship between Young's modulus and shear modulus.
2. Plastic Behavior	Animation of dislocation motion in metals, chain alignment in polymers, grain shape accommodation in a polycrystalline sample, and void nucleation and growth.
3. Machine Characteristics	Computer animation showing load cell construction, the principles behind a strain gage, the use of an extensometer, functioning of strip chart and x-y recorders, and a comparison of screw and hydraulic machines.

* In order to illustrate the difference in behavior of the various materials, the pre-laboratory diskette will include videos of metals, polymer, and ceramics that are being tested. Atomic behavior will be animated as shown in Figure 1. The hands on portion of the laboratory will include the testing of metals and polymers.

The Upper Level Course

The upper level course will assume only the knowledge given in the core course. This course is laboratory intensive and is designed to the give the students extensive hands on experience in the laboratory and in using design software. It will follow the general philosophy outlined previously. The two-quarter course will consist of three main topics: mechanical properties, optical properties, and electrical properties. Two of the modules are under development and a description follows; these cover fracture mechanics, and optical properties of materials.

Fracture Mechanics

Brittle fracture, as a result of either static or cyclic loading, is the most prevalent mode of failure in many structures. Several of the well documented catastrophic failures of planes, ships (including the titanic), chemical storage tanks, and the ‘Challenger’ space shuttle, could have been avoided if the principles of brittle fracture had been

established and utilized in the design process. It is estimated that the cost to the United States economy of the fracture of engineering structures is in excess of 4 % of the GNP. Thus, it is important that engineering students have a working knowledge of the fracture of materials.

The goals of this laboratory are outlined in Table II which includes a partial description of the implementation process.

As a first priority, this laboratory will be completed and detailed handouts describing the laboratory published. Two handouts will be published: one to enable the instructor to benefit from our experiences and development of a successful experimental set up, and the other for the student. The handout for the student will consist of three parts: (i) background on fracture mechanisms and the importance of fracture; it will have a pre-laboratory exercise in which the student is tested for his/her understanding of the basic concepts in fracture, (ii) a description of the fracture toughness measuring procedure (ASTM standard) including specimen design, and extraction of a K_{IC} value from the measured loads at fracture, a description of the design of a thin-walled pressure vessel, actual fabrication and testing to failure of the vessel, and interpretation of the results. The final report will be both written and oral.

Table II. Topics and Method of Implementation of Fracture Mechanics - Upper Level Course

Topics	Implementation
1. Mechanisms of Ductile and Brittle Fracture	Animation of ductile and brittle fracture to illustrate atomic and macroscopic behavior. Hands on laboratory component to test several types of materials.
2. Toughness and K_{IC}	A study of ASTM procedures and the methods for measuring K_{IC}, correlations between K_{IC} and toughness, and their applicability..
3.Interpretation of Fracture Surface Morphology re: Fracture Mode.	Examination of spectrum of fractographs
4. Use of K_{IC} as a Design Parameter.	Design of thin walled pressure vessel and construction and testing of the vessel.

Optical Properties of Materials

In the first half of this course, students are exposed to how the atomic and molecular structure of materials influence their mechanical properties. This laboratory module will emphasize the influcence of the atomic and molecular structure on the optical properties of materials. Thus, this course will bring together the materials courses which discuss how the mechanical properties of matter are affected by their atomic and molecular structure, and the physics courses which give instruction in electromagnetic radiation, quantum mechanics, and optics. The lecture material, videos, and accompanying demonstrations will show the connection between the mechanical and optical properties of materials. In turn, the laboratory portions will emphasize how this behavior is used in the non-destructive and non-intrusive diagnostic examination of materials to measure properties such as density, temperature, and composition. Because a relatively extensive background is required by the student, this module will contain animations and videos of basic material that can be discussed in more depth if students lack the fundamentals in certain areas. If all the topics have been adequately covered in previous courses, this material will provide a brief review before the students proceed to more advanced topics.

The laboratory manual will contain a brief description of topics such as dispersion theory, the refractive index of materials, birefringence, Rayleigh scattering, and the theory of absorption. The topics planned for the pre-laboratory video are summarized in Table III.

Two experiments will be performed during this laboratory. First, students will construct an atomic emission spectroscope and use it to measure the emission spectra of various elements such as sodium, mercury, or hydrogen. In the second experiment students will use Rayleigh scattering to measure the temperature of a gas sample.This measurement will be verified by the students as a means of independent temperature measurement.

Table III. Topics and Method of Implementation for Optical Properties - Upper Level Course

Topic	Implementation
Refractive Index of Materials	Demonstration of the variation of refractive index of a transparent materials with temperature and composition using a Mach-Zehnder interferometer.
Birefringence	Demonstration of how birefringence can be used to determine the state of stress in a material.
Rayleigh scattering	Demonstration of the Tyndall-Rayleigh experiment showing the effect of particle size on light scattering.

Summary

A two-quarter, laboratory intensive, materials course is being developed. It will emphasize the optical, electrical, and mechanical properties of materials. The philosophy of the laboratories is to use a multi-media teaching approach to help the students understand more difficult concepts, to give students hands on experience, and to have students use the measured parameters to solve engineering design problems.

Math Modeling in the Dorm

Prepared by:
Jorge J. Santiago-Avilés, University of Pennsylvania

This is a hands-on computer modeling program in the form of a workshop for first year engineering students residing in a dormitory (Kings Court) at the University of Pennsylvania. The workshop's purpose is to provide these engineering students, in a convenient and challenging way, with the means to identify themselves with the school of engineering and its faculty. At the same time they will acquire some knowledge of the power and versatility of simulation and mathematical modeling. In the first year of the program (1991-92) we had 11 students attending; this year (1992-93) we have doubled the enrollment. During the semester we meet once a week for 2 hours. The meetings are held in the computer room of King's Court (one of the first year residences) which is equipped with 10 microcomputers (6 MACs and 4 PC's) and a SPARC workstation, for programs like this one. This program has the explicit sponsorship of the Office of Residential Living.

Modeling is an integral part of problem definition and problem solving in any discipline; its inherently interdisciplinary and is more a craft than a science in that there are specific techniques to be learned and a variety of approaches. Since most undergraduate courses deal with disciplinary fundamentals, specially during the first two years, the functional core of modeling is not usually taught. Using specific examples, we show the students that knowledge acquisition and its integration into new ideas and their implementation are the essence of problem formulation and solutions, and that inherent to the successful pursuit of this process is the concept and application of modeling. We look at problems as they arise in the normal day-to-day disciplinary course routine of a student, and show that although 'once upon a time' mathematics was essential for modeling and problem solving, the personal computer precipitated change in our approach. Now, powerful and user-friendly software have brought explicit modeling (i.e. modeling based on advanced mathematics) within the reach of even the computer-non initiated. The beauty of this new technology is the versatility and latitude to the imagination that computer modeling affords. An explicit model of a problem is a mental laboratory: you can test for consistency; you can gently alter the different parts and see the consequences; and you can explore the limits of its validity.

I use the IDEAL model for improving problem solving as presented by Bransford and Stein in their book1. The components of the model are represented in the acronym IDEAL and stand for, Identifying the problem; Define and represent the problem; Explore possible strategies; Act on the strategies, and Look back and evaluate the effects of your activities. The explicit model making using the personal computers is associated with the D and E parts (Define and Explore). For this part of the workshop we use the beautiful booklet "How to Model It: Problem Solving for the Computer Age" by Anthony Starfield, Karl A. Smith and Andrew L. Bleloch. The computer software we are using is a versatile spreadsheet (Excel) and a symbolic and numeric mathematic software (Mathematica).

Goal

To teach the elements of problem formulation and solution. This is accomplished by allowing the student to explore the craft of explicit model making using computers, in the context of solving straightforward but challenging problems.

Activities

We meet twice a week for eight weeks (Tuesdays and Thursdays) in the evening for a period of two hours (8-10 PM). We devote the first hour of each session to guided discussion on how to improve our generic problem solving skills. Then we discuss the IDEAL model, improving memory skills (what we envision as the memory and retrieval process, effectiveness of associations and retrieval cues, and inventing our own memory techniques), learning with understanding, intelligent criticism (the analysis of factual claims, the analysis of basic assumptions, the transition from criticism to creativity, and the importance of effective communications). The other hour is devoted to actual hands-on model making. We closely follow our chosen textbook ("How to Model It...")2 for the problems to be solved and "systems" to be modeled. A list of the problems as described in the book's Table of Contents follows:

1. Can we estimate the reading time for this book? Definition of model and modeling terms such as variables and parameters.

2. The number of ping-pong balls that can be fitted in the classroom. This problem demonstrates interactively how the approach and solution depend on resources.

3. Purging a gas storage tank. This problem introduces time dependence.

4. The case of the hot and thirsty executive. This introduces the use of heuristics, interpreting results and presenting solutions.

5. Tennis, anyone. This problem introduces probability and stochastic modeling. A glimpse into decision making.

6. Food for thought (estimating the shortest time to cook, serve and eat a banquet). This problem stresses the importance of organizing and representing information. The use of diagrams and schematics.

7. The student's dilemma: French , calculus , time and money. A resource allocation problem.

8. A cab control system. Development of algorithms, using models to explore system dynamics and to develop and test hypotheses.

9. The case of the dishonest advertiser. This problem introduces statistical distributions. The art of the possible.

10. The librarian's dilemma. This problem creates the need for a qualitative knowledge model. Representation such as trees and tables.

The students work in small groups; they will get 30 minutes to familiarize themselves with the problem of the day by interacting with the members of their group and other groups (I emphasize group effort). I ask the students (selected randomly) to present the problem formulation, such as questions to ask, assumptions to make, and what will construe a reasonable answer. At this point the group discusses the approach and feeds back whatever criticism is deemed necessary. The students then have a week to work out their solution and associated model for the problem, and present an oral or written report.

Evaluation mechanisms

I have asked the participating students to present a five minute talk on the evolution and results of their problem solving and modeling efforts. I am interested in finding out how this workshop might clarify or crystallize the students inclinations for science and engineering, and to that effect I am keeping records of the participants' whereabouts and performance during the year following the workshop. For example, during the first year three participating students decided to engage in technical fields (two engineering and one economics).

References

1. The Ideal Problem Solver, by J.D. Bransford and B.S. Stein, W.H. Freeman and Co., New York, 1984.
2. How to Model It: Problem Solving for the Computer Age, by A.M. Starfield, K.A. Smith and A.L Bleloch, McGraw-Hill, New York, 1990.
3. Essence of Creativity - A Guide to Tacking Difficult Problems, by S.H Kim, Oxford University Press, New York, 1990.

A Laboratory Approach to Engineering Computation

Prepared by:
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Introduction

Computation is an indispensable tool for practicing engineers and scientists. Undergraduate students should have computational experiences that empower them to analyze and make decisions concerning as yet unknown problems. The goal of our project is develop two upper division courses that provide an introduction to the computational tools, both software and hardware, for analyzing engineering and scientific problems. They are to be offered in a computing laboratory environment so that the immediate benefits of instruction can be realized. The new courses are to be taught in an interdisciplinary fashion so as to complement recent engineering curriculum modifications at Drexel University, and around the country.

The participants are faculty members at Drexel University, the University of Pennsylvania, and Ohio State University. The joint effort enables us to develop resources and a computing environment that can serve as a model for other colleges and universities. A pilot course at Drexel is planned for the Spring term, 1994.

Major Focus Areas

The courses fall under the Gateway "Inverted Curriculum" paradigm in that they introduce additional mathematical and computational concepts at the upper division level. They provide students with exposure to:

- problem solving techniques
- mathematical modeling techniques
- modern computing environments, including workstations and supercomputers.

Furthermore, a broad goal of the course is to lead students into the engineering design process. This is accomplished in two steps: introduce students to a realistic computing environment by means of a sequence of increasingly sophisticated numerical methods; apply these experiences to problems that are part of the engineering design process. These courses serve as a precursor to a senior design effort, or a capstone computational experience for science or engineering students. In so doing, we provide students with the necessary computational background to work independently on further computational problems, and to appreciate more the general framework of computation in a contemporary computing environment. At Drexel, the courses offer the extra advantage of complementing a general policy to integrate computer usage into courses for students at all levels, especially those associated with the emerging "Drexel Curriculum."

The courses are accessible to motivated students in all engineering and science disciplines. By it's very nature, these courses appeal to a wide range of interests by emphasizing the generality of the physical and mathematical science concepts involved in various engineering problems, and highlighting the central position of numerical techniques. It also provides opportunities for students to work with high performance equipment that is part of the working environment of practicing engineers and scientists today.

Course Content

Regular meetings were held at Drexel during the first six months of 1993 to discuss the project. At one day-long meeting, April 27, everyone met at Drexel and agreed on a general framework for the project. The framework that resulted from of that successful meeting is outlined below. The course consists of loosely connected modules corresponding to either a description and discussion of the physical situation, or the numerical techniques proposed for the analysis. A module consists of:

- a clear statement of the problem;
- a motivation for the problem by pointing out the generality of the concepts;
- a clear statement of the important and neglected variables;
- an indication of symbolic assistance with the help of Maple;
- a solution path from the simple “geometry” to the realistic case;
- a sensitivity analysis and validation of the model.

The early modules address practical issues of the computing environment and problem solving in general. Later modules provide an introduction to ordinary and partial differential equations through the use of application themes such as environment, energy, materials, and information or data reduction. Modules address specific topics that include, but are not limited to:

- Computer Environment
- Approximation concepts
- Model Conceptualization
- Sensitivity
- Data Visualization
- Partial Differential Equations
    - Diffusion
    - Flow
    - Heat Transfer
    - Fields
- Ordinary Differential Equations
    - Dynamical Systems
    - Control
    - Feedback
    - Chaos
- Problem Solving Techniques
- Statistics
    - Model Selection
    - Model Validation
- Artificial Intelligence Techniques

The adopted software tools for most of these modules are Maple, Matlab and Algor. Maple is an symbolic algebra program that is used at many universities, including Drexel. Matlab is fast becoming the software of choice in science and engineering applications as an alternative for Fortran. Algor is a finite element package, typical of what is available today.

Each module is designed to move from a simple conceptual example, possibly solvable with Maple, to a realistic, but simplified, case treatable with Matab. Certain problems use finite element software as part the of analysis. This progression allows students to first acquire a qualitative, and possibly quantitative, understanding of the physical nature of the problem at hand, and of the numerical approaches used in the solution of the problems encountered. The finite element approach leads students to a working knowledge of a realistic computational tool.

Modules using ordinary and partial differential equations are under development at Drexel. The first one is based on questions related power generation with a nuclear reactor, and the associated power transmission problems. By looking at the different aspects of such a complicated system, we can identify subsystems which become the focus of each module. For instance, we use reactor core dynamics in the ordinary differential equations module, and a discussion of transmission lines in the partial differential equations module.

Hardware and Software Tools

The emerging standard hardware tool for the support of network communications, visualization experiments, and supercomputer activities is a high performance workstation with Unix as the operating system. The X Window System offers a good interface that is also becoming an unofficial standard. The success of the proposed courses depends on the availability of such tools and software. As an interim measure, the development work for the project is being carried out on a SUN server in the Drexel Mathematics and Computer Science Department . Gateway funds have been used to purchase additional disk storage, a high performance Tektronix X-terminal, and SIMULINK for Matlab. Additional X-terminals are being acquired so that a pilot course can be offered in 1994.

As mentioned earlier, Maple, Matlab and Algor are presently the chosen tools for the courses. Other tools such as Hi-Q and ASCL are also being considered. Both Maple and Matlab have extensible languages as part of their software system. This is particularly useful in the case of Matlab. One of the goals of Gateway is to remove "unnecessary burdens" from the backs of students, and Matlab offers one such opportunity. Traditional engineering computations are carried out using Fortran, but the high level primitives in Matlab permit students to write a program in a few lines what might take hundreds of lines in a Fortran environment. The result is increased productivity and reduced development time for computing projects. The extra time can be used for assessment and analysis.

Conclusions

There are many distinguishing features of our courses that makes it unique and worthwhile for us to develop:

- multidisciplinary aspects (examples from the various engineering disciplines, integrated via the mathematics and sciences);
- inverted curriculum aspects, in which mathematics and computer science aspects are brought in at a later stage;
- use of standard state-of-the-art software and computer environment;
- gradual presentation that emphasizes an intuitive understanding of the physical problems as well as numerical techniques;
- emphasis of the importance of the choice of the “right tools” for the solution of a problem;
- possibility of incorporating modern aspects of numerical approach via modules on artificial intelligence and possibly fuzzy logic.

It is our goal to offer a pilot course during the Spring term of 1994, at Drexel.

Wavelets and Multiresolution Imaging

Prepared by:
Dr. Om P. Agrawal & Dr. Fred L. Fontaine,
The Cooper Union

Presented by:
Dr. Om P. Agrawal, The Cooper Union

We offered a joint adventure in mathematics and electrical engineering for the Gateway Coalition. It is a senior level course that attracts students from various levels and disciplines of engineering. They receive three credits for either mathematics or electrical engineering.

Our goals for this project are (1) to introduce wavelets and multiresolution imaging (2) show why Fourier Analysis is inadequate for certain applications such as signal analysis and (3) apply the techniques of wavelets and multiresolution imaging to such diverse areas of engineering and science as computer vision, data compression, fluid dynamics, numerical analysis, and partial differential equations.

The prerequisites for this course are a nodding acquaintance with Fourier analysis and signal analysis, though these are reviewed extensively. The topics covered are foundation of multiresolution imaging using wavelets, basic principles of Fourier analysis and its limitations, wavelets and multirate filter banks, wavelets and partial differential equations in computer vision, construction and properties of wavelet functions and representations of differential operators in wavelet basis.

Term assignments are of three types: computer projects, technical reading and analytical problem solving. The computer projects develop the students' computer skills in applying wavelet techniques by having them do image representation and/or implementation of real or simulated data by using such

tools as 2-D Mallat transform and variational problems. The technical reading requires a student to select an article such as multidimensional wavelets, which extends the theory of wavelets and to demonstrate an understanding by either writing a summery of the article in clear concise notation or implementing the algorithm on a computer. In the case of analytical problem solving the students are assigned several homework problems which reinforce or extend certain aspects of mathematical issues discussed in the course such as multidimensional windowed Fourier transform. These term assignments are meant to solidify the students understanding of wavelets and multiresolution imaging.

This course not only develops an understanding of wavelets but also offers an opportunity for the students to see the interplay between theoretical research and practical design problems.

Gateway Systems Engineering and Control

Paul Kalata, Drexel University

Abstract

This paper describes the Gateway plans to revitalize and reformulate the Systems and Control Engineering Education for the undergraduate upper division. Similar to the E4 approach to engineering education, the Systems and Control plan introduces the fundamental engineering concept and problem upfront to catch the interest of the students. The mathematical skills and natural responses of the governing physical laws will be supplied as needed to solve the engineering problem. The plan is to use real hardware apparatus to introduce the engineering problem. Included in the plan is the integral use of modern software analysis and design packages to solve the engineering problem and to improve the system performance.

Introduction

The innovations in Engineering Education of the Drexel Freshman - Sophomore experimental program [1] considers three fundamental engineering fields:

Energy,
Materials, and
Systems

The three fields are primary in introducing the students to engineering problems upfront and the associated skills and methodology craft to solve such problems.

A primary concern of the Gateway Engineering Education experiment is to investigate upper division (PreJunior, Junior and Senior) educational instruction and methods. In particular, this paper presents concerns and philosophies in Systems and Control Engineering Education. Revitalization of Systems and Control Education observe the objectives of the final product as student engineers with the skills to solve real world Systems and Control problems.

Systems Engineering Coalition

The Systems Engineering and Control coalition consist of:

Coalition Partners:

Drexel U.	Paul Kalata
Case Western Reserve U.	Marc Buchner

Coalition Associates:

U. Pennsylvania	Nelson Dorney	Ohio State U.	Stephen Yurkovich

Goals

The Goals of this project is to restructure, modernize and revitalize the way Systems Engineering and Control is being presented to the upper division undergraduates: PreJunior, Junior and Senior. The objectives are to provide the engineering students fundamental knowledge and modern tools to meet the ever increasing Engineering Systems and Control technical challenges of industry and research in the 21'st century. The project outcomes are to design, develop and implement generic, interdisciplinary Systems and Control courses for the upper division undergraduate level.

Objectives

The objective of this project is to prepare students with a methodology to understand, simulate and analyze systems problems. This learning process involves the study of real hardware systems which exhibit natural phenomena. In particular, design, develop and implement real hardware laboratory experiments to study systems responses and implement controls to improve system performance. The objectives include a basic understanding of how to compensate systems to meet design specifications and performance levels using feedback/feedforward signals which will restructure/control the system. An important objective is to introduce the use of modern computational aids such as commercial software packages. In particular, the plan is to use existing software packages such as Maple, MATLAB and Mathematica to design, develop and implement computer analysis and simulation of the experiments. This will provide the students with modern tools which will make system analysis and control design more powerful than the methods of the past 50 years.

Important Issues

In defining what should be revamped in Systems and Control engineering education, the following question should be explored:

> What is educationally important in
> Systems Engineering and Control ?

To this extent, the coalition partners (Drexel and Case Western Reserve) independently developed the following important issues:

Study Real Systems

In most System/Control lectures, a mathematical model is introduce and the classroom lectures are related to that model. The assumed model may be fictions or realistic, but in either case, the students usually have no connection between Systems Engineering analysis/methodology described in the classroom and what is really going on within the system under study. To this extend, the coalition partners regard as vital the study of real systems in which *Mother Nature* exhibits natural phenomena. This gives the students meaning as to what they are studying. In fact, the coalition partners desire to bring real hardware apparatus into the classroom and into the learning process.

Hardware Experiments

In the 1980's, many engineering programs used computer simulations rather than hardware systems to study systems and control concepts presented in the lectures. The reasoning was that computer software was easier to maintain, transportable and use compared to hardware systems. However, the students were often left with an incomplete learning experience because they did not see a shaft turning, ball moving, water flowing, etc. The experiment response was a video graph display which illustrated the mathematical system states. The coalition partners regard as important the *Hands-On* experimentation with hardware systems which exhibits real, natural reactions. Here too, the coalition partners feel it is important to experiment with real hardware systems within the learning process. With real hardware systems, the students will be able to hands-on instrument, test and control systems. Although expensive, the coalition partners feel that it is important to *bit-the-bullet* and invest in real hardware systems for the Engineering Systems and Control learning process.

Modern Software Packages

Some 50 years ago, mathematical procedures were developed for system stability and performance which were translated to graphical techniques for single input/single output system analysis. There are several modern, well-developed software packages (i.e. Maple, Mathematica and MATLAB) that can be used in Systems and Control environment. Software packages can be programmed to simulate systems much in the same way as the construction of block diagrams. With simple instructions, i.e. *eig(•), bode(•) and step(•)*, eigenvalues, frequency and step responses can easily be obtained both in numerical and graphical form. The coalition partners feel it is important to provide the students with modern techniques and tools to analyze/simulate and design system controllers.

Gateway Systems Program
Systems Engineer Role

The role of a Systems Engineer in industry and research is to *make systems work*. There are some Systems Engineering fundamentals that all engineers need. These fundamentals include the traditional subjects:

Linear Algebra
Transform Analysis
Signals & Systems
Probability and Statistics
Modeling & Simulation
Controls

Various engineering curricula such as Electrical, Mechanical, Chemical call for individual courses in the traditional subjects which often do not relate to actual systems. Virtually all are individual courses sequenced over 3 years (PreJunior, Junior and Senior). The Gateway plan is to integrate traditional subjects and present a *Generic* [2,-3] approach to Systems and Control.

Program Courses

The project outcomes are to design, develop and implement a series of generic, interdisciplinary Systems and Control courses for the upper division undergraduate level. The objective courses are:

Linear Systems,
Errors, Uncertainty and Reliability,
Dynamics and Control, and
Computer Control Systems

Curriculum Inversion

A successful feature of the E4 program [1] is that of *curriculum inversion* in which the engineering problem is introduced upfront and the Physics and Math introduced as needed to complete the engineering problem solution. This curriculum inversion concept will be used in the Systems/Control learning process. Table 1 illustrates a *Typical Control Textbook* for which a Control Theory course would sequentially follow the outlined chapters and corresponding subjects. In a 10 week quarter course, the important topic of Design comes late in the term and design concepts are usually compressed to fit the remaining time. The Gateway Engineering

Systems and Control courses plan to follow the inversion order listed on the right side of the textbook outline.

Table 1. Typical Control Textbook

Chapter	Topic	Inversion Order
1	Introduction	as needed
2	Mathematical Foundation	as needed
3	Transfer Function, Block Diagrams & Signal Flow	as needed
4	Modeling of Physical Systems	1
5	State-Variable Analysis of Dynamical Systems	as needed
6	Analysis of Control Systems	as needed
7	Root Locus Techniques	as needed
8	Time-Domain Design of Control Systems	2
9	Frequency-Domain Analysis of Control Systems	as needed
10	Frequency-Domain Design of Control Systems	2

Real Control Systems

Drexel U. has developed a Generic, Hands-On Control Systems Laboratory [2-4] which include a variety of real system experiments (see the Appendix). These experiments exhibit a variety of system dynamics, time constants and non-linearities. These real systems will be the upfront subjects in modeling, simulation and control.

Systems Engineering Plan
Project Schedule

The project plan to meet the Gateway Engineering Systems and Control objectives coincides with curriculum changes of the College of Engineering, Drexel University. The Sophomore E4 Systems courses [1], will be prerequisites for the planned Gateway Systems courses. There are important issues in the scheduling to be considered:

- to design educational modules,
- to implement courses, and
- to evaluate the program.

Figure 1 illustrates the time table to design, develop, implement and evaluate the courses.

B. Collaboration Efforts

The Drexel-Case Western Reserve Gateway Systems & Control coalition have met several times discussing philosophies, ideas, goals and objectives. The coalition will meet periodically to review efforts and developments. Included will be Systems and Control workshops to exchange ideas and concepts. The plan calls for Case Western Reserve University (CWRU) to develop courses in Control focusing in on *Life Experiences* within the classroom. With this approach CWRU plans to bring real hardware systems under study into the classroom. CWRU

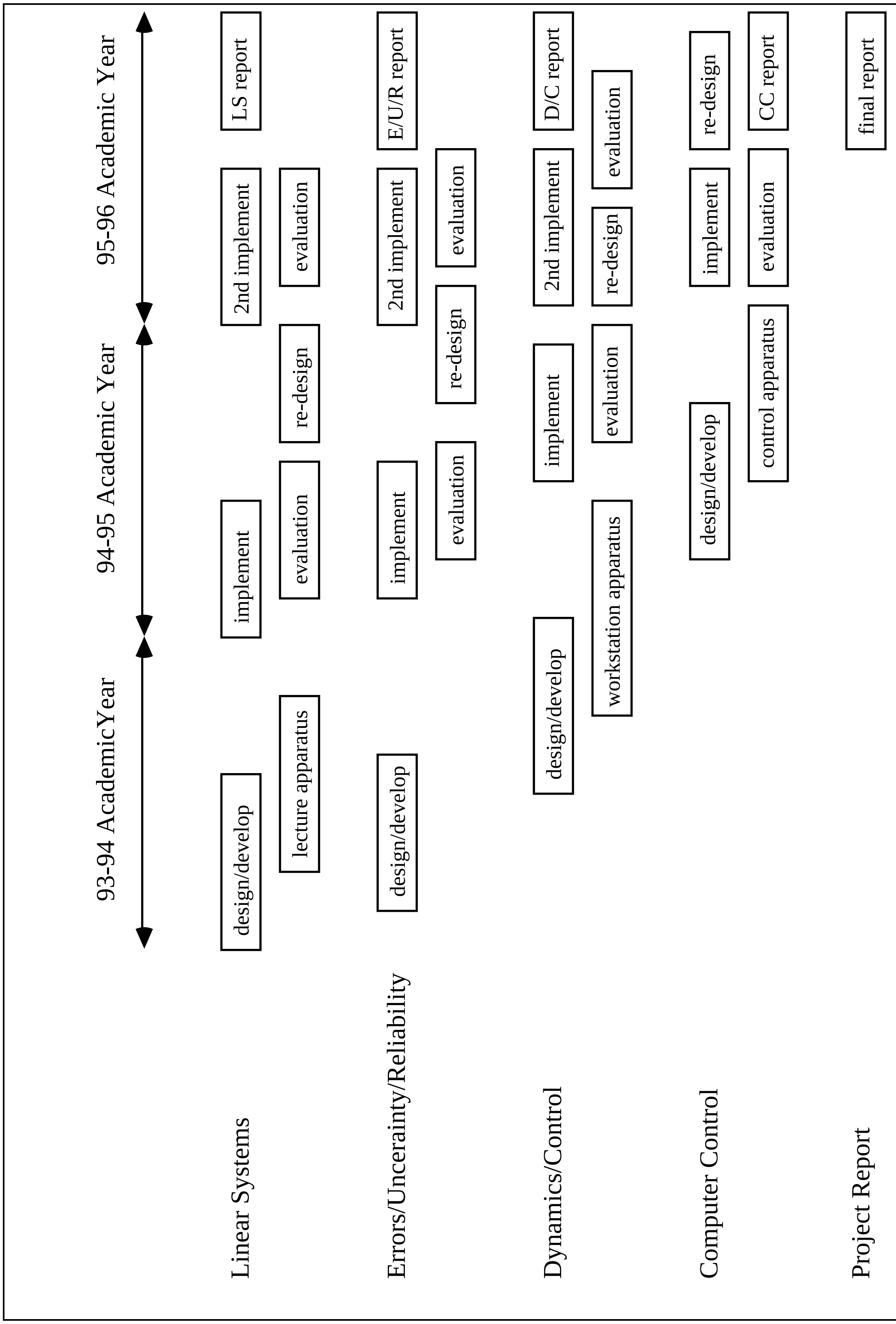

Figure 1. Drexel Gateway: Systems Engineering Course Development Time Table

plans on developing Control software using Mathematica. The Drexel plan includes developing courses on System Modeling which includes both deterministic and stochastic aspects with software using Maple and MATLAB. Drexel plans on developing Control courses which include real-time Computer Control Systems.

Evaluation Plans

A number of methods will be used to evaluate the Gateway Engineering Systems and Control Project:

- *student evaluation* **-** Periodic student questionnaires will be distributed during the course implementation to determine if the material is being presented properly (i.e. do they understand what is being presented.)
- *instructor/faculty evaluation* **-** During and after the course implementation, the instructors will review the students' progress in obtaining the fundamental Systems and Control Engineering methodology.
- *comparison to traditional* **-** A comparison will be made between the Gateway Systems program and a traditional program considering the ultimate purpose of an engineering education for industry and research needs.

References

1. R. Quinn, "Drexel's E4 Program: A Different Professional Experience for Engineering Students and Faculty," ASEE Journal of Engineering Education, vol. 82 pp. 196-202, October 1993.
2. K. Bonner, R. Fischl and P. Kalata, "A Generic, Hands-On Control Systems Laboratory", *Proceedings, 1988 American Control Conference,* pp. 1600-1604, June 1988.
3. P. Kalata, M. Kam and R. Fischl, "On the Development of a Generic, Hands-On Control Systems Laboratory", *Proceedings, 1992 ASEE Conference,* Toledo, Ohio, June 1992.
4. J. Block, M. Kam, P. Kalata and R. Fischl, "A Generic Control Interface Unit (GCIU) for Instrumentation and Computer Control Experiments", *Proceedings, 1992 ASEE Conference,* Toledo, Ohio, June 1992.

Appendix

Generic, Hands-On Control Systems Laboratory

The Hands-On Control Systems Laboratory is an undergraduate laboratory specifically set up to have students get experience in instrumenting and controlling systems in a Hands-On environment. A series of diversified, real systems have been set up with a variety of physical reactions, time constants and constraints which are provided by mother nature. The objective of the Control Lab Experiments is to teach Controls. Design Projects include designing, implementing and testing a series of control experiment through user -friendly software LabView/LabWindows for MacIIci/PC486 Computers are integrated within the control experiments.

- **D.C. Motor Control System** - The plant is DC motor with tachometer and angular position sensors. The control objective is to regulate the motor position/speed with varying load conditions. A variety of controllers are to be implemented: analog and digital computers, PID/PLC commercial controllers.

- **Laser/Bouncing Ball Tracker -** The plant is a laser beam steered by a motor controlled mirror to a steel ball suspended from the ceiling and is allowed to operate like a pendulum or bounce against a wall. The objective is to track the ball with the laser beam steered by a set of 2-dimensional, fast acting galvanometers driven mirrors.

- **Toy Train Control -** A toy train runs along a track with a photo sensor which detects the track cross members. The signal is transmitted via walkie-talkie to a ground station and the control objective is to design an observer to estimate the train speed and regulate the speed by varying the track power.

- **Inverted Pendulum Stabilization -** An inverted pendulum mounted on a motor runs along a track with potentiometers that sense track position and pendulum angular position. The objective is to balance the pendulum and move it to the middle of the track.

- **Two-Tank Water Control -** Hot and cold water sources with valve actuators supply a main tank which drains into a second tank. The tanks are equipped with ultrasonic height and thermocouple sensors. The control objective is to regulate both the height and temperatures to desired set points.

- **Automatic Lens Focusing -** An optical lens and a photo detector array detector senses image contrast. A motor rotates the lens and the objective is to automatically adjust the lens to obtain a sharp image.

- **VAR/Induction Motor Control -** This system is to sense the phase of the power supply of an induction motor and to control the system power factor.

- **Loran-C & GPS Tracking System -** A series of delayed signals are transmitted from a cluster of Loran-C master/slave land based stations (United States Coast Guard). A receiver on a boat measures the delays and determines the boats latitude and longitude. The objective is to implement an extended Kalman filter to generate the boat's speed and course direction. A Global Positioning System (GPS) is also included in the Tracking System.

- **DUSLER: A Walking Robot -** DUSLER is **D**rexel **U**niversity **S**ix **L**egged **E**xperimental **R**obot. It has six independent legs/articulators which can be programmed into a coordinated walk. DUSLER is also equipped with ultrasonic transducers to sense objects within its path. The objective of this project is to sense DUSLER’s movement and detect obstructions and/or inefficient operation such as high loading on a leg or set of legs.

- **Magnetic Ball Suspension -** This system consists of a steel ball, magnetic coil, light source and photo detector to sense the ball's shadow. The objective of this project is to implement a control signal to the magnetic coil to suspend the ball without a mechanical support.

- **Ball on Convex Rails -** This system consists of a steel ball on convex rails. The ball naturally falls to one side or the other due to gravity and the convex rails. The ball can be balanced by moving one end of the rails up or down or by moving the convex rail system side to side. The objective is to implement a control signal to balance the ball at the apex.

- **Hopping Robot -** This system consists of a one-legged machine whose hopping height and vertical trajectory are computer controlled. The objective is to stabilize the robot and maneuver it horizontally.

Generic Experiments

The purpose of the Control Laboratory is to *teach controls* and the following are experiments to be performed by the students:

- **System Block Diagram:** Draw a block diagram of the system noting the various components with a description of each block and the objective of the system.

- **Modeling:** From physical laws, write down the dynamical and/or algebraic input/output relationships for each block and/or the system components. Describe the nature of the system linear/non-linear, continuous/discrete time, time invariant/time varying, etc.

- **Simulation:** Simulate via analog and/or digital computer the system in an open loop configuration.

- **Validation:** Make physical measurements to validate the mathematical models of the block diagrams. Obtain the system gains and time constants experimentally.

- **Control Objective:** Formulate the control objective in words and mathematical form.

- **Control:** Design and implement a simple control to meet the system objectives:
  a) test the control in the simulation,
  b) adjust the control design/retest,
  c) test the control on the real system.

- **Performance Evaluation:** Evaluate the performance of the control on both the simulation and the real system.

- **Control Sensitivities:** Vary parameters of the controller and obtain control sensitivities.

A Signals and Systems Textbook

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Presented by:
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Abstract

This paper describes a set of Mathematica notebooks that have been developed for an undergraduate level course in the area of signals and systems analysis. The Mathematica environment provides opportunities for student exploration, experimentation, self-paced instruction in basic concepts of discrete time and continuous time signals and systems including signal representation, convolution, difference and differential equations, Laplace transforms, Z-transforms, and Fourier transforms. Four examples from the notebooks are presented including selections that address the definition of a system, the concept of time invariance, the computation of sample Laplace transforms and the development of simple properties of Laplace transforms.

Introduction

Signals and Systems is a core course in the Engineering School curriculum at Case Western Reserve University which is offered by the Systems Engineering Department. This course is taken primarily by sophomore and junior level undergraduate Electrical Engineers, Computer Engineers, Biomedical Engineers and System Engineers and is also an important part of the engineering curricula at many other universities. While the course content and orientation may be different at different schools, the following topics are commonly covered:

1. Introduction to Signals
2. Introduction to Systems
3. Convolution for Discrete-time Systems
4. Convolution for Continuous-time Systems
5. Difference Equations
6. Differential Equations
7. Laplace Transforms
8. Z-Transforms
9. Fourier Methods for Discrete-time
10. Fourier Methods for Continuous-time

Signal and systems courses generally assume a thorough familiarity with basic university mathematics through calculus and differential equations. Extensive use of fundamental mathematics is made throughout the course which often presents a challenge to students who are not sufficiently mature mathematically. A weakness in a student's mathematical training is often the primary reason that a student has difficulty in understanding the ideas and concepts presented by the instructor or solving assigned homework problems. Two primary functions of the use of mathematics in the course are (1) to provide a language for clearly, concisely and unambiguously expressing signals and systems concepts and (2) to provide a set of tools and techniques for solving signals and systems related problems.

Symbolic mathematics programs coupled with graphical environments and numerical tools such as found in Mathematica provide an excellent framework for students to explore mathematical concepts and to solve problems requiring mathematics. Because of the need for extensive use of mathematics in signals and systems courses and because of the increasing availability of Mathematica in U.S. colleges and universities, we have developed a set of notebooks for use in our introduction to signals and systems. These notebooks cover the primary topic areas (1) - (10) noted above. The thrust of the project has been to develop a text which is published in both a standard textbook form and as a collection of "live" Mathematica notebooks. The Mathematica notebooks contain a complete analytical development, textual description and illustrative examples for the concepts that are presented. The approach that is used is to first give the analytical devlopment of the basic concept or tool that is being examined and then to give illustrative examples of the application of the use of the concept or tool. Extensive discussions about the analytical development, the basic concept or the examples are provided to assist in understanding difficult points about the material. The standard textbook form of the project will contain the same material as the Mathematica notebooks, however the results of executing the Mathematica commands will be included in lieu of the opportunity to explore and experiment from within the Mathematica framework. In addition to the textual material a set of five packages (Signals.m, Laplace.m, Z.m, DFourier.m, and CFourier.m) are provided that contain all of the transformation rules developed in the notebooks. These packages can be used to apply the results of the course in other courses or to solve related engineering problems

Examples

The following four excerpts from the text provide examples of the use of the Mathematica framework for the signals and systems application. All active cells have been evaluated and the corresponding output given. This is not how the notebooks would appear to the student initially.

The first excerpt is from the second chapter of the text which is an introduction to the concept of a system. Note the use of the package "Signals.m" which was developed in Chapter 1. For all of these excerpts the input cells for Mathematica are in boldface.

Example 1

2.1 Definition: A system, S, is a mapping (or transformation) from one set of signals (the input set) to another set of signals (the output set). If X is the input set, Y the output set, then the system, S, maps signals from the set X to signals from the set Y, and we denote this relationship by:

S: X -> Y

Alternatively, if x is a signal in the input set X and y is the image of x under S, (i.e., the result of applying S to the signal x), then we denote this by:

y = S[x]

If the sets X and Y are sets of continuous time signals then we say that the system S is a continuous time system and if the sets X and Y are sets of discrete time signals, then S is a discrete time system.

Before we proceed to look at several examples of systems, let's read in the package Signals.m that we developed in Chapter 1 so that we will be able to use the signal defintions and properties that we have studied. Evaluate the following cell:

```
<<Signals.m
```

For a first example, consider a system that, on a point by point basis, squares the value of the input signal. This system, which we will refer to as S1, is therefore defined by:

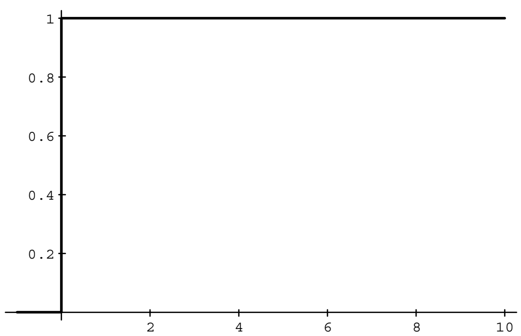
```
Clear[S1]
S1[x_,t_] := x[t]^2
```

for x[t] a continuous time signal. Clearly, the output of this system is also a continuous time signal and this system is a continuous time system. If we let x[t] be the unit step function in continuous time,

```
Clear[x]
x[t_] := uc[t];
```

then the system output is the signal uc[t]^2 which we can examine by plotting S1[x,t] vs. t.:

```
Plot[S1[x,t], {t, -1, 10}];
```

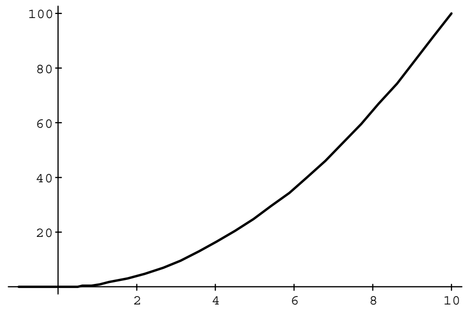


Of course, this agrees with our observation that uc[t]^2=uc[t]. If we let x[t] be the unit ramp signal (causal) in continuous time,

```
Clear[x]
x[t_]:= rc[t];
```

then

```
Plot[S1[x,t], {t, -1, 10}];
```



and the output of S1 is the quadratic signal, t^2 uc[t].

As an example of a discrete time system consider the system S2 defined by:

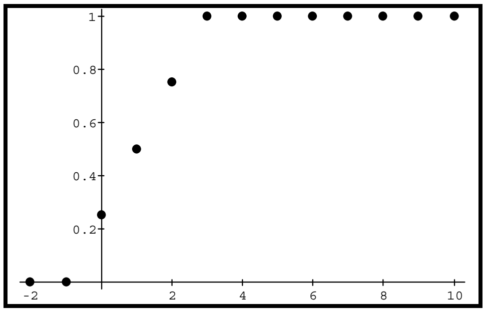
```
Clear[S2]
S2[x_,n_Integer]:=(x[n]
        + x[n-1] + x[n-2]
        + x[n-3])/4
```

with x[n] a discrete time signal. The system output is simply the result of averaging the current and past three values of the input signal. If we let x[n] be the discrete time unit step sequence,

```
Clear[x]
x[n_] := ud[n]
```

then we can plot the system output with:

```
DPlot[S2[x,n],{n,-2,10}];
```

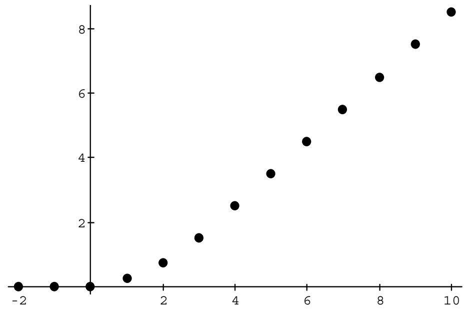


or if x[n] is the discrete time unit ramp signal (causal),

```
Clear[x]
x[n_]:= rd[n]
```

then:

```
DPlot[S2[x,n],{n,-2,10}];
```

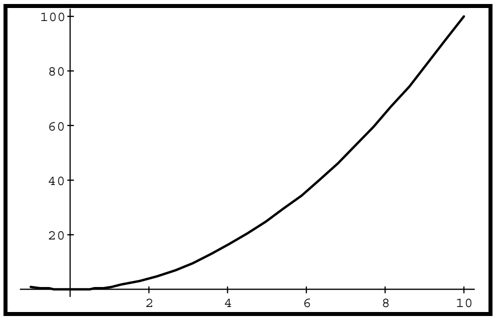


Consider a third example of a system, S3, defined by:

```
Clear[S3]
S3[x_,n_Integer,dt_] := x[t] /. t->n dt
```

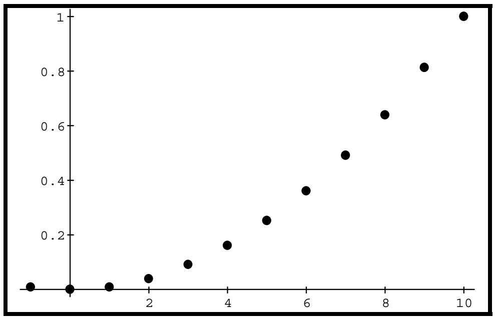
To see how this system transform the continuous time input signals, let us look at a simple quadratic input signal x[t] given by:

Clear[x]
x[t_]:= t^2
with a plot given by:
Plot[x[t], {t, -1, 10}];



A plot of the output signal (a discrete time signal) is given by;

```
DPlot[S3[x, n, 0.1], {n, -1, 10}];
```



While the input to this system is a continuous time signal, the output is a discrete time signal that is a sampled version (with a sampling period of dt) of the input signal. This system is therefore neither a continuous time system nor a discrete time system.

The examples that we have just examined are single-input/single-output (SISO) systems because they have a one dimensional input signal and one dimensional output signal. Many systems, however, have multi-dimensional inputs and outputs. In this multi-input/multi-output (MIMO) case we can view the input signal x as a vector of dimension n consisting of n scalar input signals and the output signal as a vector of dimension m consisting of m scalar output signals. In this text we will be restricting our attention to SISO systems. Many of the results that we will derive, however, can be extended to the study of MIMO systems as well. Before we continue our study of SISO systems, though, let us look at a simple MIMO system, which we will denote as S4, which has two continuous time signals as input and produces two continuous time signals as outputs. This is an example of a multi-input/multi-output continuous time system:

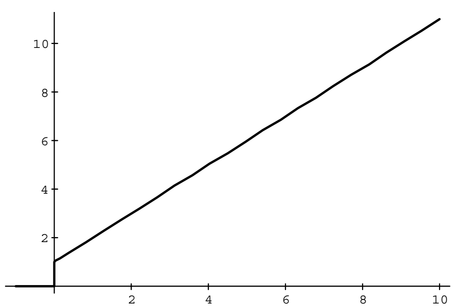
```
Clear[S4]
S4[x_,t_] := {x[1][t]
      + x[2][t], Integrate[x[1][u]
            +x[2][u],{u,0,t}]}
```

This system then produces the sum of the two input signals as one of the components of the system output and the integral, from 0 to the time t, of the sum of the input signals as the second component of the system output. Let's look at the system response to the input signal:

```
Clear[x]
x[1][t_] := uc[t]
x[2][t_] := rc[t]
```

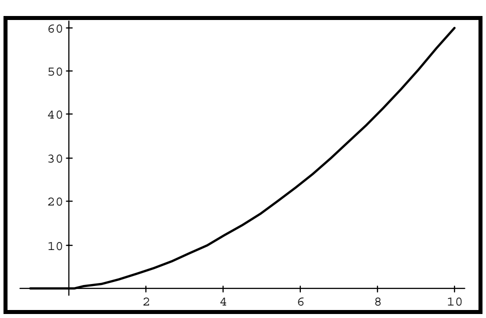
Now let's plot the system response to this (vector) input signal. First we'll plot the first component of the output signal:

```
Plot[First[S4[x,t]], {t, -1, 10}]
```



and now the second component:

```
Plot[Last[S4[x,t]], {t, -1, 10}]
```



There are many examples of systems with which you are familiar. An automobile that transforms the drivers steering, throttle, and brake signals into the movement of the car (which is

also a function of the road or environment) is a system. A telephone that transforms a voice signal into an electrical signal, which is ultimately transformed into a voice signal in another location, is also an example of a system. The New York Stock Market that maps all the broker transactions of a business day into the Dow Jones Industrial Average is another example. The human physiological processes that transform the light color and intensities that fall on the rods and cones in the eye to electrical impulses that are sent to the brain comprise a system crucial to seeing this text. All around you are many examples of systems which are important in our world.
The next example, also from the chapter dealing with an introduction to systems, develops and demonstrates the concept of time invariance:

Example 2

2.3.3 Time Invariance: A system, S, is time (or shift) invariant if for any input signal x[u] and any time delay s:

S[x[u-s], u] = S[x[u], u-s].

In other words, if an input signal x[u] produces an output S[x[u], u] then if we time shift the input by s (which may be positive or negative), i.e., x[u-s], then a time invariant system will have an output of S[x[u], u-s] (the output signal corresponding to x[u] delayed by s time units). If a system is not time-invariant, then we say that the system is time varying or time variant.

Consider the discrete time system S1 defined by:

```
Clear[S1]
S1[x_, n_] := x[n] - x[n-1]
```

For this system, an input signal x[n] produces an output signal y[n] = x[n]-x[n-1]. If we time shift the input signal by s (an integer) to form x[n-s], then the output signal corresponding to this input signal will be given by:

S1[x[n-s], n] = x[n-s] - x[n-s-1].

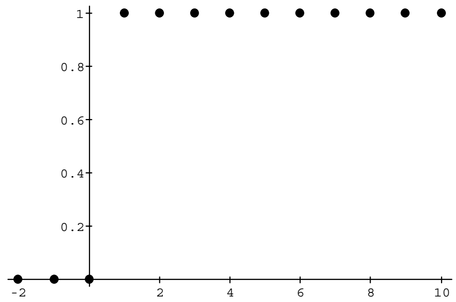
However, the signal y[n] = x[n]-x[n-1], the output signal corresponding to x[n], time shifted by s is y[n-s] = x[n-s]-x[n-1-s] which is equal to S1[x[n-s], n]. Therefore this system is time-invariant.

To illustrate this property for the system S1, consider the input signal:

```
Clear[x]
x[n_]:= rd[n]
```

Let's plot the output corresponding to x[n], S1[x,n]:

```
DPlot[S1[x,n], {n, -2, 10}];
```

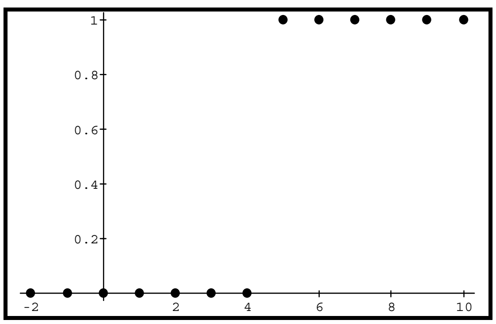


Now lets form a signal, xshift, that is a delayed version of x[n] by 4 time units:

Clear[xshift]
xshift[n_]:=x[n-4]

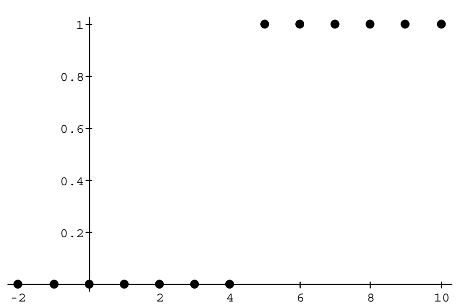
The output signal that corresponds to xshift can be plotted by evaluating the following cell:

DPlot[S1[xshift,n], {n, -2, 10}];



As the system S1 is time invariant, this output corresponing to xshift[n] should be equal to the output corresponding to x[n] shifted by 4 time units. You can check this by evaluating the following cell:

DPlot[S1[x,n-4], {n, -2, 10}];



For another example, consider the linear, continuous time, memoryless system, S2, defined by:

Clear[S2]
S2[x_, t_] := t x[t]

For this system, an input signal x[t] produces an output signal y[t]=t x[t]. If we time shift the input signal by s (a real number), x[t-s], then the output signal corresponding to this signal will be given by:

S2[x[t-s], t] = t x[t-s].

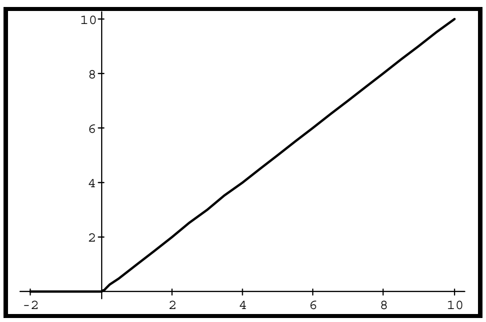
However the signal t x[t], which is the output signal corresponding to x[t], time shifted by s is (t-s) x[t-s] which is not equal to S2[x[t-s], t]. Therefore this system is time varying or time variant.

To illustrate this for the system S2, consider the input signal:

```
Clear[x]
x[t_]:= uc[t]
```

Let's plot the output corresponding to x[t], S2[x,t]:

```
Plot[S2[x,t], {t, -2, 10}];
```

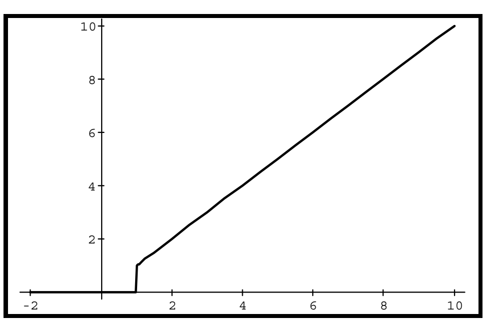


Now lets form a signal, xshift, that is a delayed version of x[t] by 1 time unit:

```
Clear[xshift]
xshift[t_]:=x[t-1]
```

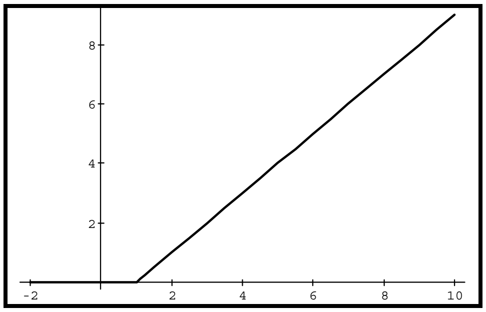
The output signal that corresponds to xshift can be plotted by evaluating the following cell:

```
Plot[S2[xshift,t], {t, -2, 10}];
```



This output, which corresponds to xshift[t] is not equal to the output corresponding to x[t] shifted by 1 time units:

Plot[S2[x,t-1], {t, -2, 10}];



The third excerpt (from chapter 7 - Laplace transforms) develops and tests simple Laplace transforms:

Example 3

7.2 Sample Transforms: Next we compute the Bilateral Laplace transform of some elementary continuous time signals. First we'll look at the Laplace transform of the unit impulse signal, ic[t]. For this signal:

```
ic[s]   = Integrate[ic[t] Exp[-s t],
          {t,-Infinity, Infinity}]
     = 1.
```

Note that this result is defined for all values of s, i.e., for all values of s in the complex plane C, which is the region of convergence for this transform, therefore:

LR[ic[t],t,s] = {1, C}

This result will now be used for defining the function LR (and therefore L also) to compute the Laplace transforms of continuous time signals. The first rule can be implemented by evaluating the following cell:

LR[ic[t_],t_,s_] := {1, C}

For a second example, let's compute the Laplace transform of the causal exponential signal x[t]=Exp[a t] uc[t]. From the definition:

```
x[s]= Integrate[Exp[a t] uc[t] Exp[-s t],        {t,-Infinity, Infinity}]

      = Integrate[Exp[a t]  Exp[-s t],
        {t,0, Infinity}]

     = Integrate[Exp[t (a-s)],
        {t,0, Infinity}]

     = (Exp[t (a-s)]/(a-s)  /. t-> Infinity)
        - (Exp[t (a-s)]/(a-s) /. t-> 0)

     = 1/(s-a)
```

The integral is defined only for values of s such that Re[a-s] < 0 or Re[a] < Re[s]. Therefore, for any finite value of a there is a region in the complex plane (an open right half plane) for which the Laplace transform converges and:

```
LR[Exp[a t] uc[t], t, s]
   = {1/(s-a), Re[a] < Re[s]}
```

The next cell will add this rule to the function LR:

```
LR[Exp[a_. t_] uc[t_],t_,s_] :=
      {1/(s-a), Re[s]>Re[a]}                    /;FreeQ[a,t]
```

For the value of a=2, let's test the internal function LR in computing the transform of this exponential signal:

```
LR[Exp[2 t] uc[t],t,s]
```

```
{(-2 + s)^(-1), Re[s] > 2}
```

Note that we can also compute this transform using the following cell:

```
L[Exp[2 t] uc[t]]
```

```
(-2 + s)^(-1)
```

Let's try and determine the Laplace transform of the unit step using this rule by letting a=0:

```
L[uc[t],t,s]
```

```
L[uc[t],t,s]
```

Thus for a=0, we need a special case of this rule because of the internal handling of this transformation (pattern matching) in Mathematica. Evaluate the following cell to provide this rule - note that this comes immediately from our calculation by letting a=0.

```
LR[uc[t_],t_,s_] := {1/s, Re[s]>0}
```

Let's test this:

```
LR[uc[t],t,s]
```

```
{s^(-1), Re[s] > 0}
```

Next we'll look at the Laplace transform of the signal -uc[-t]:

```
L[-uc[-t], t, s] = Integrate[-uc[-t] Exp[-s t],                {t,-Infinity, Infinity}]

                 = Integrate[-Exp[-s t] ,
                     {t,-Infinity, 0}]
```

```
= Integrate[ Exp[ s t'] ,
  {t', Infinity, 0}]

= -Integrate[ Exp[ s t] ,
  {t, 0, Infinity}]

= 1/s
```

The last step is valid only for values of s such that Re[s]<0 (this defines the region of convergence for this transform).

Therefore LR[-u[-t], t, s] = {1/s, Re[s] < 0} and the Laplace transforms of uc[t] and -uc[-t] differ only in their regions of convergence. We will add rules to our definition of LR to handle time reversals when we talk about general properties of Laplace transforms.

The fourth excerpt, also from chapter 7 examines the application of Laplace transforms to the solution of constant coefficient differential equations:

Example 4

7.9 Solution of Differential Equations: The results that we have derived here can be used to find solutions to constant coefficient linear ordinary differential equations. While we studied several techniques to solve differential equations in Chapter 4, Laplace transform techniques can often be used to find solutions quickly and easily. Let us first define a rule to take the unilateral Laplace transform of an equation (by equating the Laplace transform of both sides of the equation). This can be done because of the 1-1 nature of the transform if we restrict ourselves to causal signals for the unilateral transform with the region of convergence defined appropriately:

```
UL[a_ == b_, t_, s_] :=          UL[a,t,s]==UL[b,t,s]
```

Suppose that we want to calculate the response of a causal system modeled by the following first order differential equation (As a result of causality we can use the unilateral Laplace transform):

```
y'[t] - 2 y[t] == x[t]
```

with x[t]=uc[t] and y[0]=0.
First we will define the signal x[t] and set the initial condition y[0]:

```
Clear[x,y]
x[t_]:=uc[t]
y[0] = 0;
```

Next we will take the Laplace transform of the differential equation. Note that Mathematica will automatically substitute the values for the initial condition of y[0] and for the Laplace transform of x[t]:

```
eqn = UL[y'[t] - 2 y[t] == x[t],t,s]

-2*y[s] + s*y[s] == s^(-1)
```

Now we will solve the resulting equation for the Laplace transform of y[t]:

```
ysoln = First[(y[s] /. Solve[eqn,y[s]])]
```

```
(-2*s + s^2)^(-1)
```

Finally we can take the inverse Laplace transform of this expression to determine the signal y[t]. Let's use the partial fraction approach in this example. We will use the sApart function to put the transform of y into standard form for the inverse Laplace operation:

```
InvL[sApart[ysoln]]
```

```
-uc[t]/2 + (E^(2*t)*uc[t])/2
```

Let's look at another example in which we compute the response of a causal system to a unit impulse signal. Let the system be given by:

```
y"[t] - 1/4 y[t] == x[t]
```

where x[t]=ic[t] and y'[0]=y[0]=0. Following the previous method we can proceed as follows:

First define the input signal and the initial conditions:

```
Clear[x,y]
x[t_]:=ic[t]
y[0] = 0
y'[0] = 0;
```

Next calculate the transform of the differential equation:

```
eqn = UL[y''[t] - 1/4 y[t] == x[t],t,s]
```

```
-y[s]/4 + s^2*y[s] == 1
```

Solve for the transform of the output signal:

```
ysoln = First[(y[s] /. Solve[eqn,y[s]])]
```

```
4/(-1 + 4*s^2)
```

Finally, find the inverse Laplace transform of the output signal:

```
InvL[sApart[ysoln]]
```

```
-(uc[t]/E^(t/2)) + E^(t/2)*uc[t]
```

Consider now the problem of finding the impulse response, h[t], of a causal system defined by the differential equation:

```
y'[t] + 1/2 y[t] == x[t]
```

We know that because the system is causal, h[t] =0, for t < 0

and that

h'[t] + 1/2 h[t] == ic[t].

Proceeding as before:

```
Clear[x,h]
x[t_]:=ic[t]
h[0] = 0;
eqn = UL[h'[t] - 1/2 h[t] == x[t],t,s]

-h[s]/2 + s*h[s] == 1

hsoln = First[(h[s] /. Solve[eqn,h[s]])]

2/(-1 + 2*s)

InvL[sApart[hsoln]]

E^(t/2)*uc[t]
```

The general technique to solve a constant coefficient differential equation which represents a causal system is to:

1. Define the appropriate initial conditions
2. Define the input signal
3. Take the unilateral Laplace transform of the differential equation.
4. Solve for the Laplace transform of the output signal.
5. Find the inverse Laplace transform of the output signal.

If we have a system that is modeled by a constant coefficient linear differential equation but for which we cannot find the Laplace transform of the input signal, either because the signal does not have a known transform or because we (even using Mathematica) are not "bright" enough to find the transform, then we still have a way to calculate the system output for an arbitrary input signal. We can use this technique to find the impulse response of the system (the transform of the impulse signal is unity) and then use convolution to compute (either analytically or numerically) the system response to an arbitrary imput signal.

Summary

A project has been described that has developed a set of notebooks for the construction of an environment and a set of tools for studying signals and systems concepts and problem solving for engineering. The Mathematica environment provides excellent opportunities for exploration, experimentation, learning and self-paced instruction of concepts that make extensive use of elementary undergraduate mathematics.

Uncertainty - an Alternative Statistics Course for Engineers and Scientists

Prepared by:
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The Goal

The course, named Uncertainty in Engineering and Science: Statistics and Complexity of Stochastic and Chaotic Phenomena is an alternative, introductory level statistics course. I offered it twice at Case Western Reserve University, in the Spring Semesters of 1992 and 1993, as an engineering and science elective taken mostly by upper classmen and some graduate students. It was crosslisted as STAT 333/433 and MATH 384. Each time it was offered it attracted an enrollment of about 15 students guided to take it by their faculty advisors. In 1992 its development was supported by the Gateway Coalition.

The course, and the accompanying textbook [1] (most of the thoughts in this article are taken from the introduction to that book which is being written jointly with Manfred Denker of University of Gottingen, Germany, and which also includes Mathematica packages, executed by Bernard Ycart of University of Grenoble, France, and dubbed by us Uncertain Virtual Worlds) addresses the phenomenon of uncertainty, which appears in most of engineering and scientific problems for various reasons, and which can be modeled in several, basically different, ways. The course's novelty is integration of ideas about statistics of random phenomena stemming from three distinct viewpoints:

(i) algorithmic/computational complexity ,
(ii) classical probability /statistics theory
(iii) chaotic behavior in nonlinear systems.

Given the elementary level of the course, and the anticipated preparation of the targeted audience, the exposition depends heavily on the Mathematica simulation and computer experi-mentation by the students. Here, we would like to think about the instruction proceeding in the environment of the random virtual worlds. The goal is to give engineering and science students a forward looking alternative to the usual introductory statistics courses, an alternative that we feel will become the norm of the future as pressures to incorporate a study of chaos- induced uncertainty increases in the already crowded engineering curriculum.

The course and the textbook are under continuing development. Their goal is to train the engineers and scientists to understand different sources and mechanisms of uncertainty, but also to ask the right statistical questions of statisticians and perhaps even of mathematicians. Upon its completion the students should be able to decide what statistical problems are meaningful and can be dealt with in quantitative ways. It does not propose a revolution in statistics, just a radical broadening of the classical viewpoint in the teaching of statistics.

The Philosophy

Harvard's Persi Diaconis likes to say that "Statistics is a physics of numbers" and our philosophy is not too far from that statement. Loosely speaking, the course emphasizes statistics as a science (as opposed to a formal abstract study and a branch of probability theory) concerned with all facets of handling numerical data: collection, processing, analy-sis, and interpretation. It very much subscribes to the standard scientific methodology: proceed from experiment to inductive inference. It is woven around themes like:

a) decision making, design of experiments,
b) data compression,
c) relationship between different variables,
d) finding significant models (parameters).

We feel that it is important to keep track of the nature of data: discrete vs. continuous. Emphasize that all the data actually collected in today's computerized environment are discrete. Continuous models are then a convenient analytical abstraction; that is how Gaussian distribution was initially perceived by de Moivre, before the central limit theorem was proved. Examples from actual engineering and scientific studies are plentiful and are an integral part of the exposition.

In 1992, having already spent a year on this project, we were delighted to see the appearance of two, very eloquently written, popular-science books which advocated the view of uncertainty espoused in our course/textbook. It was highly gratifying to find out that just as we were putting together our ideas, influential French mathematicians and physicist David Ruelle and Ivar Ekeland wrote books (see [2],[3]) popularizing the position that was also ours. We couldn't have hoped for a better preparation of the public for the publication of our textbook. I used Ruelle's book as a mandatory additional reading assignment for students enrolled in the course, and there was a project (see Section 6) related to the book.

In the timeless Bayesians vs. frequentists debate we come squarely on the frequentist side, mainly as a more effective pedagogical approach. Recent studies in the psychology of learning showed that "the mind is a frequentist device". This may be a result of the way human brain evolved through environmental pressures. The result even found its way to the popular press and The Economist [4] argued recently, that the psychologists' findings show that "merely rephrasing a problem in frequentist rather than Bayesian terms generally increases the number of people who can solve it".

In real life, modern applied statistics takes advantage of powerful software packages. But we felt that the pedagogical benefits of using them from the start are limited since they do not give students a sufficient insight into the nature of algorithms and do not let students experiment with random phenomena. The latter have to be simulated. It is therefore a crucial topic to explain randomness from the algorithmic and computational viewpoint.

Random phenomena always have and always will attract peoples' imagination and thinking. It is a basic desire in peoples' minds to find out the rules and laws of chance. Until now there was almost no way to get a feeling for them by experience (unless you were a compulsive gambler): to detect the laws of random behavior the set of data has to be so large that one can not see or grasp the laws easily in everyday circumstances. The situation was thus basically different from, say, intuitions about mechanics or calculus children acquire by throwing baseball to each other. The only way to achieve it was by logical understanding and hideous computations. However, with the aid of computers, and especially the very flexible Mathematica, one can get a lot of insight by doing experiments. They enable students to handle large sets of data in a simple way. Such an approach has to be built-in in any statistics course.

We believe that the viewpoint presented above is going to affect the teaching of statistics all over the world. Given our linguistic backgrounds, we plan to write simultaneously English, French, and German versions of the volume, thinking, perhaps, in terms of the first global statistics textbook ever.

The History and the Present

Over the last 30-or so-years, for very understandable historical reasons, a good num-ber of the introductory textbooks of statistics for scientists and engineers presented the sub-ject from the axiomatic viewpoint. Only minor allowance was made for changes that would reflect how uncertainty was viewed outside sta-tistics proper. Having taught the subject for more than two decades, we became convinced that, from a pedagogical viewpoint, such an approach is at least questionable, and that a modified attitude towards data exploration pro-vides much better and more effective learning results for students who are not planning to be mathematicians or mathematical statisticians.

Until recently, such a modified approach was not very practical. Only with the new generation of personal computers one is able to handle large sets of data in the classroom environment. Introduction, during the last five years, of a numeric, symbolic, graphic and data manipulation language Mathematica permits one to go even one step further. That programming language does not require intensive instruction courses to learn it. It serves as a simple tool to support teaching and to make some parts of the classical syllabi superfluous. Using it, permits students to actually handle-with some understanding of the underlying mechanisms-complex simu-lations and data analyses, without being reduced to button punching on opaque statistical software packages. The course and the textbook take advantage of this development permitting students' independent exploration and self-paced instruction.

The Audience

The Uncertainty course is intended primarily as the first statistics course taken by students of engineering and natural sciences, usually during their sophomore or junior years. Although the course's primary audience is undergraduate, it can be comfortably and profitably taken by graduate engineering and science students who have never had a statistics course before.

Prerequisites for the course include a typical engineering/science 2-3 semester calculus sequence (including some differential equations and linear algebra) in addition to a fundamental programming course in computer science (generally taken during student's first year). The course can serve both as an important technical engineering statistics elective and, possibly, as a mathematics or statistics curricular requirement.

The project was initially a part of a much larger Gateway Coalition initiative in engineering education which was funded by a $12 million NSF grant to the following group of 10 universities: Case Western Reserve University, Columbia University, Cooper Union, Drexel University, Florida International University, New Jersey Institute of Technology, Ohio State University, University of Pennsylvania, Polytechnic University, and University of South Carolina. The coalition aims at restructuring of the engineering curriculum incorporating the latest technology innovations and will try to attract more and better students in engineering and science. By now, it is trying to address a broader and more global audience and elements of it were were included in statistics courses at the Universities of Gottingen, Germany, and the University of Grenoble, France. Another course based on the draft of our textbook is planned at Indiana University.

Another purpose of this project is to develop courseware which will take advantage of the Electronic Learning Environment created by CWRUnet-the all fiber-optic Case Western Reserve University computer network, and its ability to let students run Mathematica's front end on more modest personal computers in their dormitory rooms, while the kernel is running on more powerful network servers. While this courseware may be developed for a specific course, many of the concepts, graphic capabilities, data storage and retrieval, and computer interface methods will be applicable to many other courses.

The Teachers

Typically, a course like this would be taught out of a Statistics Department. However, in many schools, departments of Mathematics, Mathematics and Statistics, Applied Mathematics, or even some non-mathematical sciences departments (such as Industrial Engineering, Systems Engineering and Operations Research) could be responsible for this course.

Although the primary deliverers of this course would be statisticians, the course would be also a delight to teach for mathematicians and broader minded engineers. It goes beyond the orthodox beginning statistical offering (same for the, more or less, last 50 years) to some mathematically thrilling territory, while maintaining the fairly introductory level accessible to a broad student audience. Once the textbook and the Mathematica Uncertain Virtual Worlds packages are ready, a new instructor would need no more than a week of work to prepare himself to teach it with some enjoyment.

The Organization

Major topics included in the course are as follows:

I. Descriptive Statistics-Compressing Data: This includes chapters on numerical and graphical presentation of data, statistical functions, analytic representation of discrete data, and introduces concepts of fractals and a random fractals in association with image compression as well as the topic of computer generation of "random sequences"

II. Modeling Uncertainty: Here models arising via simple mathematical recursive relations and exhibiting some kind of random behavior are introduced. Relationships between randomness and algorithmic complexity, so important in computer science and engineering, are studied, pseudo-random numbers and questions of validity of Monte-Carlo methods are discussed. This is followed by the concept of independence and the classical Kolmogorovian probability theory. This part ends with an exposition on basic properties of chaotic dynamical systems and a discussion on how uncertainty appears in the real physical systems.

III. Statistical Inference-Selecting a Model. This part includes the following topics: estimation procedures, least square estimators, fitting curves, confidence intervals, estimating fractal dimension, testing hypotheses, testing the mean, analysis of variance, fitting distributions, experimental design, estimates for random dynamical systems (stochastic processes).

The course, and the textbook, specifically address needs of engineering and science students by a careful and rich selection of examples of statistical problems arising in real-life industrial and scientific lab situations. They will form a constant background for our discussions as we proceed through the material in a spiral-like fashion-starting at each level with real-life examples, followed by simulated computer exploration, and then formulation of formal analytical principles. The examples are being collected from engineering and scientific literature and through direct interaction with practicing engineers and scientists. In particular, we are trying to make large sets of experimental data accessible for students' analysis and for practicing statistical inference.

A series of six student projects is an essential part of the course and contributes heavily to students' grades. Students are encouraged to work on them in small groups of 2-3 people. Except for the last one, all the projects are Mathematica intensive and students are required to turn in the code, explanations, analysis and rich graphics. The Figures above and below present some of the graphics obtained by the students in projects which involved Gaussian approximation in the central limit theorem (Fig.1), analysis of the algorithmic complexity of binary representa-tions (Fig. 2), or simulation of the invariant density for the "tent-type" chaotic mapping of the unit interval (Fig. 3). Sometimes, students' explorations resulted in novel insights into well known problems. Bill Dickinson produced an unorthodox 3-dimensional orbit diagram for the logistic dynamical system which, in addition to the usual representations of bifurcations, also displayed relative frequencies of visits to different states (Fig. 4).

The computer generated projects engendered a lot of enthusiasm and indepen-dent work by the students. The length of many of the reports, submitted in hard copy because of the graphics, was a mixed blessing to the instructor. They easily run into 40-50 pages each.

The last project, required reading of Ruelle's book [2] and writing an essay on a chapter that the student found most stimulating (whether he agreed or disagreed with it). It emphasized good writing skills. Here, students displayed an amazing maturity and sophisti-cation, writing with flair and considerable depths on self-selected topics that ranged from predictably technical, through such as 'Life, Intelligence, Uncertainty", "Determinism and the Orthodox Judaism", "Determinism, Free Will and Choice", to the "True meaning of Sex" and a Platonian dialogue on the question of randomness. We intend to use some of their phrases as vignettes for our textbook chap-ters-why stick to quoting the luminaries-some students' views were quite refreshing.

The Evaluations

The regular university evaluation was conducted at the end of each of the two semesters when the course was taught. It consisted of a multiple choice query and an essay component. The average of the overall rating of the course was very good (on the scale poor, fair, good, very good, excellent) and all the students either strongly agreed or agreed with the statements that "the course stimulates critical thinking", that they "were well motivated", and that " the interaction with the instructor was encouraged".

The essay part of the evaluation generated a wealth of information for the instructor, and helped adjust the second course offering. To the question "What did you like most about the course?" a recurring answers were "Stimulated critical thinking and excitement in an area that can be very rote and boring", "Computer pro-jects were an excellent way to gain understan-ding of more complex topics", and "The lab work was challenging and more satisfying than traditional homework". Everybody liked being evaluated on the basis of a series of major pro-jects rather than routine homework and short quizzes and exams.

To the question "How could the course and/or the instruction be improved?" the typical answers were: "It would be much better if the textbook were ready rather than offered as draft chapters", and that "Some of the project were extremely slow or even impossible to do on computers with modest memory or on the net-work". Students also noted that efforts at run-ning a paperless classroom were not quite successful because of the limitations on gra-phics' transfer. There was also a scatter of opi-nions on relative emphasis of different topics. Computer engineering students, predictably, wanted more algorithmic complexity, and others wanted more design of experiments.

The Timetable

The course design and writing of the accompanying textbook is expected to take two more years to complete. So far, experimental versions of the course were offered at Case in the Spring Semesters of '92 and '93. Further testing is planned in the Spring of '93 in Gottingen, Grenoble and at Indiana University, with final tuning to be done during the 1994/95 academic year at Case and perhaps elsewhere. During the next 18 months, major effort will be spent on collecting good engineering and scientific examples and data bases for the textbook, which is fifty percent ready in a preliminary version. The final manuscript would then be delivered to the publisher in the second half of 1995.

The first bunch of simulation packages was ready by January of 1993 and was used in the Spring of '93 offering. They will have to be redone in view of the experiences gained and some new will have to be written. A consi-deration will be given also to publishing a version of the textbook as fully interactive Mathematica notebooks. We saw clear disadvantages to doing it right away before appearance of the new Mathematica front end.

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References

[1] M.Denker and W.A. Woyczynski, Uncertainty in Engineering and Science: A First Course in Statistics and Complexity of Stochastic and Chaotic Phenomena with MathematicaTM Uncertain Virtual WorldsTM by B. Ycart, to appear, 450pp.

[2] D. Ruelle, Chance and Chaos, Prince-ton University Press, 1991.

[3] I. Ekeland's, Au Hasard: La Chance, La Science, Le Monde,Paris, Le Seuil 1991.

[4] A critique of pure reason, The Economist, July 4, 1992, pp.73-74. Wojbor A. Woyczynski

Implementation of Design and Rapid Prototyping and Dissemination to the Coalition

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Introduction

While current curriculums in engineering design at the top universities give a good coverage of Computer-Aided Design (CAD), there is a need to enhance the students' ability to link CAD with the actual manufacturing processes. Rapid design prototyping facilities involving relatively inexpensive CNC machines and CAD/CAM workstations allow a new mode of education in engineering design. Through laboratory exercises, students can experience the issues related to design for manufacturability, robust designs, and optimum tolerancing. Further, prototyping of dies and molds for net shape manufacturing will train the students in innovative manufacturing processes, the use of advanced materials and their impact on product design. It is the goal of this project to develop a set of courses which will teach the students the fundamentals of concurrent engineering and to develop courseware and protocols which will allow these courses to be disseminated to other universities in the Coalition. In this project, the participating universities are Ohio State, Penn, Cooper Union, and eventually NJIT.

A special feature of the project is to structure the work in such a way that the expertise at several universities can be combined in the course development. Both the courseware in the form of computer-assisted tutorials and parts of the courses themselves will be developed at the universities participating in the project. The intent is to develop a set of courses which can be team taught; however, the members of the team will be physically located at the different universities. Communication will be accomplished through video-based teleconferencing.

The Project Objectives

The current plan is to develop several courses which can be used to teach design and concurrent engineering. The first course is currently under development at Ohio State as a result of an NSF ILI grant ($176,000) which allowed the creation of a Rapid Design Prototyping Laboratory (RDPL) and a curriculum development grant ($120,000) from the GE foundation. This course covers a basic introduction to CAD and CAM, and a companion laboratory gives hands-on experience through both CAD and CAM exercises. The hands-on experiences emphasize the practical aspects of machining that are difficult to simulate and effectively teach the underlying issues associated with design for manufacturability. Such issues include part fixturing, machining sequence, tool selection, optimum tolerancing, and general guidelines for design for machining.

The second and subsequent courses that are proposed as part of this project will provide the depth for what will, in effect, be a combination of mechanical engineering design and manufacturing engineering. The first course concentrates on the introduction to concurrent or simultaneous engineering while the second course will concentrate on design for manufacturability, design verification and visualization, robust design, design of experiments, etc. In addition to the computer workstations, the students will have access to both table-top and production machines at the participating universities. The machines include CNC milling machines, CNC lathes, injection molding machines, a coordinate measuring machine (CMM), and both wire and plunge Electron-Discharge Machines (EDM). This will provide all of the machines necessary to facilitate the engineering enterprise from design through manufacturing. Initially, the laboratory exercises may be taught as an integral part of the courses. However, as the courses mature, it is expected that the laboratory part will be separated into one or more stand alone courses. The final result expected is four courses on concurrent engineering. This will include two lecture courses and two laboratory courses. The second laboratory course will also emphasize the differences among desktop, laboratory scale, and full-scale industrial-quality machine tools. Part of this course will be taught using some of industrial quality machines in the NSF Engineering Research Center for Net Shape Manufacturing (ERC/NSF) at Ohio State as well as machines located at the other participating universities.

Each of the courses proposed will use CAD, CAM, and manufacturing simulation software in addition to CNC milling machines, CNC lathes, injection molding machines, coordinate measuring machines, and EDM machines. The courses will be packaged so that all or part of them can be used at other participating members of the Coalition, and the packaging will be done in such a way that each university need not have all of the equipment available locally. Also, extensive tutorials using AuthorWare will be developed to aid in the instruction and to reduce the number of trained personnel required to support the instruction.

The Current Status

RDPL Facility

The courses developed will be modifications and extensions of two concurrent engineering courses being taught at Ohio State. These courses rely heavily on the Rapid Design Prototyping Laboratory (RDPL) in Mechanical Engineering. This laboratory was established with the aid of an NSF ILI grant, a GE-Foundation curriculum grant, and the help of students supported by the ERC/NSM. The manufacturing aspects of the facility are based on CNC milling machines and lathes and an injection molding machine. The general objective of the laboratory is a very user-friendly CAD/CAM environment that will permit students to develop the geometric definition of a part using the computer-aided geometry software, have the part definition translated into an NC format using CAM software, and then machine the part in a relatively short time (one 2-hour lab period). The main hardware consists of five table-top CNC milling machines (DynaMyte[1] 2400 and 2800), five CNC Lathes (EMCO[2] Compact 5), and an injection molding machine (Morgan Press[3]), and these are currently attached to Macintosh IIfx workstations. The software used in the laboratory are MacBravo! (CAD) and Gibbs ncCAM (CAM). A schematic drawing of the laboratory is shown in Fig. 1.

Several courses use the facility on a limited basis; however, the main course using it is ME 683 which is a laboratory course taught in conjunction with a separate lecture course (ME 682) on introductory CAD/CAM. In ME 683, students are introduced to the concepts involved in the use of integrated CAD/CAM hardware to design and machine a component. They are given hands-on experience at engineering workstations and table-top CNC machines in the RDPL, and after taking the course, the students know how to design parts so that they can be machined easily on a CNC milling machine or a CNC lathe. In addition, they are made sufficiently familiar with CAD/CAM hardware and software that they should be able to design and machine a relatively complex part within a short amount of time. ME 682 and 683 are the initial courses which will be modified and disseminated as part of the Gateway project.

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[1]Dyna Mechtronics, Inc., 926 W. Maude Ave, Sunnyvale, CA 94086
[2]EMCO Maier & Company, Austria
[3]Morgan Industries, Inc., 3311 E. 59th Street, Long Beach, CA 90805

The laboratory exercises and projects in ME 683 have been carefully made up to guide the students in the learning process in a sequential manner. The laboratory meets for two hours per week, and assignments are arranged as shown in Table 1. The first two assignments are done on the CNC milling machines. In these two assignments the students become acquainted with the machines, the command structures and various features of the machines.

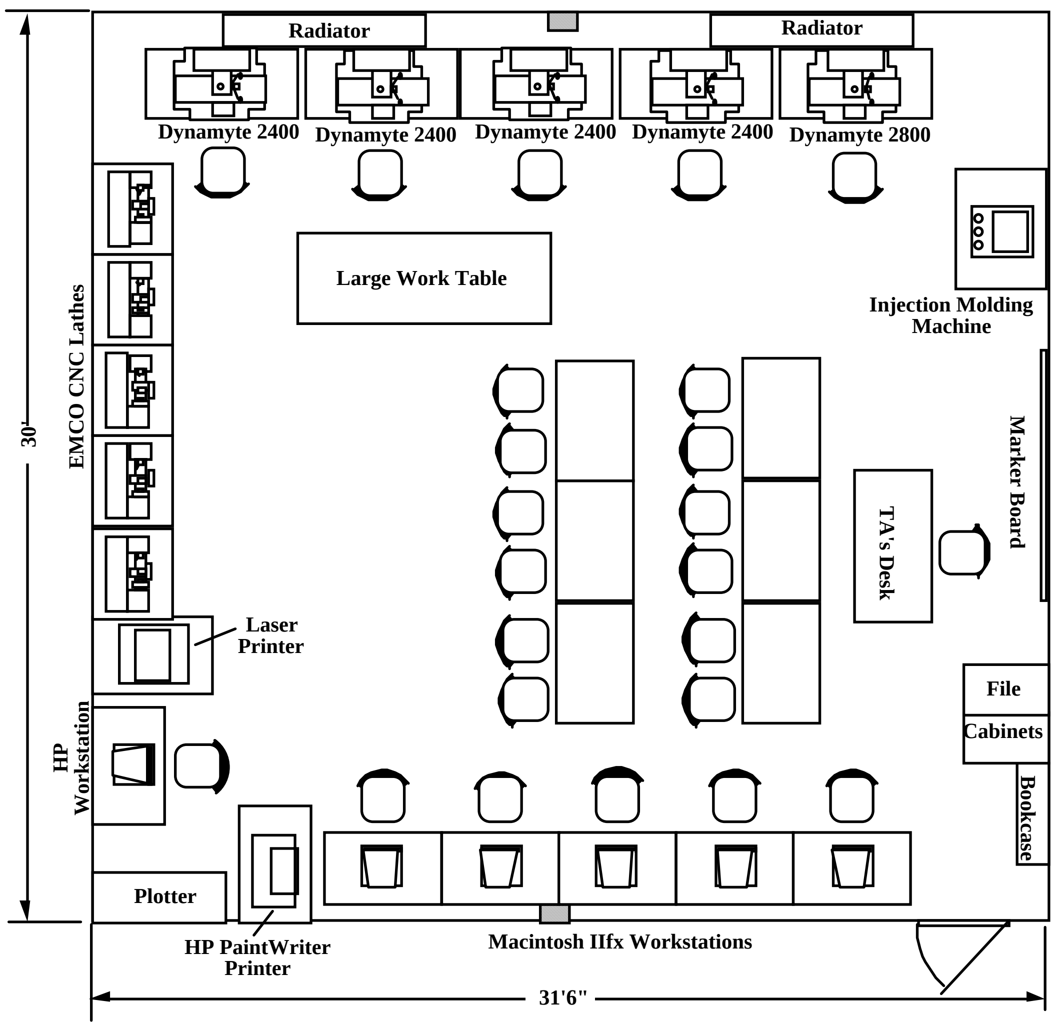

Fig. 1: Current Layout of the CAD/CAM Laboratory

In the subsequent assignments, the students use the computer to design the parts, and NC files are then transferred to the machines. The students have to determine how to fit the parts on the starting stock, the feeds and speeds and depth of cuts for machining, and the ways to fixture the part during machining. The fixturing of the part is an important issue, and the students are made aware of the problems associated with it.

A project is assigned at the end of the course to integrate the concepts presented. The scope of the project varies, but in all cases, simultaneous engineering issues are emphasized.

Tutorials

To teach the laboratory, a highly trained staff is required, and a large amount of instructional time is required to show the students how to use the machines and software. Also, some of the students will take the course with little or no previous experience in machining, and this adds to the instructional burden. There is therefore a need to improve the means of training the staff and the students who are novices in a machining environment.

To facilitate the instruction of both staff and students, a set of Macintosh-based tutorials have been written using Authorware to explain the most complex aspects of the laboratory. These can be used by instructors during the training period and by the students as part of the laboratory classes. The tutorials were tested last year (Winter and Spring quarters, 1993), and the introduction of the tutorials was a great success. In written comments, most of the students

Table 1: Topics Covered in ME 683

Topic	Weeks
Introduction to DynaMyte CNC machines & programming for 2-D tool paths	1
Programming for 2-D & 3-D tool paths, machine simple part in wax	1
Introduction to CNC Lathes	1
Introduction to Gibbs ncCAD system, design simple part	1
Use of Gibbs ncCAD, ncCAM and ncPOST to machine simple part	1
Combine CAD, CAM, and CNC to design and machine complex part	2
Use of MacBravo! Detailer & Modeler	1
Final project	2

have indicated that the tutorials have helped greatly when they were learning how to run the machines and software. Eventually, the tutorials will permit a larger number of students to enroll in the laboratory course than would be possible otherwise. Because the tutorials can run independently of the machine tools, the students can practice using the interactive tutorials and be more efficient when using the machine tools. Efforts have been made to simulate actual working conditions wherever feasible and to provide comprehensive working procedures. This helps reduce the time required to learn on the machines themselves and also encourages better utilization of the facilities. The tutorials are user-friendly and graphics-oriented and provide an interactive environment and multimedia interaction with the student. Hence, a strong emphasis is placed on communication aspects such as visualization, graphics, animation, sound, and video with an effective blend of interaction during the development process.

During the course of the project, five tutorials have been developed. These include tutorials on:

1. Dyna-Myte DM2400 Basic Operations
2. CNC Lathe
3. Gibbs ncCAD
4. Gibbs ncCAM
5. Injection Molding.

A brief overview of each tutorial is given below.

CNC Milling

The DynaMyte tutorial is designed to familiarize the user with the DM-2400 and DM-2800 manual and programmable operations, as well as associated workpiece referencing, tool recalibration, and fixturing plans for the machining of a part. The tutorial includes sections on basic operations, set up, tool recalibration, and fixturing.

CNC Lathe

This tutorial introduces students to the different modes of operation of the EMCO Compact 5 CNC lathe. The tutorial includes sections on hand-operation, CNC-operation, tape-operation, and tool changing and tool alignment, presenting a detailed, illustrative approach to familiarize students with the working of a CNC lathe and related issues in the turning of axisymmetric parts.

CAD/CAM Software

Gibbs[4] ncCAD and ncCAM are CAD/CAM software packages used to define the part geometry and generate tool paths for machining on the DynaMyte milling machine.

a. ncCAD

This tutorial has been developed to assist the user in becoming acquainted with the ncCAD part of the Gibbs program. A step-by-step procedure guides the user through the steps that are necessary for defining the geometry for a sample part. The ncCAD and ncCAM tutorials are used sequentially, in the sense that the geometry developed in the CAD part is used in the CAM part to define the tool paths.

b. ncCAM

This tutorial has been developed to assist the user in becoming acquainted with the ncCAM part. A similar step-by-step procedure leads the user through the sequence of steps that would be necessary for generating the machining information for the part defined using ncCAD.

Injection Molding

This tutorial is intended to assist the user during various stages of the injection molding process. The section on mold design introduces basic mold design concepts and presents some guidelines from practical considerations. The material selection section gives a description of the characteristic properties of some commonly used glass-reinforced thermoplastic resins and presents a procedure to assist the user in the process of selecting the right material for a particular application. The component parts of the Morgan-Press G-100T injection molding machine are illustrated and their functional characteristics explained.

The Current Plan

The current laboratory and courses will be expanded under the Gateway project through the participation of universities other than Ohio State. The intent is to use the RDPL as a base from which to perform manufacturing operations, but to add design, design analysis, and solid visualization to round out the teaching program.

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[4]Gibbs & Associates, 9320 Deering Ave, Chatsworth, CA 91311

The revised goals of the concurrent engineering project for the first year are four fold.

1. Establish real-time communications via teleconferencing among the four schools.
2. Establish a concurrent design environment in which teams of students at each of the participating universities have distinct responsibilities.
3. Develop preliminary concurrent-engineering courseware which can be shared among the four schools and which can be sent to others not in the Gateway Coalition.
4. Verify the environment established with an example project which will include concrete contributions from the four schools.

Goal 3 will expand the scope of the current courses offered at Ohio State, and will make the courses available in a form which can be disseminated to each of the schools. The preliminary responsibilities of the four schools will be as follows:

Ohio State: Establish the structure and protocols by which simple parts can be evaluated for manufacturing or actually manufactured given product files which are electronically transferred from the other schools.

Penn: Establish the protocols for teleconferencing and data transfer. Also, develop the design procedures which can be used as test cases for the project.

Cooper Union: Develop protocols, courseware, and tutorials for design analysis and manufacturing analysis. This will involve a finite element program (probably ANSYS) for functional/structural analysis and an injection molding program (probably C-Flow).

NJIT: Develop protocols and file structures required for product visualization through stereolithography.

During the autumn term of 1993, the bugs will be worked out of the communication systems. To make the system work as intended, it must be possible to transfer design files from any one of the four schools to any of the others easily. The communications concept is shown schematically in Fig. 2. To facilitate remote team teaching, teleconferencing from the

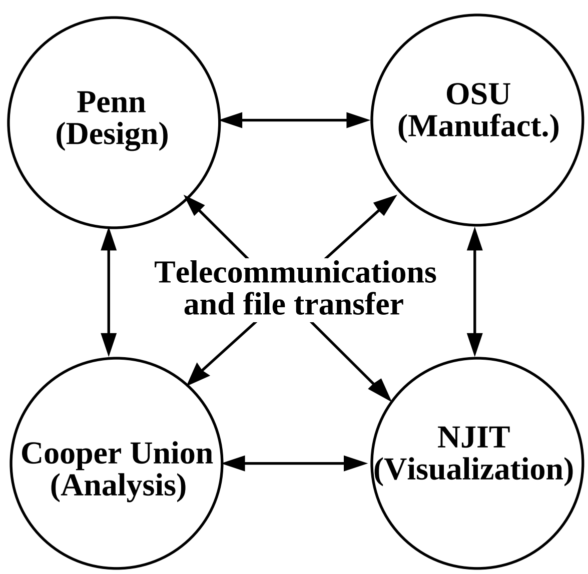


Fig. 2: Communication Network for Four Schools

laboratories where the work is done is a necessity. This will include the computer labs at Penn and Cooper Union, the stereolithography lab at NJIT, and the manufacturing lab at OSU. Basically, the idea is that the students can communicate as the work is being done so that questions can be asked at the time of the real-time explanations. This will have tremendous educational benefits to the participants since they can "share" equipment to which they would otherwise not have access. There are some obvious scheduling challenges, but these will be worked out during the course of the project.

By January, 1994, each school will select a team of two or more undergraduate students who will agree to participate in the project.. Currently, this will include a design team at Penn, an analysis team at Cooper Union, a visualization team at NJIT, and a manufacturing team at OSU. A typical scenario would be for the team at Penn to develop the initial design and to send the design file to NJIT for visualization, to Cooper Union for a preliminary analysis, and to Ohio State for a preliminary manufacturing evaluation. After these preliminary evaluations, the students will discuss the design via a teleconference. The design would then be modified at Penn, and the evaluation process would be repeated. After a second teleconference, the design would be finalize and checked visually using the stereo lithography at NJIT. The final analysis would be done at Cooper Union along with the final mold design (if appropriate). The part or mold would then be machined and finished at Ohio State. If applicable, molded parts would be made at Ohio State and sent to the other universities via express mail.

To help in teaching the course(s) and to make them easily transferable to other schools, a number of new tutorials will be written in addition to enhancing those already available through Ohio State. The new tutorials will address the following areas:

1. Data Formats and Data Transfer. The formats will include but not necessarily be limited to IGES, DXF, Machine Code, FTP, those associated with E-Mail.

2. Finite-Element analysis. This will probably involve ANSYS and will address basic finite elements applied to the types of components likely to be involved in the design exercises.

3. Mold Design. Many of the product examples will involve injection molding, and this tutorial will address mold flow simulations to facilitate mold design.

4. Process Planning. This tutorial will address process planning on a high (generic) level. The current plan is to do this on a case-study basis where the cases will correspond to the types of parts which will be addressed in the project.

5. Coordinate Measuring Machines. Metrology is an important part of concurrent engineering, and this tutorial will cover basic concepts in measurement as well as the specific operation of the CMM machines available at Ohio State.

6. Teleconferencing. The idea in this module will be to introduce the concepts of teleconferencing so that little time will be spent in setting up the equipment and preparing for the sessions. This module should be very useful for universities who are trying to cooperate with each other.

An effort will also be made to generate meaningful design problems which can be approached in the context of a concurrent engineering course. These will be useful for both the participating universities and for others not initially participating in the Consortium.

Summary and Conclusions

We believe that this project will open up new avenues in cooperative teaching in general and concurrent engineering in particular. The results of this project should make it possible for other schools to set up cooperative arrangements for team-teaching concurrent engineering and by extension, other topics. It should also provide a means through which universities can genuinely share equipment and expertise.

Acknowledgments

Although the lead university on this project is Ohio State, it is truly a cooperative effort The other participating faculty are Vijay Kumar at Penn, Stan Wei at Cooper Union, and Golgen Bengu at NJIT.

Rapid Prototyping with Stereolithography - The SLA Center at NJIT

Geraldine B. Milano, New Jersey Institute of Technology

The SLA Center at New Jersey Institute of Technology will provide participants of the Gateway Engineering Education Coalition with the use of a Stereolithography Apparatus (SLA). The SLA is part of a Rapid Prototyping Laboratory in the Center for Manufacturing Systems at NJIT. This collaborative initiative will permit Gateway participants to transfer three dimensional solid model CAD files electronically to NJIT's Freshmen Design Laboratory consisting of networked Sun workstations where they will be exported to the SLA for processing.

Stereolithography is a process of creating three dimensional, solid, plastic prototypes from CAD generated data in a matter of hours. The SLA consists of a 10" x 10" x 10" vat containing 7.7 gallons of liquid photo-curable resin, a helium cadmium 15mW laser, a 486 slice computer and a 286 build computer.

Functional Information

CAD/CAM/CAE data files which can interface with the SLA are received at the slice computer which is a 486 UNIX operating system with an ethernet interface board. Solid or surface data is "sliced" into horizontal cross sections of 0.003 inch to 0.015 inch in layer thickness. Thinner layers provide more accuracy in the geometry of the part, while thicker layers add strength to the part. The sliced file is then processed at a build computer which controls the laser beam and elevator motion. Control parameters such as laser intensity, elevator speed, recoating speed, and layer thickness are specified.

The actual building is accomplished by the computer-controlled optical scanning system. This scanning system controls a HeCd laser which generates a small intense ultraviolet beam of 10 to 20 milliwatts moving across the top layer of liquid resin. The laser beam solidifies the liquid polymer as it scans each sliced cross section. An elevator system lowers the first formed layer into the resin while recoating the surface and leveling the system to establish the next cross section layer thickness. The process repeats this sequence as successive cross sections are formed layer upon layer, forming the finished part.

When the build process is complete, the part remains submerged in the vat until the elevator is raised. The partially cured prototype is removed from the elevator platform and placed in a curing oven with high intensity UV lights to complete the polymerization process. This is the post processing phase. The finished solid can then be sanded, painted, or dyed.

SLA Center Purpose

Stereolithography provides conceptual models from design ideas created in a solid modelling CAD system. Turn around time is within days, thus facilitating design optimization. Students can provide an .STL file in IGES (Initial Graphics Exchange Specification) format to interface with the SLA. These CAD files can be generated on any solid modelling software package that has the ability to interface with numerically controlled or rapid-prototyping equipment, in particular, the SLA. Preferred solid modelling software packages include Pro/ENGINEER, I-

DEAS, ALIAS, Catia, and Unigraphics. AutoCAD Rel.12 also has an interface module that will permit the export of an .STL file.

The CAD files can be transmitted via ftp (file transfer protocol) to the NJIT facilities, downloaded onto the NJIT server, and delivered to the SLA for prototyping. This can provide physical, real-life models for the students to analyze for dimensional quality, assembly fits and manufacturing feasibility.

The SLA Center provides an expensive laboratory resource for collaborative efforts among Gateway participants to share this state-of-the-art technology. Students and faculty from several engineering educational universities can work toward shared projects whereby components of a product can be designed by diverse groups of students from the different universities, transmitted to the NJIT SLA Center, and returned to their respective student groups for evaluation. This type of project effort can demonstrate multi-university collaboration.

Instructional Information

NJIT will be providing an instructional manual, User's Guide for Stereolithography Apparatus at New Jersey Institute of Technology, which will offer assistance in creating the model, sending and receiving files, and answers to some common questions. The appendix contains two example sessions demonstrating the creation of a part and support structure done in SDRC's I-DEAS software and again in Pro/ENGINEER software. Instructions on setting up the .STL file are explicitly outlined in these example sessions.

Proposed for release in the spring of 1994, NJIT will also be providing a tutorial diskette displaying the SLA and its slice and build computers. Slice and build parameters will be demonstrated while permitting the user to set certain of these parameters for the SLA process. Once set, the software will display the building of the part layer by layer on the screen just as the process will execute these parameters in the SLA. Further information on this program will be made available to the Gateway participants upon completion of the program.

Rapid Prototyping and Concurrent Engineering

Prepared by
Chih-Shing Wei, The Cooper Union

Introduction

The Mechanical Engineering Department is active in the integration of computer-aided engineering tools into its undergraduate curriculum. Since 1983, the Department has introduced a number of courses in the general area of computer-aided engineering (CAE). These are Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM, ME 453); Computer Vision and Robotics (ME 458); Computer-Integrated Manufacturing (ME 464); Engineering Kinematics (ME 321); Production Automation (ME 311); Manufacturing Engineering (ME 312); Mechanical Engineering Projects (ME 163); and the Senior Capstone Design Project (ME 164). The last three courses are mandatory for mechanical engineering students.

The major support for these CAE courses is provided by the Cooper Union CAE Laboratory. The CAE Laboratory houses an IBM RS/6000 workstation based CAE system (consisting of the software packages ADAMS, ANSYS, FLUENT, PROCAST, PRO/ENGINEER, and Q-MESH), two HP/Apollo graphics workstations, a Sun Sparc-2 workstation, a Bridgeport Interact 412 CNC milling machine, a PUMA UNIVAL 762 Industrial Robot, a table-top manufacturing cell consisting of a 3-axis NC milling machine and a 5-axis robot with vision input, and several personal computer stations.

With the industrial scale design and manufacturing equipment the CAE Laboratory currently supports, the mechanical engineering students are able to learn firsthand the application of the first principles of manufacturing engineering in a practical design and manufacturing environment. However, the urgent task of demonstrating the important role of rapid machine parts prototyping [1-3] in the globally competitive, computer-based manufacturing discipline is yet to be fulfilled, mainly because of the relatively small number of high-precision manufacturing workstations available to the Mechanical Engineering Department.

A focus of the current departmental curriculum development activities is to integrate leading edge rapid prototyping technologies into these manufacturing specific courses, by forging alliance with other universities willing to share expertise and resources in this field.

The Project

The current goal of this cooperative project is to combine the expertise at the participating universities (Ohio State, Penn, Cooper Union, and eventually NJIT) to develop a three-component course module which can be used to teach rapid prototyping and concurrent engineering.

The main objective of the Cooper Union portion of this cooperative project is to design and implement a senior-level course submodule (the simulation/analysis submodule) which will enable the students of mechanical, industrial, and manufacturing engineering to experience, hands-on, the engineering advantages of the practice of concurrent or simultaneous engineering, based on the analysis of the manufacturing process for a number of simple mechanical systems consisting of parts that can be manufactured with a moderate-capacity plastics injection molding machine. The design and structural analysis of the systems will be performed at Penn (the design submodule), while the physical production of the systems will be performed at Ohio State (the manufacturing submodule). These three submodules will be integrated into a self-contained course module. This course module will be structured such that it can readily be incorporated into a senior-level CAD/CAM course by a typical engineering college at a reasonable cost.

The Cooper Union submodule will address issues relating to the classroom use of commercially available software tools for analyzing design and manufacturing criteria of the injection molding process. Use of such commercial software packages typically requires lengthy on-line user training sessions which can not be practically provided in a senior-level design and manufacturing course. The course submodule will take the form of an off-line computer-aided tutorial with which the students can learn the basics of operating the designated software tools, to a level that the accompanying case studies can be carried out without straining the instructor's time. The software packages PROCAST and Q-MESH will be utilized for the proposed injection molding process analysis.

The Development Plan

An organizational meeting between the participating universities was held in Columbus, Ohio, on September 24, 1993. The team decided to adopt a common multimedia-flavored authoring software, possibly Macromedia's Authorware, for use in developing the course submodules, to facilitate the editing and compiling of developed materials. It has also been decided that use of certain teleconferencing facility to provide an interactive link to connect the team schools' students be explored. Further thoughts are needed for the collection and analysis of evaluation criteria and data.

Concluding Remarks

The participating faculty from the team universities share the belief that this project will open up new avenues in cooperative teaching in the field of concurrent engineering. This project may also serve as a case study on how universities can share equipment and expertise in a cooperative teaching environment.

The author acknowledges the assistance provided by the participating faculty: Gary Kinzel and Kos Ishii of Ohio State, Vijay Kumar of Penn, and Golgen Bengu of NJIT.

Bibliography

1. Ashley, S., "Rapid Mold-Making for Investment Casting," Mechanical Engineering, pp. 49-51, November 1992.

2. Cromwell, W.E., "Prototype Casting Fabrication by Stereolithography," Second International Conference on Rapid Prototyping, University of Dayton, Dayton, Ohio, Conference Proceedings, June 23-26, 1991, pp. 143-148.

3. Jacobs, P.F., Rapid Prototyping & Manufacturing: Fundamentals of Stereolithography, Society of Manufacturing Engineers, 1991.

An Innovative Inroduction to Engineering Biotechnology: Genes to Biopharmaceuticals

Prepared by:
Raj Mutharasan, Wayne Magee, Margaret Wheatley and Young Lee
Drexel University

Goal

The primary goal of this project is to develop a set of lecture and laboratory courses that introduce underlying biological and engineering principles in developing and manufacturing biopharmaceuticals. A total of two lecture courses and one laboratory course are expected to be developed. In the first year, the focus of effort is on the first lecture course.

Course Audience

The proposed course is expected to be one of the cross-disciplinary electives offered to all engineering pre-juniors and juniors in the Drexel Curriculum.

Rationale & Approach

With the advent of significant fundamental advances in biosciences, increasing number of products, particularly pharmaceuticals, are manufactured using biological agents. New applications of genetic engineering in other industrial segments are reported at a seemingly increasing rate. Consequently, a larger fraction of engineers of tomorrow would need to be familiar with fundamental precepts of applications of biosciences, genetic engineering. The central idea of the proposed course is to treat in a single course all significant scientific and engineering issues that encompass converting genes, the starting material, to final product that is manufactured for the market place. In our view, it is important to tell the whole story in a single course in sufficient depth so that the relevancy and significance of the emerging area of biotechnology can be communicated.

Traditionally the concepts covered in the proposed course would be developed over many, courses in biochemistry, cell biology or cell physiology, genetic engineering, biotransport phenomena, bioprocess engineering and unit operations. Although the proposed course will not cover the same material, it is expected to equip an engineer with important tools needed to pursue a career in biomedical or biochemical engineering. The content will build upon the biological and engineering principles covered in the E4 core courses. Because the material will be organized on a relevancy-basis and because the style of instruction will be 'lateral' rather than 'pyramidal,' the student is expected to be better equipped for problem solving and design.

Rationale of Course Content & Instructional Methodology

In order to provide a common application theme (or thread) through all the course topics,the group chose insulin. Insulin was the first product of genetic engineering in the market place and a fair amount of literature on its manufacture is in the open literature. A detailed course outline is given in Table 1. The course is organized into four segments: insulin genetic engineering, manufacture of insulin in bioreactors, delivery of insulin in the human body and biosensors and monitoring devices for biopharmaceuticals. The course will be team taught by four instructors whose teaching and research training correspond to the four topic areas to be taught. In the first edition of the course, all four instructors will be present in the lecture room. The three audience-instructors will carefully interact with lecture-instructor so that appropriate expertise for the question at hand is brought to the fore. Additionally, they will assist with comments and suggestions to improve learning in the class room. This approach is expected to integrate the expertise of instructor(s) and enhance student learning.

Course Content

A number of important aspects of biopharmaceutical drug development and manufacturing processes will be studied, including the gene cloning, biological efficacy, pharmacokinetics of and physiological response, molecular biology of industrial organisms, bioreactor operation, cultivation strategies, bioreactor monitoring, GMP/FDA requirements, drug purification and drug delivery and biosensors. A detailed course outline of Winter 1993-94 edition of the proposed course is given in Table 1. This edition of the course is being offered to seniors as an elective, as no course slot is available in the present curriculum at pre-junior or junior levels at Drexel. A slightly enlarged version of this course will be offered at the pre-junior level in 1996/97 when students of the new Drexel Curriculum will be seeking cross-disciplinary electives.

The initial lecture will be devoted to giving a 50 minute overview of the entire course by all four instructors. Starting with the need for insulin, its structure and pharmacokinetics in the human body and treatment schedule will be outlined. Questions of how such drug molecules can be produced will be raised. How insulin was used prior to 1983 will be narrated. Productivity of natural cell lines will be discussed. The poor economics of processes employing natural cell lines will be outlined and design concepts of ‘biological efficiency’ of cell and process productivity will be introduced. This will set the stage to describe in detail genetic engineering aspects in both general and specific terms leading to process configurations. Lectures will be used to illustrate such concepts as principles of genetic engineering, cloning systems, ‘material and energy balance on cell systems,’ cell culture process systems for bacteria, fungi, animal, insect and plant cells.

The course will be organized into four main modules [6 to 8 instructional hours each]. Each module will include written outlines of lectures, questions, discussion points, illustrative problems, homework problems and suggested further reading. Background concepts needed to learn a module and the new concepts illustrated in a module will be included. The main modules will be organized as several logically cohesive sub-modules, each covering approximately one to two hours of instructions. It is expected that each module will deal with a specific process or product while sub-modules within it will illustrate one or several molecular biology and/or processing concepts. The sub-modules will be organized as much as possible in a lateral order rather than in a sequential organization. A suggested order of selecting the modules (or sub-modules) in increasing order of detail will also be prepared.

Pedagogy.

Engineers of the future will need an understanding of biological systems and their application in design, production processes, environmental systems, agriculture and others. The proposed course, although focused on biopharmaceuticals, includes engineering science principles that are applicable to many of the areas listed. Consequently, the proposed course will be a good broadening elective for all engineers and at the same time will serve as a core elective for students interested in a career in biotechnology and biomedical engineering.

Current Collaboration:

The topic, “Dynamics of insulin and glucose in circulatory system,” is part of compartment modeling module currently being developed by Professor Reid (A Gateway PI, Biomedical engineering, Drexel) and growth kinetics experiments are being developed as part of Physiology Laboratory Modules by Professors Litt and Bogen (Gateway PIs, University of Pennsylvania). In addition, the lecture modules being developed are expected to be used in BE 100, BE 223, BE 210 and possibly in BE 324 and 309. These courses are currently offered by the department of bioengineering at University of Pennsylvania.

Future Collaborations & Developments:

In the coming year, we expect to interact and develop ties with Case Western Reserve University, which has expressed very strong interest in the bioengineering effort. Collaborations are sought from those who would develop modules compatible with the goals of the program, especially related to the use of genetic engineering applications in separation technology, agriculture, environment and others.

Project Schedule

This project was started in Spring AY 92/93. The first edition of this course will be offered in Winter 93/94 as an elective to senior students as a 3 credit course. Outline and selection of material are currently under development. During Summer AY 93/94, initial documentation of the course modules will be completed.

Evaluation Methodology

We are planning to use course evaluation forms that are currently used in the department, and personal interviews of representative students to obtain information on effectiveness of the proposed course and its methodology. We will seek assistance and guidance so that the methodology that will be used this winter will be the same as that used in other Gateway courses.

Deliverables

First Year: 7/1/93 - 8/31/94

- Outlines of the main four modules will be written during 8/93 - 3/94.
- A 3-credit course will be offered in Winter term, AY 93/94
- Student reviews and instructor experiences will be documented.

Second Year: 9/1/94- 8/31/95

- Approximately additional 8 modules will be developed during summer 94/95
- A second 3-credit course will be offered in Spring AY 94/95
- Documentation of the modules of first course will be completed by 9/94
- Workshop/seminar for Gateway schools, 9/94 will be given.
- A multimedia presentation of instructional and supplementary materials will be prepared.
- Student reviews and instructor experiences will be summarized.
- Preparation of a paper for presenation at ASEE conference.

Third Year: 9/1/95- 8/31/96

- Two courses in a sequence, Winter and Spring terms will be taught.
- The second course modules will be documented.
- A paper for presenation at ASEE conference will be prepared.

- Multimedia developments for the remaining modules will be prepared.
- Student reviews and instructor experiences will be documented.

Accomplishments

Detailed outline of several lecture modules (see Table 1) has already been developed. Collection of teaching aids and problem set are under preparation.

Table 1 Course Outline of Engineering Biotechnology to be offered in Winter Quarter, 1993/94

Engineering Biotechnology

3-0-3 Winter 93/94

Instructors:

Raj Mutharasan, Chemical Engineering Dept., 27A-281, X2236
Wayne Magee, Biosciences & Biotechnology, 5-105, X6906
Maggie Wheatley, Chemical Engineering, 27A-478, X2232
Young Lee, Chemical Engineering, 27A-277, X2230

Instructional Objectives To introduce underlying biological and engineering principles needed to develop new biopharmaceuticals based on their properties, structure and processes for manufacture. Specifically, the course will be structured to illustrate concepts in genetic engineering of insulin, production and purification of insulin, insulin delivery to human system and glucose sensing.

Organization of Topics and Lectures Meets Tu for one hour and two hours on Th. The first session [labeled as 1] refers to the Tu meeting.

Week of	Instructor	Topic	Assignment
Jan 10	ALL WEM	1. Introduction 2. Insulin and Physiology	Reading on insulin
Jan 17	WEM WEM	1. Cloning 2. Identifying insulin gene & DNA amplification	Reading on cloning
Jan 24	WEM WEM, RM	1. Gene transfer , expression and regulation 2. Stoichiometry and thermodynamics of growth	“gene” calculations
Jan 31	RM RM	1. Design of High cell density reactors 2. Cell separation & disruption. Insulin Recovery	Reactor problem set
Feb 7	ALL RM	1. **[Mid Term 1]** 2. Good Manufacturing Practice & FDA Regulations	Separation problem set
Feb 14	MAW MAW	1. Protein properties relevant to drug delivery 2. Pharmaco kinetics and dynamics: Insulin & others	Manuf. problem set
Feb 21	MAW MAW	1.Insulin delivery requirements - strategies 2. Controlled release mechanisms & methodology	Kinetics problem set
Feb 28	ALL YHL	1. **[Mid term 2]** 2. Glucose sensing: application in insulin delivery	Diffusion/Kinetics set
March 7	YHL YHL	1. Detection methodology for in vitro applications 2. Use of biomolecules for sensing	Electrode problem set
March 14	YHL YHL, ALL	1. Design of biosensors for in vivo applications 2. Design of biosensors for in vitro applications Course Evaluation and student interviews	biosensor calibration & dynamics
March 21		**Finals Week**	

Recommended Text: There is no recommended text for this course. Copies of lecture notes will be provided during the course. Copies of recommended reading material will also be distributed.

Bioengineering Laboratory Module Development

Mitchell Litt, University of Pennsylvania

This development is part of a project to prepare two types of bioengineering teaching modules : multimedia instruction modules in rehabilitation engineering and laboratory/instructional modules. The latter are the subject of this report. These modules are intended to be used in two ways:

1. Units that can be incorporated in traditional courses in mechanical, systems, electrical, or chemical engineering at schools which do not have a program in bioengineering, and wish to teach traditional engineering concepts using biomedical applications.

2. Units that can be combined in various ways to become the basis of a course applying different engineering concepts to biomedical applications.

These modules will be available at several levels suitable for either introductory or advanced courses. They will be entirely self-contained- all necessary background and instructional materials will be included, both for classroom and laboratory use. Such components include:

- Software for analysis, simulation and data reduction;
- Background literature, with both engineering and biological references;
- Homework Problems and solutions;
- Outline of lecture material for the instructor;
- Sample quizzes;
- Complete information on laboratory equipment, procedure, parts list, drawings for special apparatus;
- Videotaped laboratory instructions and demonstrations;
- Complete databases for software, calculations, homework, and related work.

Year 1- Results

The first project year was devoted to establishing and evaluating the list of modules to be developed, and to organizing the information nedded in terms of a general data base for biological applications of engineering. Greatest consideration was given to topics that are of direct interest in bioengineering curricula, but have a major component of interest to other fields. The modules initially selected for development , at various levels, are:

1. Pulmonary function measurements for freshmen: A fluid mechanics lab project organized around air flow in the respiratory system using self-made equipment.

2. Non-invasive cardiovascular measure- ments - blood pressure, pulse, EKG, etc. with emphasis on data acquisition and signal analysis of low frequency signals.

3. Nerve action potentials, using mechanical stimulation and recording and amplification of electrical output.

4. Thermochemistry, involving deter-mination of heats of combustion of biologically important organic sub-stances.

5. Acid-Base chemistry, involving titration of amino acids and biopolyelectrolytes, and design and programming of a computer controlled automatic titrimeter.

6. Biochemical kinetics, involving determining the growth kinetics of a single-celled organism and system analysis of the bioreactor.

7. Chemical Analysis using UV-VIS and atomic absorption spectrophotometry, involving principles of interaction of radiation with matter and application to analysis.

Since the intention is to design the module around the laboratory experience, and in some cases to have the laboratory serve as the only or major instructional medium for teaching the material, the first year was devoted mainly to developing and testing suitable lab projects and equipment, and evaluating them by incorporation into an existing sophomore level laboratory course that covers topics in biophysical chemistry, biosystems, and biomathematics. The projects tested were initial versions of items 3-7 above. Specifically tested were:

- Analysis of the action potential in a cockroach leg mechanically stimulated by a vibrating needle;

- Determination of heat of combustion of sucrose using a relatively inexpensive commercial bomb calorimeter system;

- Analysis of cations using an atomic absorption spectrophotometer, and determining the visible spectrum of hemoglobin;

- Acid-base behavior of different amino acids, and titration of a protein; Growth kinetics and yields of Baker's yeast on a sugar substrate.

Two of these projects were adaptations of previously available laboratory setups, the remainder were new. In addition to carrying out lab procedures and analysis, background work and problem solving, and preparation of data analysis routines were included. Valuable experience that will be needed in organizing and preparing the detailed modular materials was obtained.

Work for Current Year (2)

The cell growth project has been selected to be the first detailed module to be developed. Extensive development work is now underway to select the optimal cell system suitable for undergraduate laboratory experience. The goals of this module will be:

a. Teach the basics of chemical kinetics as applied to organisms;

b. Methods for measuring cell growth;

c. Determine, for the selected organism, dependence of growth kinetics parameters on such variables as temperature, pH, pO_2, stirring speed, at steady state;

d. Develop a computer simulation of the reactor, incorporating not only the chemical kinetics but mixing phenomena and their effects on heat and mass transfer, and control theory as applied to batch and continuous reactor operation.

e. Design of a control system to operate the reactor in continuous rather than batch mode;

f. Study of the system response to a step change in one of the operating parameters.

By June 94 we expect to deliver aspects of the module at least through item d above including not only the laboratory part but the background and instructional materials listed earlier. The module will be tested in the lab course during the Spring 94 semester. Evaluation will be carried out by questionaires and exit interviews of the individual laboratory student groups and lab assistants. Aspects of both the specific module and evaluation relative to traditional methods of covering this material will be included in the analysis.

In addition, during year 2 the other laboratory projects, intended for modular development in future years, will be retested, with suitable modifications based on our earlier experience.

Collaborative Aspects of Project

This project is ongoing in collaboration with workers at Drexel University and Cooper Union. In particular, the lab modules development is ongoing in conjunction with Raj Mutharason and others at Drexel. It is expected that suitable modules will be used at Drexel in upper level engineering courses being developed, and the Drexel Biotechnology course can be incorporated in and tested as part of the Biotechnology subprogram being developed at Penn. An interactive group from Penn and Drexel will soon be operational. Also, the kinetics module we expect to deliver at end of this year will be suitable for immediate inclusion into any Bio or Chemical Engineering curriculum within the coalition. We welcome any inputs or suggestions as how to generalize the mthods or contents to encompass the broadest possible dissemination.

Future Years

Year 3:Implement Cell Growth Module at Penn and Drexel.
Develop 3 more modules to testing stage.

Year 4:Deliver Cell growth module to other coalition schools.
Implement 3 new modules at Penn and Drexel.
Develop remaining modules projected.
Evaluate and fine tune Cell growth module.

Year 5:Deliver 3 more modules to coalition schools.
Implement remaining modules at Penn and Drexel.
Evaluate all delivered modules and fine tune.

Saturday, October 16, 1993

Session II Discussion

Eli Fromm, Gateway Central & W. Sanford Topham, CWRU - Facilitators

Eli Fromm, Gateway Central: You will notice that the agenda identifies us as facilitators. As I said at the outset of the meeting, our role is to draw you into a discussion and perhaps to be a little bit provocative in doing so. I will start by indicating some things that I heard and saw today with the intent of being provocative and stimulating some discussion. I hope that no one takes offense with any specifics that I offer.

First, we have some projects in which there are multiple institutions involved that cover a range of topics. Yet, I was troubled to see that in many instances the projects are still individual institution efforts. There are exceptions, of course. Perhaps we can have some dialog about this. I know it is a difficult task. That is one of the reasons that we are working on trying to establish some more communication mechanisms. How will we get institution to institution transfer if we do not get this kind of interaction and buy-in as the material evolves?

Second, in some instances, the courses described were really "stand-alone" and there did not seem to be an attempt to make them anything other than that. That was troublesome. I can see the possibility of bringing them together and that is our challenge. I use the word "course" and that is another point that I wanted to raise. We must think of all of this change as more than just the course content. As Raj [Mutharasan] mentioned, it is the broader context in which we provide the educational experience. One of the important aspects of getting groups together from different institutions is, in fact, to try to push this issue of looking at the broader curriculum and experience that the

student receives rather than just the pedagogy of the specific course. We really must work more on that. Any comments are welcomed.

Third, people were talking about "modules". For most, I think, that means putting material together in segments that are transferable and transportable. But, I found it disappointing that in a few instances it was not clear to the developers what that module would be. Now I am speaking as the Director of Gateway and the Principal Investigator. I am troubled that we are into the second year, having supported some projects for more than twelve months, and we are hearing: "I don't know yet what the module really means". I am not referring to the content but the actual media. That is something that we should have clarified by now.

Other than that, the material was very interesting for the most part. My concerns revolve around "where is the collaboration and how strong is it?" I think the most evident place where this is occurring is in the presentations that dealt with Concurrent Engineering. Maybe it is more natural that collaboration takes place when the project work involves physical and design kinds of activity. Maybe it is easier to envision it that way.

I will make one comment about the last presentation, just for clarification. Not all of the students in E^4 meet with all the faculty every week.

W. Sanford Topham, CWRU: As we listened this afternoon to presentations about different courses that are being created, there were some excellent ideas expressed. What we see is a change in many courses in terms of organization, structure, method of material presentation and a different matrix or paradigm of how that course is going to be put together. As I see this presented, I wonder what involvement other people in other parts of the Coalition will have in that particular course. It was interesting that I heard much about "we will export" or "we would like other schools to use some of the things that we are discussing" but I saw almost no one say that "we were going to import or accept from other schools." I think that this is something that we all probably should look at more carefully if we are really working together as a coalition. We must be willing to accept from other schools and not only export.

Another thing that came to mind, as I was listening to these discussions, is that there appears to be a need for some method of generating textbook material. This is true whether the textbook material is put together electronically or it is actually a physical textbook that we hand out to our students. In almost all cases, in the courses that are being developed, there is no textbook available. We did hear one presenter say that students like to have something physical in their hands that they can use and look at. How do we generate these textbooks? How do we put this material together so that it is effectively used by the students in these courses as we develop them? We want to make sure that as we develop these courses and make these modifications in engineering curriculum that we are doing the right thing.

Also, how do we conduct evaluations? I think evaluation can be as important as perhaps the production of the material itself. It is important so that we know for sure that we are really doing something to enhance the quality of engineering education within our various institutions and across the coalition. How do you do the evaluation? Do you do it on a weekly basis in which you talk to the students? Do you do it at the end of a course? As someone suggested earlier , we may really not know how effective a course is until two years later when we talk to the students. Who does the evaluations? Students, faculty, our alumni, industry,... Who provides us with the evaluation tools? It is not a simple process and it is something that we have talked about within the coalition but it is something that I did not see addressed today in terms of these courses that we are putting together. As we look at the changes we are making in our courses, I think we want to make sure that the changes really are increasing the quality of engineering education. I emphasize the word engineering. That is what we are doing. Are we bringing new material in? Are we focusing on things that are not really engineering? Are they going to increase the ability of our students to function as engineers within society? We have to be careful about that. These are the comments that I have and I invite your discussion.

Art Hucklebridge, CWRU: Something that was mentioned several times over the last two days, by different presenters, is the fact that the engineers we are training will be working in a world of limited resources and with very real economic restraints placed upon them. Many of the things I see presented here, in terms of new tools and methods of teaching, have very healthy price tags. Something that I have not heard addressed but that we must take a very serious look at is the cost-effectiveness of these tools and how we can provide the most "bang for our bucks" in educating engineers. We did not talk much about this. I think that this could become a big issue and is now an issue at most institutions. This is something else that needs to go into the evaluation process. Not only in terms of how much better do we educate but how much better do we educate in terms of the investment made.

Jordan Spencer, Columbia: Two of the major conclusions I will leave this meeting with are that much interesting work is going on and that there are very exciting opportunities for collaboration. There are also barriers to collaboration. Speaking personally, I think I have a history of missing meetings with myself. People two floors up may as well be on the next planet. What can Gateway do, in addition to encouraging collaboration in a theoretical way, to make collaboration easier or to remove some of the barriers to collaboration?

Edward Ernst, USC: Any suggestions?

Jordan Spencer, Columbia: I think this meeting is an excellent step in promoting collaboration but I am not sure that the momentum shown here will continue.

Richard Parker, NJIT: My comment is to follow up on that. I think it might be effective if we could break into smaller groups at a meeting like this. Then all of those who are interested in a specific topic could thoroughly discuss it and explore ways that we can help each other.

Geraldine Milano, NJIT: I think many of us have come to this conference to toot our own horns about what we have been doing but I just wanted to say that everyone should take advantage of Drexel's Team Teaching Workshops. I want at this time to thank Drexel. For the past two summers I have attended these workshops and have brought much information back to NJIT. Even though it may not have been expressed in my presentation or any presentations by NJIT, we have been using the ideas taken from that Team Teaching Workshop and have put many of them to use. Maybe workshops on how we can share information, instead of conferences where individual speakers get up, would be more effective. This could be done during school breaks or summer session. We could invite each other to our universities and have workshops on specific projects that we are working on and share in that way.

Eli Fromm, Gateway Central: In response to one of the questions asked: "How can we get more cooperative efforts across the institutions?" I have found over the last year and a half that we must all be very conscious of the communications issue, even within our own institutions, let alone across institutions. What I see happening is that one or two Institutional Activities Leaders or a Governing Board member will be asked, based on their own backgrounds, to attend a particular meeting that NSF or another organization is holding. Too often, the information obtained at these meetings is not promulgated. One of the things that we must work on, and will be working on, is to attempt to change that. For example, we will now require a short trip report when people attend meetings and we intend to distribute these reports. Another approach to facilitate collaboration may be desktop teleconferencing such as CuSeeMe. At Gateway Central, we are looking into other commercial products that may provide a better capability. From my point of view this is the type of tool that is needed to bring small groups of faculty together efficiently. If the products work as advertised, faculty would be able to share and edit documents collaboratively while sitting at their own desks. This technology may be a key to effective communications on our own campuses as well as across the coalition.

Mitchell Litt, U. of Penn: In response to what Sam Topham said about exporting versus importing, it is only natural when one is standing and talking about what one is doing to say: "Here, I've got it. I'm gonna sell it". But if you don't know what is being sold by others, it is hard to buy. That ties in with communication. Has anyone thought about setting up a Gateway news group? As soon as someone has anything to communicate, it could be posted. There are 5000 news groups in which you can communicate on anything whatever. We should have a Gateway news group bulletin board that anyone can access. It is a cheap way to link everyone .

J. Brooks Breeden, OSU: That news group idea is a wonderful lead-in to a question that I have been mulling over for the last day: What about Tripoli? I received a message that announced that there was a bulletin board called Tripoli and that provided the address. I signed on and went to the proper directory and there were many, many folders. I could get into my folder which had nothing in it. But I could not get into anyone else's folder to leave them a message. There is absolutely no communication as to how I am supposed to use it. I have never gotten any messages. This is exactly what Mitch was talking about. It appears to be set up but there are no instructions.

Raj Mutharasan, Drexel: With regard to Tripoli, you can get into it. At least there is a password with which you can access it but it is so outdated that it is almost meaningless.

J. Brooks Breeden, OSU: I entered my password which allowed me to get into the system. Once into the particular sub-directory, there was just a series of files. I could not access anyone else's folder but my own.

James E. Mitchell, Drexel: There actually is an application using a standard method to go into the bulletin board structure. There is a discussion group, etc. The problem is that nobody is using it and that is the death knell for anything like that. As soon as people see that nothing is going on, it is dead.

Elizabeth Pittenger, FIU: If I may voice some observations. I would be perfectly willing to offer any help that anybody would find useful if there were a quarterly newsletter distributed to all Gateway participants. I'll tell you why. Electronic mail is a wonderful wizardry of our age but our colleagues in the Humanities and your poorer cousins in English are not, for instance in my university, traditionally on E-mail. If you truly want to have a cross-coalition influence and have people on board when you are in the planning stage, not when you are asking for a service from them, if you do it through a newsletter, you might reach those people more efficiently.

Eli Fromm, Gateway Central: You folks have touched a very sore point. It is an extremely important issue and a problem that we have. We have tried twice, asking around the coalition, for information for a newsletter. We want to publish a quarterly newsletter. Indeed, we must publish a newsletter. But, we are not getting information. We are not going to make it up at Gateway Central. We have to get the information from you. It must start as information from the individual institutions. The only way to achieve this is with the help of everyone. By help, I mean contributions. Please contact your Institutional Activities Leaders. Our communication link is through them who, we hope, have been passing our requests for information out to the rest of the community within their institution.

Elizabeth Pittenger, FIU: But you still have not told me the name of your publication. Who is my audience? Who am I writing for?

Eli Fromm, Gateway Central: Initially, our audience is the Coalition itself, several hundred fellow colleagues who are working on various projects. We will distribute it more broadly than that but the intent is really to distribute information among ourselves on what is being done. We could also have some information that perhaps we might not want to distribute beyond the coalition. By and large, we try to use electronic communication where we can. But we will do whatever is effective. You must raise the issues or provide us the information. If you have ideas on how to distribute, they are certainly welcome.

Mohamed El-Sayed, FIU An important point is the communication within an institution. I feel that being divided as ten institutions is not working the way it is supposed to. The coalition is working in many different areas and a representative of an institution is knowledgeable in the area that he is working in but information about other areas is getting lost in the process. My feeling is that we should divide the coalition based on task forces, not by institutions. For example, people working on design and development courses could be grouped in a task force for the design area, for the materials area, etc. That is the way you could organize a conference. If you do it that way, I think communication will be much better.

Eli Fromm, Gateway Central: Mohamed is not the first person at the meeting to indicate to me that we have not sufficiently spread the word on how Gateway is organized. We have attempted to organize something along the lines that he described. There are individuals at each institution who are the Institutional Activity Leaders. The intent is that these people be the leader and the source of knowledge for activity going on within that institution. Also, they should help distribute Gateway information around the campus.

Also, we have grouped the projects into several Program Areas: Curriculum Innovation and Development (CID) Lower Division; CID Upper Division; CID Design; Educational Technology and Methodology (ETM); Evaluation and Quality Assurance (EQA) and Human Potential Development (HPD). We have individuals identified as Program Area Leaders (PALs): Sam Topham - CID Lower Division; Nihat Bilgutay - CID-Upper Division; John Demel - Design; Mort Friedman - ETM; Ed Ernst - EQA and Gordon Hopkins - HPD. This conference has been organized, largely, by Program Areas. That is, we have divided the agenda into CID Lower Division, CID Upper Division, Human Potential Development and so on.

Mohamed El-Sayed, FIU: Now that I know the structure, I hope that the group leader that you identified will hold a meeting while we are here, in a separate session, with the people working in the area so that we can get to know each other. Again, I recommend that at a conference like this we have separate sessions for people interested in a particular area.

John DiNardo, Drexel: I am going to comment on one of the questions that Sam Topham raised related to the nebulous aspects of evaluation. I think that evaluation is many different things to different people. Yet, Gateway would probably like to have some certified means of doing evaluations. I would like to have some guidance related to evaluation of an individual project, so that we do not waste time and that we do it right.

James E. Mitchell, Drexel: Next week, NSF is sponsoring a conference for evaluators from all of the coalitions. I will be going with some others. Maybe they will tell us some of the evaluation criteria that they want to use.

John DiNardo, Drexel: I think that would be an ideal topic for a newsletter

W. Sanford Topham, CWRU: I have one other comment about communications. We, at CWRU, have set up what we call an FTP server which allows people to put documents, simulations or whatever on it so that other institutions can download them. It is not perfected yet but if you have a Mac document, for instance, regardless of what kind it is, you can upload and download it and the document stays in full context. This works with simulations, Powerpoint presentations, etc. These would be accessible to anyone in the Coalition. We would like to develop it further. I have presented this to the Governing Board, perhaps 6 or 8 months ago. It is something that is worthwhile. The idea is to eventually be able to upload/download a document created on a Mac or a PC. That kind of technology is here; it just has not been fully implemented yet. The annual report was placed on the server and it worked extremely well, except for PC-based institutions that had trouble with downloading. I wanted to let you all know that it is partly operational and we can expand it very rapidly if people are interested in sharing more than just text. Sharing courseware documents and multimedia should be possible. You do need a password to access the server but that simply means contacting CWRU.

Wayne Magee, Drexel: Along some of those same lines, with everyone developing different modules and methods of input and output and multimedia, I think it would be very useful to have some consolidation of software, something that we could all center around.

Eli Fromm, Gateway Central: Commonality of software is a major issue. We discussed that in an early Governing Board meeting. I raised the issue and was almost ridden out of the room because we have to recognize the fact that what we do, as important as we think it is, is only a part of the total University. For instance, by and large, Gateway is not going to dictate what the Math or Computer Science Departments do or influence, for example, whether Mathematica or Maple is used. We rapidly came to the conclusion that we would have to let the institutions use what institutionally is their primary vehicle and establish a mechanism such as a file server in which files can be up-loaded and down-loaded by all participants. I do not think that it is feasible to standardize software among the ten institutions.

Edward Ernst, USC: Thank you all for your contributions. We will now adjourn the meeting. You are reminded that there is an SLA/CAD demonstration by NJIT in the hospitality suite.

Nomadic Computing In and Out of the Classroom

by: Mort Friedman, Columbia University

Paper unavailable

TUTOR EM
Implementing CAI into an Engineering Core Course

Prepared by:
George H. Staab and J. Brooks Breeden
The Ohio State University

Introduction

Starting Autumn Quarter of 1993, The Ohio State University began to implement its pilot version of Drexel University's E^4 engineering curriculum. The pilot series contains three courses: an engineering fundamentals course, a laboratory course and a math and mechanics course. Other components of the Freshman engineering curriculum are taught by departments outside the College of Engineering (e.g. English). A total of 30 students are enrolled in the pilot curriculum.

The math and mechanics portion of the pilot course is designed to follow closely Drexel 's *MSFE I* course. The traditional engineering curriculum requires all engineering students to take an engineering mechanics class, (traditional statics with an introduction to strength of materials). Approximately 400 students take this course each Autumn Quarter. Both mathematics and mechanics are viewed by students to be very demanding, and it was felt that this content area is well suited for a study of Computer-Aided Instruction (CAI).

Two forms of CAI are available to students: 1) tutorials specifically developed for critical areas of a typical engineering mechanics courses in statics and dynamics, and 2) homework assignments requiring numerical parametric studies best accomplished via a symbolic math manipulator such as *MAPLE* or *MATHCAD*. Students in the pilot are required to use both forms of CAI. Students in the traditional program are required to work only the CAI homework; the tutorials are available, but without specified credit attached to their use, it is doubted the students will use them. The usefulness of the CAI components of the course is to be evaluated by comparing the students enrolled in the pilot program with those enrolled in the traditional program. If CAI can reduce students' perceived difficulties with the topics, its use can be viewed as a success. Students taking the traditional courses serve as the control group.

Simple comparisons can be made using similar exam questions for the traditional and pilot students during the quarter. A more rigorous comparison can not be undertaken until students have enrolled in their majors, and can be compared to other students with similar professional goals. Since the control group initially targeted only students who were directly enrolled into Engineering (generally students with high ACT scores), the effectiveness of the CAI tutorials can not be efficiently assessed, and viable methods for evaluating them currently being considered.

CAI Homework

Homework assignments requiring numerical computations employing existing computer codes are assigned throughout the entire first year of the pilot program. An acceptable solution to these problems requires two components: both a mechanics formulation and a numerical solution. The mechanics formulation must contain the appropriate free-body-diagrams and the governing equations generated in terms of the variables. The numerical solution requires students to use a symbolic math manipulator such as MAPLE (site licensed at OSU) or MATHCAD, to solve the equations generated in the mechanics component of the solution. This requirement is imposed on both the Gateway students and those enrolled in the traditional engineering curriculum.

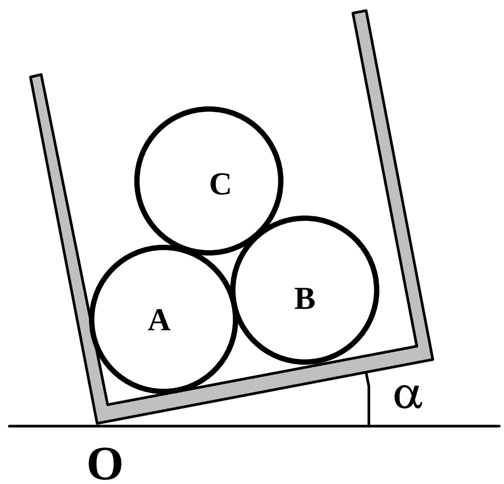
Students in the Gateway pilot program learn to use *MAPLE* in the *Fundamentals of Engineering* course and are asked to work two homework problems in their first quarter. The number of assigned problems increases in subsequent quarters. Students in the traditional curriculum (who typically have a minimum of one complete year, and often more, as OSU students) are asked to work four such problems, since they have been introduced to the use of MAPLE in a prerequisite course.

A typical problem assigned early in the quarter is illustrated below:

> Three identical spheres (radius 2-in, weight 10-lb) are stacked in a box. All contact surfaces are assumed to be frictionless. The box is pivoted about point O at some angle α.

A. Draw the free-body diagram for each sphere, and clearly indicate the reaction forces at all contact points. Using the free-body-diagram, determine the expression for each reaction as a function of α, for reactions >0 only.

B. On the same graph, plot each reaction force as a function of α for $0^\circ \le \alpha \le 90^\circ$, and define the range of α (to within 0.10^o) for which static equilibrium exists.



CAI Tutorials

Several CAI tutorials have been developed using *Authorware Professional* to focus on various aspects of engineering mechanics. The tutorials offer certain advantages over conventional texts, view graphs, etc., in that concepts can be dynamically illustrated. This helps students visualize important concepts not easily grasped through static illustrations and verbiage alone, and a certain degree of student/tutorial interaction.

Tutorials concentrating on both statics and classical dynamics have been and are being developed. A listing of the tutorials is shown in Table 1.

Table 1 CAI Tutorials

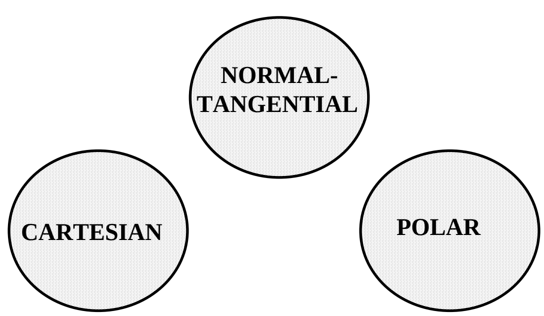
Statics	Dynamics
Force Vectors	Accelerations
2-Force Members	Coriolis*
Zero-Force Members	
Mast	
Cylinders	
Free-Body-Diagrams*	

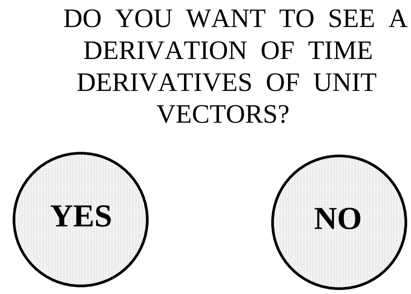
* currently being developed

The dynamics tutorials both discuss topics and illustrate concepts which students typically have difficulty visualizing. The statics tutorials blend topical discussions, illustrative examples and quizzes. At appropriate places, students are provided the option of working a quiz relating to concepts previously discussed. Randomly generated numbers allow for extensive repeatability of concepts without repeating the specific numerics of a problem. Therefore, students get the needed repetition in solving certain classes of problems.

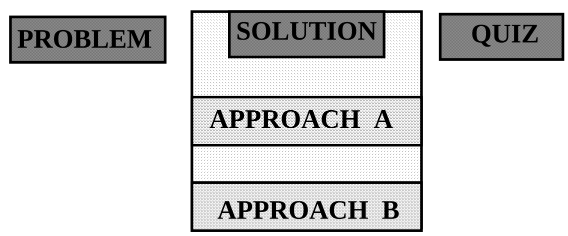
Tutorials are structured in two distinctly different formats. Some are in the form of a text in which each screen builds on the previous screen. At appropriate junctures in derivations which require a knowledge that is perhaps not common to all students, they are prompted. Their response will either allow them to further investigate subtle aspects of the derivation, or continue. An example of such a path is illustrated below, and comes from the accelerations tutorial. Two illustrations are shown, one in which students have three choices, and one in which either a *yes* or *no* response required.

WHICH TYPE OF ACCELERATION
DO YOU WANT TO SEE





The second format offers students the luxury of selecting which topic they wish to investigate. After a brief introduction, students are asked to select topics from a pull down menu. Within each menu, students can select from several options, as illustrated below.



Both formats have certain merits which are best evaluated by the users. Some students may prefer the step-by-step logic of the first format, while others may find the pull-down-menus a better learning aid. The second approach is definitely better for allowing an instant re visitation of selected topics. Students will be asked to evaluate each type of presentation in terms of its effectiveness as an educational tool.

Evaluating CAI

Both forms of CAI (homework and tutorials) require critical evaluation. The effectiveness of the homework form of CAI, as implemented at OSU, is best evaluated after students have acquired sufficient practice with it to incorporate its use in upper division courses. A critical assessment of this form of CAI will be solicited from both students and faculty after it has been in effect for several years. It is expected that once students become efficient in using such instructional aids, faculty can assign more problems requiring parametric studies, which are probably the most effective means of gaining a thorough understanding of various types of problems. At this stage of the CAI homework assignments, the faculty within the Department of Engineering Mechanics at OSU is generally viewing it as a positive approach to strengthening undergraduate education.

Evaluating the effectiveness of CAI tutorials is somewhat more difficult. Many factors come into play when evaluating these tutorials: presentation style (either format listed above, background color, etc.), topics considered, audience, etc. Academic diversity among coalition members may render tutorials which were effective at the institute of their origin completely ineffective at another venue. Although the contents of tutorials may be topical consistent between institutions, the background of students, or other variables may dilute their effectiveness. For this reason, coalition members should attempt to use these tutorials for students at their institutions and assist in their critical evaluation.

Conclusions

Two forms of CAI are being developed and evaluated at OSU; both forms show potential. The homework format is relatively easy to implement, while the tutorials require a certain amount of effort. We feel that the tutorials are a good approach to assisting students, but an evaluation by students and concerned faculty at coalition member institutions is needed and is requested. Only through an interaction such as collaborative development can a truly effective form of CAI be developed. Will you help us?

Electronic Courseware for Materials Engineering

Prepared by:
Mark R. De Guire, Case Western Reserve University

Introduction

One of the objectives of Case Western Reserve University's participation in the Gateway Coalition has been to expand the use of CWRU's Electronic Learning Environment (ELE) in undergraduate engineering courses. The ELE provides a campus-wide fiber optic network (CWRUnet) that links student residences, faculty offices, classrooms, libraries, and labs with file servers, printers, libraries, CD-ROM databases, the Cleveland FreeNet, and InterNet and BitNet.

During Gateway's first year, the ELE was incorporated into EMSE 201, "Introduction to Materials Science," first in the form of an electronic bulletin board, and second in a hypermedia tutorial and study guide for the course. This paper will present the educational philosophy behind each of these projects, give examples from the courseware, report on in-class experience to date with these projects, and describe plans for further development.

The educational goals of this project are consistent with several of the goals of the Gateway coalition, *i.e.* greater integration of science and engineering; early introduction of engineering concepts; and greater retention of engineering majors, particularly underrepresented groups, by encouraging individual exploration and stimulating interest in a wide variety of engineering concepts.

The Course

Like similar courses in engineering programs at other schools, CWRU's EMSE 201, Introduction to Materials Science, is a first course in the properties and processing of engineering metals, ceramics, and polymers. It is a prerequisite for further study in materials science and engineering (majors or minors), but it is sufficiently broad in scope to serve as a self-contained overview of engineering materials for non-materials students. At CWRU, it meets for 3, 50-minute lectures per week for 15 weeks, with weekly homework and reading assignments drawn from one of the standard texts in the field. It is offered every semester to 100-130 students per semester. The majority of these are mechanical, biomedical, chemical, civil, and materials engineering majors. The course prerequisites consist of one semester each of college chemistry and calculus and at least current registration in first semester physics. Roughly 50% of the students are sophomores, 20% juniors, and 30% seniors.

Both in content and position in the curriculum, EMSE 201 was an appropriate choice for the development of computer-based study aids to augment what is otherwise a traditional lecture-homework-exam course. First, most of the students have had recent experience with CWRUnet and the ELE through their early chemistry, math, and physics courses. Second, EMSE 201 builds directly on the concepts introduced in these introductory courses to explain the behavior of materials. This conceptual continuity with core courses complements the carryover of computer skills and the students' familiarity with the ELE.

Electronic Bulletin Board — "The EMSE 201 Forum"

The bulletin board — "The EMSE 201 Forum" — can be likened to forums or special interest areas on national information services and computer bulletin board systems. It is a sub-menu on the Cleveland FreeNet. This means that it is accessible from any student dorm room and faculty office, almost every fraternity and sorority house, and the campus computer labs through CWRUnet. Off-campus students have access via modem. FreeNet is essentially limited to

ASCII-text communication; scanned notes, graphics files, and formatted word processing documents can and have been made available via file servers on CWRUnet, but these are only accessible through personal computers hooked up to CWRUnet on campus.

The Forum is intended as an extra avenue of communication between students and instructors — an avenue coexisting with, not replacing, traditional sources of information such as lectures, textbooks, office hours, and in-class questions. It consists of six sections:

- *About the EMSE 201 Forum:* Brief text descriptions of the other sections.

- *How the Course is Run:* Grading policy, reserve list, and other administrative information.

- *Syllabus & Calendar:* Course schedule by week, with lecture topics, reading assignments, and the schedule for homework and exams.

  (The preceding three sections consist of information that is also contained in the syllabus handed out at the beginning of the semester. These sections remain unchanged throughout the semester, and are "one-way" (instructor-to-student) sources of information. In contrast, the following sections are updated several times a week.)

- *News and Announcements:* Current homework assignments, schedule changes, and posting and administration of team projects.

- *Q & A:* Where students can leave questions about lecture and text material, homework, etc. Questions can be answered in private by the instructors or, when they are of general interest, answered and posted for public view.
  (The option of an "unmoderated" section, whereby students can post public messages without prior approval by an instructor, is possible with FreeNet but has not yet been exercised in this course.)

- *Class Averages:* Average scores and standard deviations on individual assignments and on the total class performance to date.

  (The course is graded on a curve (average is the B-C cut-off, average plus one standard deviation is the A-B cut-off, etc.) Students who keep track of their scores can use the information in this section to know after every assignment where they stand with respect to the rest of the class. The confidentiality of grades is not compromised because individuals' scores are not posted.)

The Forum was first made available during the fall '92 semester and was fully implemented in spring '93.

Use Patterns

The Forum was well received by students. Of 55 (58% of those enrolled) who returned a survey given at the spring '93 final exam, 76% used it regularly (at least once a month). Those who did not use it regularly cited limited access to FreeNet or satisfaction with traditional information sources as their main reasons. However, past experience has indicated that access to, and familiarity with, the network on the part of the student body increase with each semester. The long-term projection would appear to be even higher usage of the Forum in the future, as long as students deem it useful.

Figure 1 summarizes the students' responses regarding how frequently they used the various sections of the Forum in the spring '93 semester. Those sections that provided "static"

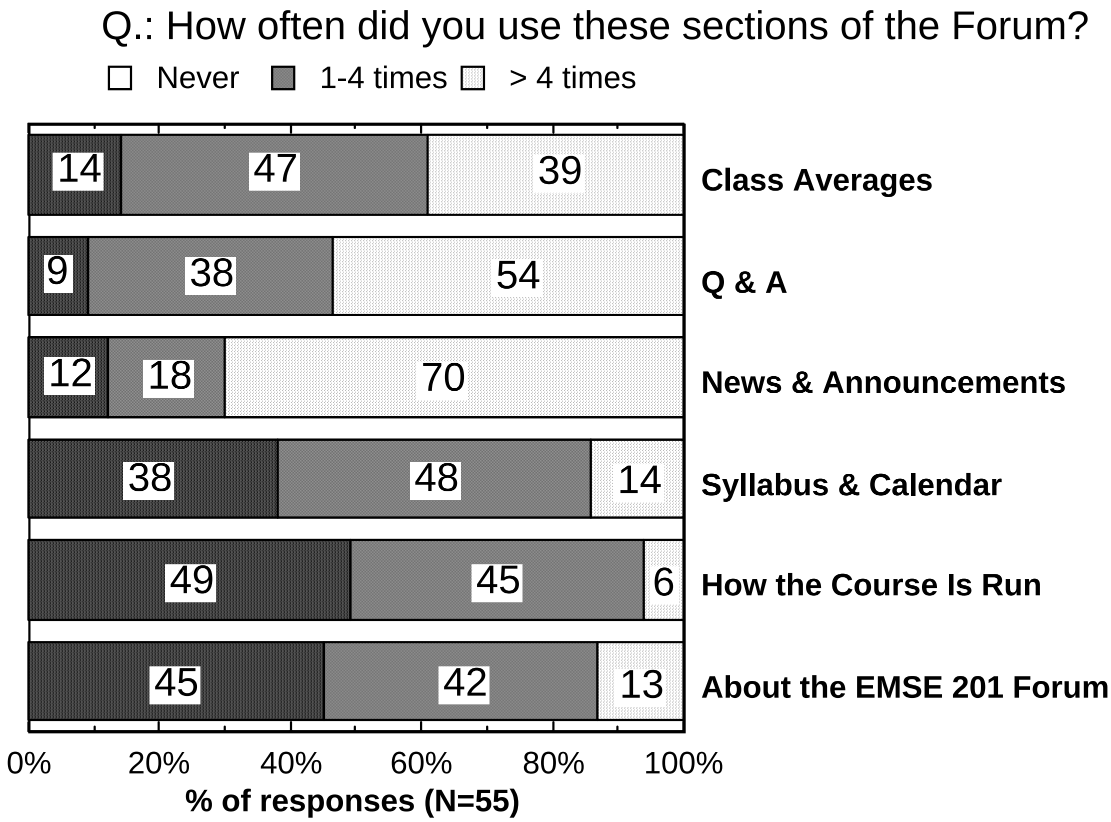


Figure 1. Survey results on the frequency of use of various sections of The EMSE 201 Forum.

information that was duplicated in the hard-copy syllabus (About the EMSE 201 Forum, How the Course is Run, and Syllabus & Calendar) were used infrequently. Nevertheless, slightly over half of the respondents read each of these areas at least once. The "dynamic" sections (News & Announcements, Q & A, and Class Averages) were, not surprisingly, read more frequently, with over 85% of the respondents checking each section at least once. Solid majorities checked Q & A and News & Announcements more than 4 times, and students checked these areas more often than they checked the Class Averages.

An important observation that is not evident in the survey results is that the Forum was rarely used as an aid to *learning*. Few students posted questions about the course content or asked for help on homework, even though such questions were encouraged (and given generous responses when asked). This outcome mirrors students' general reluctance to ask questions in class unless coaxed. The loss of anonymity associated with asking a question is even more acute when done in a "written" format, but although the instructor would always know who submitted a question, the public posting could be (and usually was) done without identifying the questioner.

Perhaps more importantly, however, the dearth of technical questions may reflect a timing mismatch: students, many of whom first look at the homework only the night (or hours) before it is due, want immediate responses. In contrast, our response time was usually at least a half-day. We infer from this experience that use of an electronic bulletin board as a learning tool will require instructors who are willing to establish and maintain a pattern of predictable and frequent electronic feedback.

In comparison to more conventional information sources outside of lectures and the text, the EMSE 201 Forum fared well, though no single avenue exhibited a large margin of popularity over the others (Figure 2). The course is taught from transparencies, and students expressed a strong desire to have access to hard copies of these materials *prior* to lecture. (In Figure 2, "Overhead files on CWRUnet" refers to the word processing files that were placed on the campus file server early in the semester, which constituted most of the material on the class transparencies; whereas "Copies of overheads in library" refers to photocopies of all of the in-class transparencies, placed on reserve a day or two after each lecture.) It appears that although the current level of computer familiarity and accessibility is high and growing at CWRU, non-electronic information sources continue to play a large role in students' study habits.

When students provided comments on The EMSE 201 Forum survey, they were generally favorable:

- "… a great idea! Please continue it so other courses will follow your lead."
- "A+++!!!"
- "Keep up the good work."

The few negative comments were hardware-related: limited network access at some fraternities or lack of computer ownership by some students, and IBM-vs.-Macintosh hardware incompatibilities unrelated to the Forum.

Finally, the availability of a common information-exchange network made certain assignments much more practical to administer for a large class (100-130 students). For example, in response to one of the Gateway goals as well as to input from industry, three team projects were assigned in spring '93. The second involved writing a report on some specific engineering application and the reasons that particular materials were currently used for that application. The third project required students to propose an alternative material for some other team's application from project two. Teams were given extra credit for exchanging information with each other. Administering these projects, which the students generally enjoyed, would have been

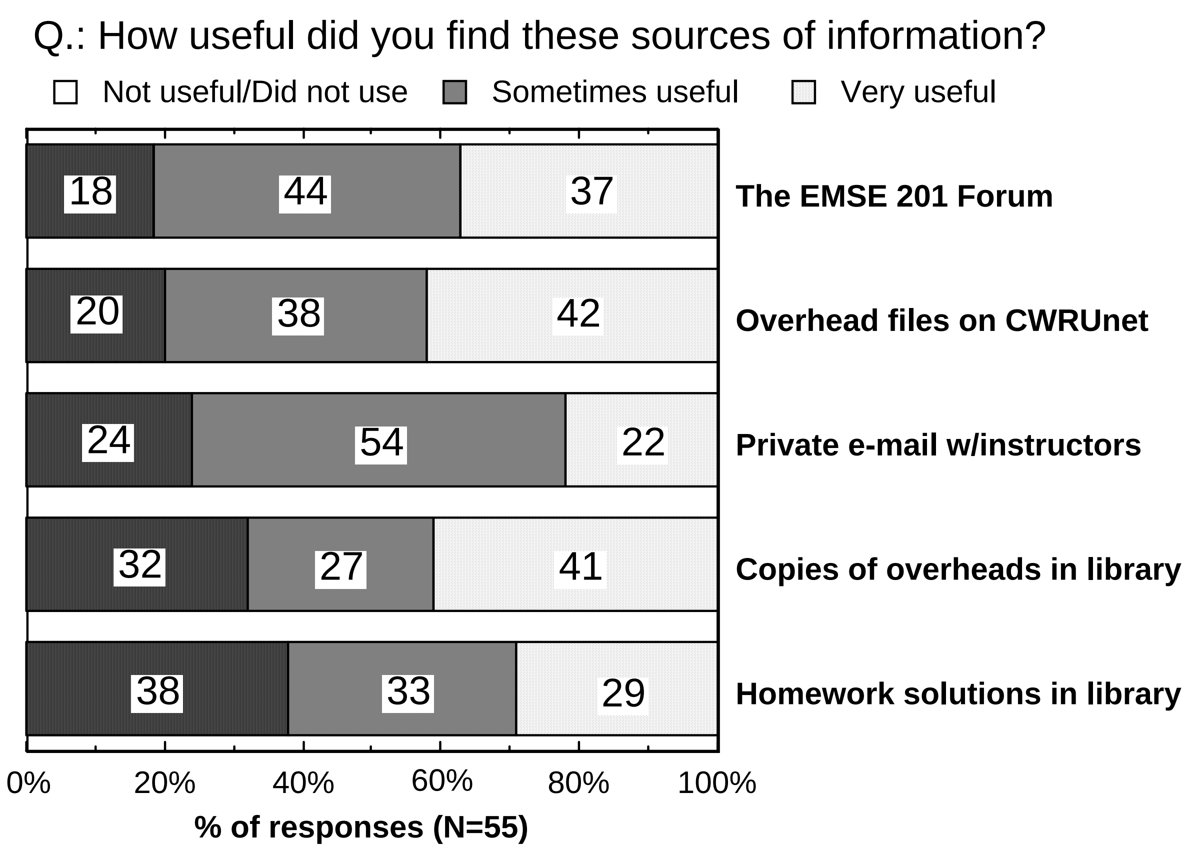


Figure 2. Survey results comparing the usefulness of The EMSE 201 Forum to other sources of course information.

prohibitively cumbersome without the network.

A small but tangible benefit was that most of the course's paper handouts have been eliminated, supplanted by ASCII messages on The Forum and (where ASCII files are inadequate) reserve materials in the library and formatted documents on file servers. A downside, which will perhaps be unavoidable until complete network access and familiarity can be taken for granted, is the extra effort required of the instructors to maintain what amounts to a redundant information channel.

The results of this survey and our experience with The EMSE 201 Forum lead to the following conclusions:

- In our implementation, the electronic bulletin board saw its greatest utility as a source of information regarding course administration and organization, rather than as a learning tool. Greater use for conveying help with course content will require greater immediacy of feedback from the instructors.

- When multiple electronic and non-electronic sources of information exist for a class, all get used. Students exhibited no clear preference *e.g.* for network sources vs. library reserve materials, e-mail vs. an electronic bulletin board, etc.

Hypermedia Study Guide for an Introductory Materials Science and Engineering Course

To students and instructors, an introductory materials science course poses the dual challenges of 1) surveying a large body of information in a short time and 2) maintaining the interest of many students who may never take another materials course. Both these challenges can be met if the underlying connections between basic science, materials behavior, and engineering applications can be made manifest to the students. Glimpses of the rich framework of concepts that underlie materials science can be provided in lectures, but more could be uncovered if students were encouraged to look for them on their own.

The hypermedia study guide for EMSE 201 is intended to facilitate this kind of self-guided exploration as a way to strengthen a student's grasp of basic concepts. It is intended as a tool for study and review — a *companion* to lectures and text reading, not a substitute. Currently written as a HyperCard stack for the Apple Macintosh platform[1], it consists of replicas of the overhead transparencies used in the course lectures, linked together by the following hypertext features:

- A student can jump to any one of 20 main course topics by clicking on its entry in the table of contents (Figure 3).

- From any point in the study guide, students can bring up a combined index and glossary (Figure 4). It provides not only brief definitions of unfamiliar terms, but also a list of locations and contexts where that term is used. A click on any entry in this list takes the student directly to that location in the program (Figure 5).

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1 When the Macintosh text-and-graphics version is complete, a version that will run on the IBM platform under ToolBook (from Asymmetrix Co.) will be created using a HyperCard-to-ToolBook conversion utility.

- A “Digging Deeper” function, not yet implemented, will bring up a wide variety of ancillary material, ranging from etymologies of scientific jargon, illustrations of engineering concepts in everyday experience, and applications of more advanced basic science concepts to the core material in the course.

Hardware Requirements and Other Hurdles

In the present version, widespread accessibility and portability has been a primary design goal. Therefore, the study guide has been intentionally written to run on bottom-of-the-line systems. In the Macintosh line, that means Pluses, SE’s or Classics, all of which have small monochrome screens. (When the version for IBM compatibles is available, it will be designed for the minimum hardware configuration that will run ToolBook software at a reasonable speed.) As a result, the study guide is entirely in black and white. To fit on a single disk, the graphics have been kept simple — mostly PICT line drawings, no scanned images; and no sounds, video, or animation are included.

The major constraints with this approach have been:

- The size and resolution of the small screen on compact Macintoshes. This demands a careful choice of layout, typefaces, type size, and image size (choices which probably can still be improved upon).

- Overall sluggishness of our current HyperCard script, particularly in certain search functions. There are cur-rently two working versions: one that runs acceptably fast over the network, but that is difficult to expand and re-vise; and one that is easy to update but runs very slowly on the network.

Presently, the study guide, which lacks many line drawings and all of the Digging Deeper function, takes up just over 400 kb, so it appears there will be enough room to complete the first version and still have it fit on an 800 kb double-density disk. So far, the above-mentioned constraints have not dissuaded us from keeping this first generation of the study guide accessible to as many users as possible.

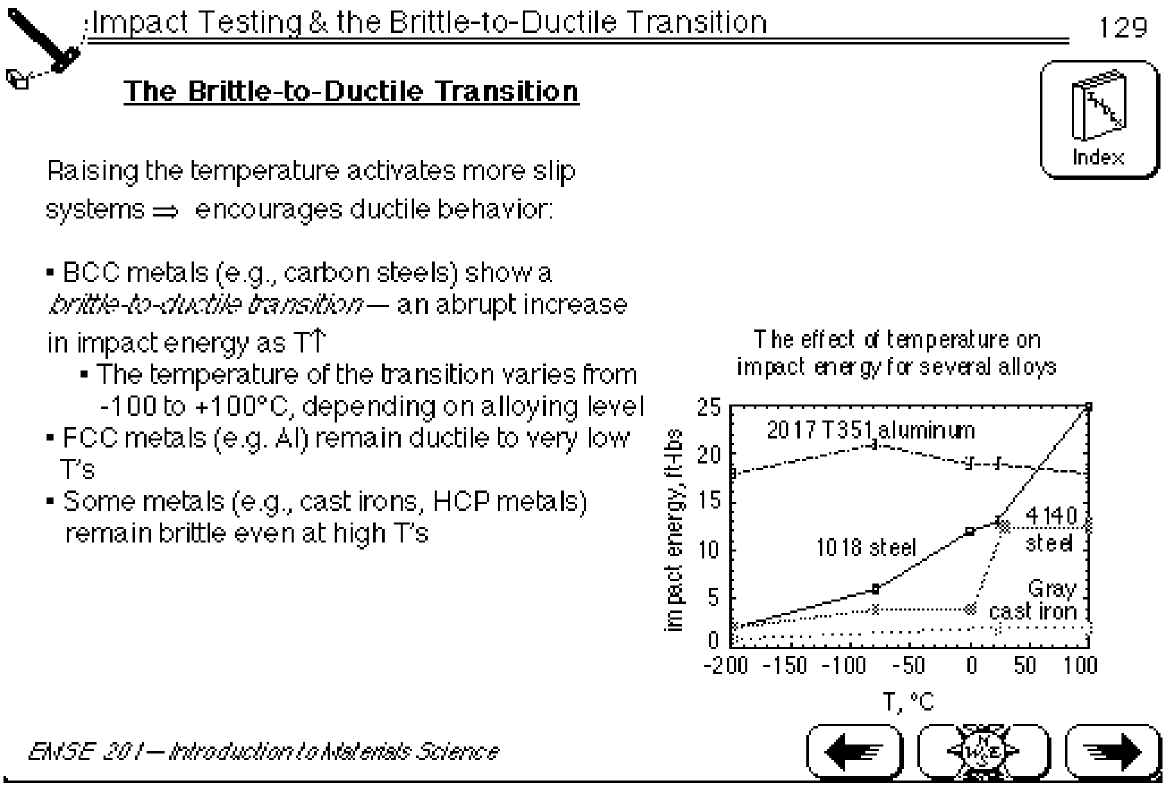

Figure 5. The screen that appears when "Impact Testing" is selected in the list at the lower right of Figure 4.

Finally, the missing graphics will need either to be created from scratch, obtained from some public domain source, or cleared for inclusion by the current copyright holder(s). The software will then be translated into an IBM-compatible version as explained above. Meanwhile, much of the content of the "Digging Deeper" function has been written and needs to be programmed into the HyperCard version.

The stack will then be distributed to other schools in Gateway and in other NSF coalitions that offer similar introductory courses in materials science and engineering. (It is this intention to disseminate the work electronically that makes some copyright holders reluctant to release their material.)

With the appropriate equipment, the study guide could replace the current overhead transparencies as the visual aid to accompany lectures. Two small (~30-seat) classrooms at CWRU have been equipped with network connections and large-screen projection systems. Plans for equipping larger rooms are underway, but legibility of the display will need to be evaluated in a large hall. (This will involve both hardware issues — brightness and resolution — and software design — font sizes and the limited screen resolution of HyperCard text and graphics.)

The advantages of the study guide as a lecture tool would be the ability to navigate quickly and on the spur of the moment to any related visual aid in the course; and easy and inexpensive updating of the material. Disadvantages would be the inability to write on the screen, though this might be overcome if the wall screen can by rolled up to allow projection onto a blackboard; and the pitfalls of relying on more complex hardware.

Ultimately, we feel that this version, when complete, will meet our goals as a learning tool, while serving as a core for a more ambitious (and more hardware-intensive) implementation of the study guide.

Future Plans

The preceding would constitute completion of the first-generation study guide. The next step would take advantage of the burgeoning capabilities of multimedia, to incorporate material beyond text and static graphics. This would include animation, video, sound, and simulations. There are concepts in EMSE 201 that virtually cry out for moving pictures of one form or another:

- The evolution of microstructures during solidification or heat treatment of an alloy, synchronized with paths being traced out on equilibrium phase diagrams or time-temperature-transformation curves;
- Rotatable crystal unit cells to aid in the visualization of different crystallographic planes and dynamic processes such as slip;
- Synchronization of a video of a tensile test with the tracing out of the stress-strain curve, with pauses for explanatory comments describing the various stages (elastic region, yielding, necking, failure);
- Animation showing various manufacturing processes: shaping processes such as drawing, rolling, and machining; surface treatments such as galvanizing, electroplating, or thin film vapor deposition; or actual video clips of manufacturing processes.

That is, while the basic principle of self-guided browsing to strengthen concepts would be maintained, the ability of the stack to illustrate dynamic scientific concepts as well as real engineering processes would be greatly enhanced.

Not all of this material would need to be created from scratch. First, existing instructional materials in Materials Science would be surveyed, such as videos and computer tutorials from the Materials Research Society, the Institute of Metals, and previous federally-supported initiatives in materials education. When original courseware needs to be developed outside of HyperCard, such as graphic animation or linkages between modules from different sources, suitable software packages will be evaluated for such development.

This would of course impose much higher hardware demands for both the developer and the user: faster CPU, large color monitor, fast video card, more RAM, and much higher storage capacity. Portability and a certain universality would be sacrificed.

Concluding remarks

Both of these projects, the EMSE 201 Forum and the HyperCard study guide, were intended to improve the information delivery capabilities for a conventional lecture course. However, the potential exists for downplaying or replacing large, formal lectures with smaller, informal discussion sections. The responsibility for learning the subject from the study guide and the (conventional) course textbook, and for asking instructors for clarification in the discussion section or over the Forum, would then fall more heavily on the student. The electronic capabilities discussed here could facilitate that process and perhaps make it more practical than in the past.

Second, it is clear from our experience to date with EMSE 201 that students will make use, in one way or another, of most of the learning resources made available to them, electronic or not; and clear preferences for either the old or the new have not emerged. Two factors play a large part in determining what tools students actually use in their education: 1) convenience, and 2) perceived impact on their course grade. To insure that what they use also *teaches* them something, quality still counts, whatever the medium. Well-organized, dynamic, and stimulating lectures will continue to elicit enthusiasm for learning, and electronic resources will need similar attenion to insure their effectiveness at conveying educational information.

Acknowledgments

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Graphically Driven Electromagnetics for Undergraduates

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[Figures/Tables are not available electronically]

Electromagnetics (EM) is a difficult subject for most students. The course material is abstract and relies heavily on vector mathematics. It is also hard to use EM in "real world" problem solving. Closed-form field solutions are only available for highly symmetric, idealized geometries. Thus, in an introductory course, it is difficult to show students *how* to use EM, and *where* they will use EM.

The focal goal of this project is to make EM more approachable, interesting and exciting to electrical engineering undergraduates. The project covers the development of an *application-enhanced approach* in an introductory junior-level course in EM. This is feasible through the use of *numerical calculations* and *interactive visualization*. Numerical calculations permit the determination of field solutions for actual applications; interactive visualization allows the student to identify and formulate relationships from the numerical calculations. Specifically, we have written a general-purpose, user-friendly Graphically Driven Electromagnetics (GDE) field solver. GDE was adapted for student use from a research program and is fully capable of modeling contemporary electronic devices and structures in detail. Showing applications with numerical calculations and interactive visualization is a way to make students more enthusiastic about EM.

The traditional way of introducing EM is to concentrate on theory, and to limit illustrations to textbook-type examples. One reason for delaying the coverage of applications in the present curriculum is the extensive time needed to teach rigorous analytical methods and their engineering approximations. In practice, however, many simple geometries are analytically intractable. Hand calculations do not take you very far. Numerical calculations can circumvent this limitation, and at the same time show the basis for analytical approximations and their proper use in realistic engineering applications. By using numerical tools, the introduction of applications is accelerated.

Applications are *not* replacing the presentation of theory. Instead, applications are being used as vehicles to explain fundamental theoretical concepts. The utility of numerical calculations for analyzing complex problems shows the students at an early stage of their studies the importance of basic theory in practice. In fact, general-purpose numerical tools allow the introduction of engineering design into a course that traditionally has no design content. If the present pace continues, more material will be covered this semester with GDE than in past semesters with a textbook alone.

As part of the course development effort, the advantages of interactive visualization are also being exploited. The manipulated graphical display of fields, potentials, and currents makes the subject more exciting, and is naturally coupled to numerical calculations. One of the strengths of graphical design tools is that it allows students to visualize effects of key parameters on the performance of components or systems, effects that would otherwise be overlooked with the use of traditional, non-graphical approaches. The intent is that students form mental models of the theory, and improve their problem-solving skills and intuition.

Other work claims that a general-purpose numerical solver with interactive visualization is the most effective learning tool a computer can provide to a student. It is the best way to actively engage and challenge the student [1]. GDE is this type of software.

GDE is a rigorous method based on the generalized finite difference method and the current simulation method [2,3]. The computation of electric fields and electric parameters is based on the solution to Laplace-type equations where is the permittivity, is the conductivity, and V is the potential. This equation can be used to calculate the potential distribution within a lossy inhomogeneous dielectric region. The effective capacitance, C_{eff}, or conductance, G_{eff}, is computed fromwhere V is the voltage within the computational space and V_{diff} is the voltage difference with respect to ground. In the generalized finite difference method, since every grid point in 3-D space is treated as a junction of eight different dielectrics, arbitrarily inhomogeneous materials are handled as easily as homogeneous materials, making the numerical algorithm very efficient.

Despite its power and flexibility, GDE is easy to use for both students *and* the instructor. GDE has a graphical user interface by which all structures are entered and calculations are displayed. GDE is largely mouse-driven, but there are keyboard equivalents for nearly every operation. The post-processor can generate 2-D and 3-D plots for equipotential contours, vector fields, and current magnitudes. Screen dumps in various output formats are available, e.g., postscript and HPGL. On-line help for every operation, as well as a complete Users Guide with examples, are available to users. *Ease-of-use* means less student frustration, less lecture preparation effort, and less classroom time spent on how to operate GDE.

Efficient sparse matrix techniques make GDE fast and small enough to run on a PC with at least 8 Mbytes of memory. To improve access to GDE, part of this project is to port the code to X-Windows so students can use it on our workstation network. Upon installation of a PC lab in our department later this year, students will be given GDE for use in homework assignments, design projects, and exploration.

GDE can be used in a variety of ways. In the classroom, the GDE can be used simply as a 3-D visual aid. In a less trivial application, idealized solutions can be shown and compared to actual solutions. In this way, the extent of analytic approximations can be investigated. One example of this is shown in Figs. 1 and 2. In the idealized case, the field is constant and uniform between infinitely-planar charged plates. Figure 1 shows a cross section of a 3-D parallel-plate capacitor; the plates do not have infinite extent. Using GDE, the field for this capacitor is plotted in Fig. 2 along the cut plane, as shown by the heavy horizontal dashed line in Fig. 1. Figure 2 shows that a uniform field is a good approximation in the center if the plates are large compared to the distance between them, but poor near the edges.

The impact of visualization can be used in classroom presentations to show how fundamental equations can be applied to complex engineering problems. It can be used to demonstrate solutions to problems that cannot be solved on the blackboard. An example of this technique is shown in Figs. 3-4. An annotated diagram of a Tape Automated Bonding (TAB) lead connecting an Integrated Circuit (IC) to a Printed Circuit Board (PCB) is shown in Fig. 3.

In addition, since GDE will be given to students, it can be used both as a tool for homework assignments or design projects, as well as a self-study aid. It will help students visualize and experiment with EM theory, and to dissect application examples. Letting students play with the software is perhaps the most effective learning exercise [4].

Figure 1: A parallel plate capacitor created in GDE. Intersections of the grid lines show where the difference equations calculate the potential. The horizontal dashed line shows where the electric field magnitude is plotted in Fig. 2. Circles represent sources: 1.0 V is applied to the bottom plate, 0 V to the top plate. The relative dielectric constant of the material between the plates is 20.

Figure 2: Field magnitude computed by GDE for the cut plane indicated by the dashed line in Fig. 1. The Idealized approximation is valid in the center between the plates, but fringing must be considered near the edges of the plates.

Figure 3: Diagram of TAB lead connecting an IC to a PCB. This is an example of an engineering application, showing the utility of EM theory, that can be analyzed by GDE. (Dimensions provided courtesy of NCR Corp., MTRC, Columbia, SC.)

Figure 4: Equipotential surface through a vertical cross section of the TAB lead. A 1.0 V signal is applied to the TAB lead. Since it is a conductor, so the voltage is constant everywhere along it.

Students become best motivated to learn something when they can see its relevance [5]. We will let the students explore the concepts and learn firsthand the effects of changing boundary conditions, driving terms, and initial conditions. In this manner, we hope to enliven the intrinsically exciting and challenging topic of EM and to achieve major changes in the way it is taught. In EM, as in many other areas of engineering, basic design can be achieved in a numerical context with relatively simple theoretical models. To exploit this, students will be encouraged to use newly introduced theory to obtain first-order approximations to the solution of design problems. Although the software is specific to EM, the application-enhanced approach to teaching can be applied to other engineering courses as well. Emphasizing applications will help students see the importance and usefulness of the theory.

In summary, numerical calculations and interactive visualization are bringing a new dimension to the way EM can be taught. GDE is showing how fundamental equations can be applied to complex engineering problems. Students are learning the role of design tools in bridging the gap between theory and practice. This is working by taking an *application-enhanced approach* to instruction supplemented by graphical, computer-aided design tools in an introductory junior-level EM course.

The authors are grateful to the NSF Gateway Coalition for Engineering Education for their support of this project. Thanks are also extended to the AVX Corp., Myrtle Beach, SC, and NCR Corp., MTRC, Columbia, SC for their partial support of the development of GDE.

[1] J. F. Hoburg, "Can computers really help students understand electromagnetics?" *IEEE Trans. Educ.*, vol. 36, no. 1, pp. 119-122, 1993.

[2] B. Beker and G. Cokkinides, "Computer aided analysis of co-planar transmission lines for MICs and RDM," *Int. J. MIMICAE*, vol. 4, no. 1, 1993

[3] B. Beker, G. Cokkinides and A. Templeton, "Electromagnetics analysis of low inductance decoupling capacitors," *Proc. Conf. Electrical Performance of Electronic Packaging*, Monterey, CA, October 1993.

[4] R. Cole and C. Brune, "Visualization, simulation and computing: new tools for learning, new paradigm for teaching" *Comp. Applications Engineering Educ.*, vol. 1, no. 1, pp. 65-72, 1993.

[5] For example, C. H. Durney, "Principles of design and analysis of learning systems," *Engineering Educ*., vol. 63, no. 6, pp. 406-409, 1973.

An Integrated Environmental Initiative: Common Ground for the Humanities, Social Sciences and Engineering

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For the Arts and Humanities, and to some degree for the Social Sciences, the terms *postmodernism* and *poststructuralism* refer in part to the blurring, even to the dissolution, of genres and other categories and their subsequent reordering. In the engineering fields as well--as is typified by the Gateway Project--the boundaries of traditional bodies of knowledge are being stretched; and it might not be going too far to claim that these bodies of knowledge may be due for a fundamental restructuring. Such changes are not in the broadest sense unique and in fact they can be viewed to be, especially within the university setting, both normal and necessary.

Indeed, if many in these three fields harbor doubts about the plans of Gateway, then comfort might be taken in being reminded of the founding notion of the modern university that began in the Middle Ages. To someone like Thomas Aquinas the Latin verb *scire*, *to know*, the root of our modern term *science*, indicated the activity of acquiring knowledge of a specifically theological nature, for this was *knowledge*, yet we already see in Aquinas's thinking the distinct branch of knowledge that came to be called *philosophy* in the modern world--and in turn the idea of science such as we today think of it, the hard sciences. But of course we need not look back all the way to medieval times in order to present a warrant for today's kinds of activity. Rather, modern developments in mathematics and the sciences--the emergence of particle physics, for example--suggest the limitations and perhaps even the dangers of practicing a single discipline in isolation, as if in a vacuum. The vacuum, the void, by some philosophical lights, is what underlies the manifest world, and so science is science of the world.

The same can and must be said for education. What underlies the Gateway enterprise is the assumption that students learn better, learn more, and quite possibly faster, when what they are learning is contextualized within parameters that exceed a single discipline and is integrated with other disciplines--as is coming to be widely recognized.[5] Embracing an interdisciplinary approach to education, however, will present problems of a practical and otherwise a logistical nature. What, for instance, might be a likely focus for training students to comprehend the engineering impulse and practice within the wider world? At the New Jersey Institute of Technology this question is being answered in two very different, and at the same time utterly related, ways.

There are the obvious, and promising pedagogies in which various disciplines can be presented together by aligning their respective activities and by pointing out their resemblances and often their shared roots. Thus, in the first year Gateway sponsored NJIT Fundamentals of Engineering Design course, engineering students work in teams in each of three modules--one generally oriented around electrical engineering, another generally around civil engineering, a third around engineering graphics. The student work includes presentation and analysis of poetry and various writing activities involving both the poetry and engineering dynamics. As well, Gateway

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[5] See for instance: C. R. Mitra, "Existential Reality of Engineering Education towards 2000," *1992 Frontiers in Education Conference Proceedings*, 336-39; Anthony D. Robbi and Norbert Elliot, "The Engineer as a Professional: An Interdisciplinary Approach," *1992 Frontiers in Education Conference Proceedings*, 79-83; William D. Wyant and Ronald W. Eck, "Engineers: Building Interdisciplinary Teams," *1992 Frontiers in Education Conference Proceedings*, 190-95.

students will be attending common hour lectures and film presentations that ask them to consider the work of the engineer as regards engineering's broadest applications; they will see a PBS film called "The Skyscraper and the City," and they will hear a talk by an art historian on the development of the concept of three dimensionality in the Western world from the earliest times up to the present.

While these are no doubt worthy activities, they do not fully insist on the student engaging his or her world in a manner precluding approaches that are defined by any single exclusive discipline. All the same, these are important activities. They are activities, however, that bear their greatest fruit when employed in a further activity that owes its existence to no one category of knowledge. Hence NJIT, while carrying out a rapprochement between engineering, on one side of the equation, and Humanities and Social Sciences on the other side, has added a third and decidedly viable term: Pollution Prevention.

The inclusion of Pollution Prevention studies is not only timely but at NJIT convenient, since already in place is an ongoing EPA funded project to produce an interdisciplinary textbook of case studies that consider the environment, its exploitation and preservation, from a wide range of viewpoints (the book's chapters and case studies are listed below--see Fig. 1 below).

Figure 1. Contents of Pollution Prevention Book

POLLUTION PREVENTION FROM A HUMANITIES AND SOCIAL SCIENCES PERSPECTIVE

Chapter 9: Policy Dimension: Legal Context
Introduction
Case Study 14. Planning for Ground Water Protection
Case Study 15. Environmental Dispute Resolution: The Phohl Brothers Landfill Case
Chapter 10: The Policy Dimension: Communications
Introduction
Case Study 16. Cutting Through the Red Tape: Reading Environmental Rules
Case Study 17. The Substance and Process of the Pollution Prevention Act
Chapter 11: International Perspectives
Introduction
Case Study 18. International Aspects of Pollution Prevention
Chapter 12: Federal Programs
Introduction
Case Study 19. Federal Government as a Model: Investigating and Implementing Pollution Prevention Practices in Federal Facilities
Chapter 13: State, Local and Small Private Programs
Introduction
Case Study 20. Newark Radiator Repair
Chapter 14: Industrial Programs
Introduction
Case Study 21. Source Reduction Versus Recyclability: The Nine Layers of a Snack Chip Bag
Case Study 22. Industrial Response to Eliminating HalonL An Ozone-Depleting Chemical

The book's original purpose was its application in possibly any course offered within the institute; typically, one or a number of case studies could be employed in the service of a particular course's ultimate aim, although the hope was that even within the confines of a single course discipline the book might lead students to think of the respective discipline within a larger field of understanding.

A course in manufacturing engineering, for example, might employ the book's case study on "The Nine Layers of a Snack Chip Bag" or a case study entitled "Industrial Response to Eliminating HalonL, An Ozone-Depleting Chemical." Similarly, a course in American literature or in World Civilization might integrate into its curriculum the book's case study entitled "Exploring the Idea of Nature as a Spiritual and Physical Entity: The Nineteenth-Century Writing of Ralph Waldo Emerson and the Twentieth-Century Writing of Gary Snyder."

Furthermore, the book can be applied specifically within the more obvious Gateway parameters. For example, the NJIT common hour presentations can be augmented by case studies in the book on art and architecture, which serendipitously correspond to these presentations (e.g., a case study entitled "To Live with Nature or To Dominate It?: Two American Architectural Approaches, Skyscraper Versus Adobe and Pueblo"). Yet the book can also be used within the context of each Fundamentals of Engineering Design module. The students in each section of the FED course also take a course called "Writing, Reading, Thinking," which is meant to be complementary (a typical course syllabus is reproduced below--see Fig. 2).

Figure 2. A Sample "Writing, Speaking, Thinking" Syllabus for First Semester Gateway Students

WRITING, SPEAKING, THINKING

REQUIRED TEXTS

- *American Heritage Dictionary.* 3rd Ed. Boston: Houghton Mifflin, 1993.
- Perrin, Robert. *The Beacon Handbook.* 3rd Ed. Boston: Houghton Mifflin, 1993.
- *Pollution Prevention from a Humanities and Social Sciences Perspective*. Newark, NJ: NJIT, 1993.
- Tarvers, Josephine. Ed. *Science and Society.* New York: Harper Collins, 1992.

COURSE SCHEDULE

9/7: Introduction.
9/9: Eiseley, "Science and the Sense of the Holy"; free writing and discussion.
9/14: Hardison, "Disappearing through the Skylight"; paraphrasing and discussion. PAPER (one and half pages) on your definition of *holy* DUE.
9/17: Dictionary assignment due; discussion of dictionary use. *Genesis* 1.1-5; discussion of light as phenomenon and metaphor.
9/21: Biblical usages of *light* (pp. 1-2 of "Light" handout); Oral paraphrases and discussion. PAPER (one and a half pages) on *play* DUE.
9/24: *Beacon Handbook* pp. 20-54. Discussion of composing process. REVISION of *holy* paper DUE.
9/28: *Pollution Prevention from a Humanities and Social Sciences Perspective* Chapter 5: Introduction, Method of Analysis, and all of the second Case Study entitled "Exploring the Idea of Nature as a Spiritual Entity" (including the articles by Adams and Gould); viewing of slides and discussion in preparation for written responses to one of the four sets of questions in the Assignments section of the case study.
10/1: Continuation of previous discussion. PAPER (one and half pages) responding to previous Case Study questions DUE. Reading and discussion of student papers, and peer review.
10/5: REVISION of *play* paper DUE for peer review. *Beacon Handbook pp.* 265-75.
10/8: Diction Handout; group analysis. *Beacon Handbook pp.* 238-63. FINAL REVISION of *play* paper DUE (3rd draft).
10/12: REVISION of "light" case study paper DUE .
10/15: Original POEM on the theme of *light* DUE. Readings and discussion. *Continued on next page*
10/19: FED oral reports; discussion of differences between oral and written communication. *Beacon Handbook* pp. 276-90.
10/22: Group writing, analyzing a poem that utilizes the theme of *light* (to be one full page when word processed).
10/26: FINAL REVISION of *"Light" case study* paper DUE (3rd draft). Reading and discussion of student case study papers.
10/29: Heller, "Born in Water"; McPhee, "Ice Pond"; paraphrases and discussions (including analyses).
11/2: *Pollution Prevention from a Humanities and Social Sciences Perspective* Chapter 9 and its first case study (up to "tasks").
11/5: Discussion of case study and article, "Information for State Groundwater [. . .]." Group writing of Tasks 1 and 2.
11/9: Discussion of "Local Regulations for Groundwater" Pts. I and II. Group writing of Tasks 3 and 4.
11/12: PAPER on Tasks 4, 5 and 6 DUE. Peer reviews of papers. Discussion of case study overall.
11/16: Leopold: "January"; and Thoreau: "The Pond in Winter"; both in *Pollution Prevention from a Humanities and Social Sciences Perspective.* Discussion. REVISION of draft presented in the last class meeting DUE.
11/19: In class brief descriptive essay on the coming of winter (what is the light like now, the water in the surrounding area?).
11/23: *Pollution Prevention from a Humanities and Social Sciences Perspective* Chapter 4 (all preliminary text) and its first case study entitled "To Preserve Nature or to Use It? The Story of Hetch Hetchy Valley and the City of San Francisco." Discussion and analysis.
11/30: Written responses to "Guidelines" section of Hetch Hetchy case study DUE. Group discussions and presentations.
12/3: Written responses to "Assignments" section of Hetch Hetchy case study (paragraphs 1 and 2 only) DUE. Class debate.
12/7: PAPER (one and a half pages) responding to the last paragraph of "Assignments" section DUE. Group analyses and reports.
12/10: REVISION of draft presented in the last class meeting DUE. FED oral reports.

Just as the students discuss poetry in their engineering course, they will make oral and visual presentations of their respective teams' individual projects; a group that has been assigned the task of designing and manufacturing a toy, for instance, will have to present its work, not in its engineering but in its English class. Moreover, in conjunction with the electrical engineering module, the English class will consider a variety of readings on light--for example, texts like the biblical *Genesis* in which God says "Let there be light," and as well writing by the contemporary poet William Bronk whose poem "The Annihilation of Matter" concludes, "Objects are nothing. There is only the light, the light!" Such classroom activity is enhanced by using the pollution prevention book's case study that compares the use of light in the landscapes of the nineteenth century painter Frederick Turner and those of the twentieth century photographer Ansel Adams. Likewise, with the civil engineering module, whose theme is reservoirs, the English class will discuss and write responses to texts with the theme of water, or employ appropriate case studies from the book. And so on.

These applications are, nevertheless, incidental and in some sense trivial ways of coming to see and to become an active shaper of the world. That is, the pollution prevention book offers another, more profound opportunity, one that is germane to Gateway, especially when case studies whose purviews are a variety of traditional disciplines are employed together within a new and what is fast becoming a crucially significant discourse.

Not only do we now find programs in Environmental Engineering but, as is true at NJIT, a program in Environmental Studies under the auspices of the department of Social Science and Policy Studies, which also offers both a major and minor in a curriculum entitled "Science, Technology and Society." We need not consider here whether or not environmental studies and the like are central to humanity's survival. Yet we might profitably contemplate how the pollution prevention book helps to realize the deepest potential of the Gateway Project.

Case studies like "The Ethics of the Commons: An Examination of the Moral Obligations regarding Commonly Owned (or Unowned) Resources" and "The Ethics of Restoration and Mitigation: An Examination of the Moral Value of Natural and Restored Environments" ask students to consider their individual conduct as professionals and as citizens. These case studies are enhanced if used in connection with others in the book.

A case study entitled "Ethical Science and its Relationship to the Natural World: Journals of Life in the Woods by Henry David Thoreau and Aldo Leopold," for instance, details the relationship between observation of the physical world and a consequent psychological bond with that world, which leads to feelings of connection and responsibility. Among other tasks, at the end of this case study students are asked to keep a written record of observations of a specific site and of themselves, and ultimately to compare and contrast the two and to draw conclusions from their work overall. And a case study entitled "Overcoming the Car Culture: Developing a Program to Modify Human Behavior," or one entitled "Environmental Dispute Resolution: The Phohl Brothers Landfill Case," asks students to make ethically as well as practically related decisions as concerns the environment; in fact, the book also contains a case study whose title might reveal its connection to the problems of ethical decision making--that is, "Critical Thinking in a Plan for Pollution Prevention."

These case studies thus prepare the student to make critical and/or ethical decisions because of subject-related and cognitive-related although not -identical tasks. In short, when the pollution prevention book is considered as whole, and when a variety of case studies is used, one of the things the student comes to realize is the unity of knowledge and how individual disciplines are applicable widely, often within the contexts of other disciplines.

And what of our diminishing natural resources? Isaac Asimov, several years ago, painted a bleak picture of our future in his discussion of the exploding world population. What future role will the philosophy of ethics, for example, play in our actions both political and technological? The pollution prevention book is engaged in answering this question. The ultimate goal of this book can be said to be the student's arrival at some essential and principle knowledge of a discipline, which is the most useful of tools--yet its dimensions mark it as something far greater than any tool. The impulse and procedures that constitute this book, then, and arguably the Gateway initiative, might lead to the desire to construe the world as a vibrant and highly articulated whole.

Has knowledge *per se* come full circle since the Middle Ages? That is, are we now in some sense revisiting Aquinas's concept of epistemology and spiritual grace as one that comprehends other fields of knowledge? Well, yes, if we are being tongue-in-cheek. The challenges we face on the threshold of the twenty-first century, however, are those that involve the greatest issues. What, for instance, will happen to the West's cherished notions of privacy and civil liberty as the momentum of information technology grows ever greater? Does such a question fall within the purview of the engineer? Increasingly, we are finding that it must.

Works Consulted

Brown, Lester R., Christopher Flaven and Sandra Postel. *Saving the Planet How to Shape an Environmentally Sustainable Global Economy*. New York: Norton, 1991.

Gashlin, Kevin F. and Daniel J. Watts. "Modifying Process and Product: Two Pollution Prevention Case Studies." *Journal of Environmental Regulation* (Winter 1992-93): 139-49.

Mitra, C. R. "Existential Reality of Engineering Education towards 2000." *1992 Frontiers in Education Conference Proceedings*. 336-39.

Robbi, Anthony D. and Norbert Elliot. "The Engineer as a Professional: An Interdisciplinary Approach." *1992 Frontiers in Education Conference Proceedings.* 79-83.

Royston, Michael G. *Pollution Prevention Pays*. New York: Pergamon Press, 1979.

Wyant, William D. and Ronald W. Eck. "Engineers: Building Interdisciplinary Teams." *1992 Frontiers in Education Conference Proceedings*. 190-95.

The Engineering Prep Bridge Program - A High School to University Transition Project

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New Jersey Institute of Technology

The engineering talent pipeline reaches a critical point (one of many critical junctions) in the freshman year of their post-secondary education. This is the most serious retention problem of the typical university program, especially in engineering and especially for minority students.

Presently, a large number of minority students drop out of science and engineering during their first two years. This situation, which is intensified for disadvantaged inner-city youth, can be attributed to a number of factors directly related to elementary and secondary school experiences. Inner-city minority youngsters are relegated to low-ability track science and math classes in disproportionately higher numbers. Typically, they attend schools with lower quality math and science teaching, curricula, laboratories, equipment and textbooks.

Teachers at these schools often judge their students to be of low ability and thus place less emphasis on developing inquiry and problem-solving skills and stimulating involvement in science and math learning. These circumstances result in students having little or no opportunity to take advanced science and math courses or to be exposed to courses, curricular goals, and strategies that generate interest and promote achievement.

Without effective intervention the current retention rate will result in very few minority scientists and engineers for the twenty-first century. A comprehensive program of academic and personal development is needed to help these students overcome the many barriers to their success. More science and math courses that build motivation, knowledge, and skills must be introduced prior to college entry. But even more important is the need for counseling, guidance, and mentoring that will build self-esteem and the desire to succeed.

A high school to university transition project entitled the Engineering Prep Bridge Program (EPBP), designed to remove identified barriers to success for educational disadvantaged, inner city high school students, was piloted at NJIT in the summer 1992. Based on the success of the 1992 program, NJIT was able to obtain private funding to offer the program again in 1993. NJIT will be available to help other coalition schools extend the program. The project included intensive coursework dealing with the basic physical concepts and mathematics that lead to the study of calculus, and hands-on experiences in engineering topics. The intensive academic experience was supported by counseling, guidance, and mentoring by college students from similar backgrounds and experiences. Starting in the summer between the eleventh and twelfth grades, students were involved in a six week program that provided intensive instruction in the concepts of physics (through an "Overview Case Study", OCS, approach) and specially designed engineering modules dealing with engineering design systems.

This report will focus on the major components of the EPBP, the OCS approach to physics, and the engineering project. As the attached schedule indicates, physics was taught four mornings each week (averaged over the length of the program) for six weeks. Engineering/design was scheduled for total of eighteen sessions, an average of three per week. In addition, classes in mathematics, communications and computers were included in the program.

At the undergraduate level, evaluations has shown that the OCS method works extremely well in helping students to understand and retain the principles and concepts of physics. For example, at

NJIT in the fall 1991, three of the nine sections of Phys 111, our standard freshman engineering physics course, were taught via the OCS method, while the remaining 6 sections were taught in the traditional manner. The two instructors teaching the 6 traditional sections made up the commonly graded exams, and determined the criteria for grades at the end of the semester. The OCS students significantly outperformed the traditionally taught students, usually by around 15% or more.

The physics instruction in the program was built around an alternative approach to teaching physics, called Overview Case Studies (OCS). OCS physics is a conceptual method for teaching physics first developed for the college level by Prof. Allen Van Heuvelen at New Mexico State University under a grant from the Fund for the Improvement of Post Secondary Education. This program brings OCS physics to the pre-college level.

With OCS, physics concepts are introduced using essentially no mathematics. Using OCS workbooks and problem solving sheets developed by Prof. Van Heuvelen, learners draw motion diagrams--diagrams of velocity vectors with changing magnitudes--of cars moving faster and slower, balls going up and down, objects sliding up and down planes, etc. In this manner learners develop a conceptual understanding of kinematical quantities such as velocity and acceleration.

OCS instruction confronts misconceptions head on. in the very first days in an OCS course, students deal with motion diagrams where they learn about the differences between the directions of velocity and acceleration. The notion of force is brought in with force diagrams, i.e., Free Body Diagrams (FBDs). Learners construct FBDs for a variety of force situations--weight forces, friction forces, normal forces, pushes and pulls, etc. The idea that forces affect motion through acceleration and not velocity is gradually brought in, and learners essentially discover for themselves Newton's 2nd Law, $F = ma$. The OCS format continues through other areas of mechanics such as energy, momentum, and rotational motion. Learners are shown that when approached in the proper way, these apparently very diverse areas are actually quite similar.

Learners work on concepts and problem solving in small groups of about three or four, under the guidance of the instructor and teaching assistants, and in this manner learn from each other. Learners also perform hands on laboratory exercises reinforcing the OCS materials. In this way, collaborative learning of physics is taking place. Students are learning physics. The source of learning is not a master of great knowledge and authority standing in front of the class spouting the truths about physical laws. Physical principles are being discovered by the students themselves from their activities and discussions, under the guidance of the instructor who is facilitating the connections between lecture materials, text book studies, laboratory experiments, and the interactions of students as they try to explain concepts and problems to each other.

As part of a cooperative science teaching improvement program between NJIT and the Ridgefield School District in Northern New Jersey, a new physics instructor at Ridgefield High School was introduced to the OCS method during the summer program. She worked side-by-side with the NJIT physics professor in the program. During the following school year, she began teaching her high school physics class with the OCS method. The NJIT professor made monthly visits to the classroom for support as the teacher implemented the physics program. She reported that she and her students became markedly more enthusiastic about the subject after employing the OCS method. Her students learned physics, and enjoyed learning physics as well.

Feedback from the summer participants was very positive. All of them believed that the summer experience would give them a real advantage in their high school physics course. The experience gave them a higher level of comfort and confidence to take more science and mathematics. Some students indicated that, before the summer program, they were not planning to take more science courses. But after participating in the summer program, they had changed their minds and were going to take physics in the next school year.

As the focus for the engineering/design component of the program, the field of civil engineering was introduced as it relates to land use, site development and transportation planning. A basic overview of land use and zoning regulation was presented, especially as it relates to the classification of roadway that service various land uses.

With a background of site development principles as to setback lines, parking requirements, local zoning ordinances, and topographical and environmental constraints, the students (in small groups) designed sites for office and commercial uses. The students designed the sites considering grading, storm runoff and utilities. They designed the parking spaces, driveway and internal roadway design, and loading bays.

The students applied then newly acquired knowledge to a real-world situation - the development of a University Heights Science Park contiguous to the college campuses in Newark, New Jersey. The proposed University Heights Science Park, expected to be built over the next 15 years, promises to make Newark a world leader in the technological research and development field. The Science Park will link the resources of Newark's major colleges, the New Jersey Institute of Technology (N.J.I.T.) and the University of Medicine and Dentistry of New Jersey (UMDNJ) with the business world.

The students were part of a group assigned to explore ways that would reduce the number of vehicles travelling to the Science Park, by proposing parking policies and regulations and by suggesting initiatives to encourage employees to find alternative means of commuting rather than the single-occupancy automobiles. The students were provided with information regarding the proposed Science Park, and were asked to suggest ideas to reduce vehicle usage and encourage mass-transit usage. Suggestions regarding parking, namely the number of spaces required and the location of lots was also discussed. The findings and recommendations of the students became part of a report submitted to the New Jersey Department of Transportation.

The students in the Summer 1992 program were followed up during the school year. During the school year, the participants were asked to complete one of our tracking instruments. The responses to that survey are summarized at the end of the report. The summary also includes some initial information on the Summer 1993 participants as the program has been continued with funds from other sources. Of those 1992 program participants who responded, 80% reported that the program impacted on their choice of math/science courses in high school. Responses demonstrated that the program had a significant impact on the academic preparation. Another survey will be sent to these students during the current year.

A most important benefit of the funding received through Gateway was that it served as the "seed" so that we were able to attract funding from two local foundations that allowed us to continue the program in 1993 and will allow us to offer the program in 1994. NJIT faculty are available to work with faculty from other Coalition Universities to develop and implement analogous programs at their institutions.

Gateway's Human Potential Development Effort at Florida International University

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Abstract

Gateway's Human Potential Development effort at Florida International University (FIU) is aimed at motivating high school students develop career interests in the engineering field. To this end, a set of experiment/lecture modules in the area of energy, environment, biomechanics, recycling, mechanics, and logic were initially developed by a group of FIU faculty and subsequently refined and validated in workshops consisting of FIU faculty, high school science teachers and public school science advisors. Because the hand-on learning experience and topics are based on the application of science principles in everyday life, it is expected that the modules will help capture the student's imagination. To sustain the motivation of the student, parental involvement is designed into the learning experience.

Introduction

Gateway's Human Potential Development (HPD) initiative serves the goal of recruiting more and better students to engineering with special focus on attracting more of the traditionally under-represented population groups such as minorities and women. Recognizing that without the strong and active participation of minorities, the nation will not be able to maintain its leadership role in the next century, Florida International University and Dade County Public schools have been jointly managing the Florida Minority Engineering (FLAME) program. This program provides high school students with the tools and motivation to pursue a career in engineering. Thus it so happened that our involvement in Gateway's HPD is a natural extension and complement of an existing effort. As a background of our prior experience, a brief description of the FLAME program is presented. This is followed by a summary of our first year experience and projected second year effort.

Prior Experience: the FLAME Program

Miami Coral Park Senior High School serves as an engineering magnet center for administering the FLAME program. Students are selected from various schools throughout Dade County and offered the opportunity to transfer to Miami Coral Park Senior High. The program starts with a residential summer program at FIU. This "Full Immersion Summer Program" lasts three weeks and is designed for students that will enter the tenth grade. During the regular academic year, participants take Introduction to Engineering and Critical Thinking Skills besides their regular math, science, and English high school courses. In their second summer, students participate in the "Engineering Summer Institute" which is also a three-week residential program. While in the eleventh grade, students attend Florida International University every day of the week for two class periods and take Applied Mathematics and Applied Engineering Principles besides their regular load. During their last summer, students participate in a six week "Executive Internship" Summer Program in which they are placed with engineering or engineering related companies. During their senior year, students take six credits of dual enrollment courses at Florida International University and also take Applied Mathematics II and Applied Engineering Principles II.

The central objective of FLAME is to instill in students a desire for academic excellence, to prepare students to complete college, and to encourage them to become responsible, contributing citizens. Specifically, the goals are as follows.

- Provide a structured rigorous three year academic program which will enable high academic achievement in talented college-bound students.

- Offer strong background to those students interested in science, mathematics, computers, technical careers, and engineering.

- Help develop resourceful, self-motivated, well rounded graduates who can analyze new situations, make decisions, and communicate their ideas effectively.

- Help develop individuals who will be responsible, well adjusted citizens that are able to compete in the complex society of the future.

- Give students opportunities for external experiences as direct extensions of the magnet program through the mentorship program, summer institute career shadowing, and field trips.

The goals of FLAME, in fact, constitute an articulation of the following Gateway goals.

- Recruit More and Better Students to Engineering

- Developing Better Ways of Recruiting Students

Hence, it is easily inferred that FIU's experience with the FLAME program serves as a natural platform for Gateway's HPD initiative.

First Year Effort

Developing the Learning Modules and Structuring the Delivery System

The Human Potential Development effort is aimed at motivating high school students develop career interests in the science and technology field. To this end, a set of experiments/lectures in the area of energy, environment, biomechanics, recycling, mechanics, and logic were developed by a group of faculty that were interested in this effort. An experiment/lecture consist of two videos, written material, and a laboratory working kit. The various learning materials have parts that involve parents in the learning process. The daily learning activities will be carried out by a University instructor, a high school math or science teacher, and student interns, majoring in Science or Math education. Student interns will also be engaged in the parental involvement aspect of the effort.

Validation and Refinement: Integrating the Quality Assurance Function

Because the learning material was developed by FIU professors, without the active participation of high school teachers, the validation process had to be explicitly Hegelian. The learning material developed by FIU professors constitutes the thesis of the Hegelian process. To this end, two one-day workshops were held at FIU in which some of the learning modules were presented by the authors. The workshops were attended by high school teachers and district science advisors. In addition to serving the objective of soliciting suggestions for modifying the learning material, the workshops also served as a basis for spanning a coalition of educators dedicated to the same purpose. Following is a report of our experience in utilizing principles of quality assurance for validating and refining the learning modules.

The Make Up of a "Quality Assurance Continuum"

The key element of what is known as "Quality Function Deployment" is the creation of an information continuum that links the user (customer) to the supplier (maker) whereby information regarding customer needs is timely incorporated to the production of goods and services. In our context, the users of the learning material are the high school teacher and their students. It is safe to assume that the teachers and the science advisors represented both theirs and their students' needs. Therefore, the conference constituted a "quality assurance continuum" and as will be seen later, it also became a quality circle.

Setting the Stage: Perspectives for Evaluation

Evaluation criteria pertaining to learning material and student performance were proposed to the workshops. Following is an outline the proposed the criteria.

A. Learning Material Evaluation
  1. Technical content: evaluate appropriateness to targeted group
  2. Motivational content:
     a) Is material captivating or not?
     b) Does material have long or short term motivational effect?
  3. Presentation
     a) Readability?
     b) Module sequencing?

B. Student Performance Evaluation
  1. Short term effect
     a) Competency in subject matter presented
     b) Motivational effect
  2. Long term effect
     a) Level of interest
     b) Attitude
        i) Class selections
        ii) Academic performance

A Spontaneous Formation of a Quality Circle

Following the presentation of the learning materials, the workshops of that day organized itself into a working quality circle. Why not; the elements were there. The product was presented, the customers and the producers were sitting at a large conference table. (The hosts ,who were also the producers, created an atmosphere for genuine cooperation and free exchange of ideas.

Outcomes

The quality circles developed an operational objective and guidelines for designing new learning materials and modifying those that are already designed. A summary follows:

Objective: To unleash student creativity in the learning process.

Objective Operationalized: As much as possible transfer the "thinking" process in learning from the teacher to the student

Examples of this objective as operationalized were discussed.

Parameters for developing and modifying the learning material:

- Tie modules to current high school curriculum.
- Present science as an investigation.
- Develop expectation at the begining of a learning session the fullfilment of which will be seeking tsought after during the session.
- Eliminates computational aspects that hide science.

These are the outcomes of the quality assurance process. The climax of the workshops had to be the agreement to form teams for developing the next generation of learning materials. Appropriately, the teams will include FIU professors and high school science teachers.

Summary of First Year Achievements

- A full set of nine experiments/lectures were developed by FIU faculty from the College of Engineering and the College of Art and Science.

- Approval from the Dade County School Board members for the delivery and use of these materials at the ninth grade level.

- The schools (six) have been selected, one in every region of Dade County. In addition all of the science teachers in the Public School System will participate in the program.

- The College of Education has selected the student interns that will participate in the program.

- All the supplies and material needed for the magnet experiments/lectures have been purchased.

- Two workshops (full day) have taken place at FIU with all the science teachers and science supervisors from participating Dade County Public Schools.

Planned Second Year Effort

We are prepared to execute the second phase of our outreach plan: Delivery and continuous evaluation and improvement of the experiments/lectures and the new learning environment that were developed in the first phase (first year). Our student target population will be ninth graders, a total of six high schools and eighteen public schools science teachers will be participating in the program. In addition, the College of Education at Florida International University will provide the students interns. Each school will be served for an average of five weeks in which all ninth graders will participate in at least four experiments/lectures. We are currently developing concepts for extending this learning experience to the remaining high school grades. This will provide an effective structure for a sustained application of the effort .

The faculty that developed the set of experiments/lectures will be involved in the training, self criticism, and improvement of the learning material and the guidance of the science teachers, and students interns. The BellSouth foundation is providing two state-of-the-art learning centers, one at Miami Coral Park Senior High and the other at Florida International University, College of Education-Computer System Center. These two learning centers will support the delivery of training to participating high school teachers.

Conclusion

We have been successful in obtaining an enthusiastic support of the Dade county public school administration, school principals and high school science teachers. A critical mass of FIU professors support and actively participate in this project. Pending funding from Gateway, teams consisting of high school science teachers and FIU professors are ready to work on the second generation of experiment/lecture modules. Timely support by Gateway Central is critical for the maintenance of the momentum that we have gathered .

Implementation of the Gateway Curriculum at a Community College

Prepared by:
Ian Davis, Miami-Dade Community College

Need for Gateway at M-DCC

The Engineering Department is located at the Kendall campus, which is the largest campus of Miami-Dade Community College (M-DCC). Kendall's enrollment is approximately twenty thousand credit students, as compared to over fifty-five thousand for the entire college. There are also eight hundred honors students and over seven hundred Engineering majors, not including the one hundred and forty Electronic Engineering Technology students. Our Engineering department at Kendall provides three quarters of the Juniors for the Florida International (FIU) School of Engineering. Consequently, when FIU wished to revamp their curriculum, they realized that any changes in the first two years would have to be mirrored at M-DCC.

The Beginning

Following the example of Drexel University, FIU and M-DCC have been collaborating for some time on a new and integrated approach to Engineering, the Gateway Program. One of the first fruits of this collaboration is a two-course combination of Introduction to Engineering and English Composition I. Students successfully completing both special Honors sequences will receive a Gateway certificate. This will permit them to continue in the Gateway program at FIU.

In Miami, FIU offered the first pair of Gateway courses, and M-DCC faculty collaborated extensively during the developmental stage. This pair of courses comprises two three-credit courses, one in Engineering and one in composition. The composition courses still covers the original objectives, but there are some changes. Readings related to Engineering are assigned and discussed, technical writing is covered, joint assignments are planned, and in general the English course is related to the Profession. At M-DCC, a third course, History of Science, provides a historical perspective. This takes the Engineering student from the ancient Babylonians up to just before Isaac Newton. Engineering applications are integrated into the curriculum from the start of the degree, and the communications and nonmathematical aspects of Engineering are emphasized. To complete the recommendations for the first semester, students take an appropriate level Mathematics course. This first Math course could be anywhere in the spectrum from Introductory Algebra to Calculus I. Those taking the Algebra course, will be required to pass Calculus I before they enroll in the second tier of Gateway courses.

The Introduction to Engineering Course, Gateway Section

The Introduction to Engineering course is the heart of the new curriculum at M-DCC. The two major topics of this course are The Design Project, and The Profession of Engineering.

The project entails the entire Engineering life cycle of a product. It starts with the perception of a problem, though the proposal, design, manufacturing, and even touches on the sales strategy. The other topics in the course fall under the heading The Profession of Engineering.
These include topics like Engineering curricula, licensing, ethics and Professional Societies. Each topic is related to Engineering practice.

Students pick a project, and, based on their choice of project, they split into groups. From the very start team work is emphasized. Electronic and programming projects are eschewed, so that students can construct their designs with minimum technical knowledge and cost. Students build their prototypes at home, without any workshop support from the college. First semester students do not have much formal training in Engineering, but this is considered during grading. There are several aspects of the project:

1. *Journal: In* their journals, students discuss their progress in their projects, or they may introduce other topics. They introduce a problem, discuss it, and then write a conclusion.

2. *Proposal:* After the students select their topics, and meet with their groups a few times, they write an illustrated proposal to build a prototype. The grading will focus on the students' abilities to communicate in written and pictorial form, rather than on their technical abilities as a draftsperson.

3. *Design process:* The second day of class the students are involved in the design process. They discuss their choice of project and building the prototype. During the semester, they test and redesign the prototype repeatedly.

4. *Manufacturing and Manufacturing Economics:* Students outline a manufacturing process to make a product that is marketable. The words "Manufacturing Process" are interpreted very loosely. This process might involve two employees and a garage, or it could be outlined on a larger scale. All estimated costs are tabulated in a spreadsheet. Furthermore,a strategy to finance the manufacturing project is part of this report.

5. *Human factors:* The product's ease of use, its' eye appeal, and its overall marketability are examined. Students prepare an advertisement for their product.

6. *Patents and Copyright:* Students investigate the protection a patent or copyright would provide. They outline the procedure to obtain a patent or copyright, and analyze whether it would be cost and resource effective to obtain either.

7. *Ethics and Ethics role playing:* An ethical problem relating to their projects, is given to the students. Their way of dealing with the problem is presented as a skit.

8. *Entrepreneurship:* Students write a paper outlining how they would start a small technical business to manufacture and/or distribute the market version of their prototypes.

The other topics in the course fall under the heading The Profession of Engineering.

1. *First View of Engineering:* Students give their initial view of the profession as a reference point. This is similar to a pretest of Engineering knowledge.

2. *Curriculum report:* Here students define their personal educational and career goals. The Engineering curriculum is both extensive and demanding. Students must employ some critical path analysis if they are to graduate in a timely manner.

3. *Resume:* Students write a Resume reflecting either actual or projected accomplishments. This Resume is part of the individual student's personal planning and evaluation process.

4. *Professional societies:* Students attend at least two professional society meetings, and write summaries of these. Students are encouraged to join the Student Chapter of the Florida Engineering Society at M-DCC.

5. *Interview Assignment:* Students interview a practicing Engineer, preferably working in the field of the student's choice. They write a report on this. This gives the student first hand knowledge on what an engineer actually does for a living.

6. *Engineering tools:* Students use the Digital Multimeter to measure the values of several resistors with the same color code. Spreadsheets are used to create a histogram and to compute the mean and standard deviation of the resistors, and these are then incorporated into a short report. Spreadsheets are also used to itemize the manufacturing costs. Word processors are used for report writing.

7. *A Day in My Life as an Engineer:* The student makes a projected report describing a typical day in their Engineering job, referring to at least one ethical concern that may arise. We are encouraging the student to visualize him/her self as a working Engineer.

Logistics and Laboratories

Initially, FIU and M-DCC planned to integrate the computer and mathematics courses with Engineering. Later, FIU decide to integrate English, and M-DCC immediately responded by approaching the English Department for help. Just before the Fall Semester of 1993, a sequence of Introduction to Engineering, and a sequence of English Composition I were reserved for the Gateway Students. Both sequences were offered through the Honors' Department. These changes were made very late, and did not appear in the published schedule. The news spread and, after we had a major mixup with non-Engineering students enrolling in the English course, there are now about sixteen students in each of the two classes. We are now about five weeks into the first offering of this new curriculum, and although the students appear to be enjoying themselves, we are not ready to evaluate the program. Gateway courses will be in the next schedule, and this should help our enrollment. The English Department was not happy with the low enrollment, and shifted the next semester's English to a less desirable time. With over seven hundred declared Engineering majors, several combined sections are projected in the long term, if these Gateway courses become mandatory for FIU.

At M-DCC, students have good access to computers. Engineering shares a brand new computer laboratory with Architecture. There are twenty-four 486 66 MHz machines, with 340 Mbyte hard drives in the new laboratory. Engineering also has two Electronic laboratories with about sixteen suitable 386 and 486 computers. A one credit laboratory is being proposed. This would be shared by English and Engineering, and would have two beneficial effects. First, the students would be able to receive help with their projects and assignments, most of which involve the use of a computer. Both faculty members would be available. Second, it would give the faculty additional time to devote to the course, and to coordinate with the other instructor. Initiating any new curriculum involves a tremendous amount of work. Faculty who are ready, willing and able must first be located. Faculty are paid the same for a Gateway course as for any other, so incentives should be developed for Gateway faculty, especially those in the supporting departments, like English and Physics. The lab. hour may be such an incentive.

Conclusion

After the first semester of the Gateway curriculum, the student will have a grasp of what engineering is and what the engineering process involves. This will give the student a frame work to hang the rest of his/her education on. The aspiring engineer will be less culturally isolated, and more empowered to communicate with the nontechnical population.

Table 1

First Two Semesters Engineering Curriculum

First semester	13+ credits
ENC 1101	English Comp. I EGS 1001 Intro. Engr.
ISC 1010H	Hist. of Science Appropriate math
Second semester	15+ credits
ETD 1330	CAD
Next level of math	
Educational core requirements	

Engineeering Research Experiences for Undergraduates

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Presented by:
John Demel, The Ohio State University

Abstract

Undergraduate research is an activity for undergraduate engineering students that helps meet the Gateway goal of Human Potential Development. It does this by providing a practical experience for engineering students so that they can be involved in doing "Engineering from day one."

From the NSF/ERC perspective, having undergraduates as part of research teams creates a pool of domestic undergraduates that are excellent candidates for graduate school. It also provides the ERC/NSM member companies with direct student contact.

In order to acquaint students and faculty with the benefits and opportunities associated with research for undergraduates that have become an integrated part of the Ohio State ERC, the investigators created a video. The video provides a quick method to inform both faculty and students. In addition, the Gateway Coalition will be provided with the materials that the NSM ERC uses for advertising, organizing, and managing a research program for undergraduates.

Program

Today there are too few of our domestic undergraduate students that are considering graduate school as a viable alternative to going to work in industry. In addition, and perhaps a larger problem, many of our students do not see the role that research plays in the industrial enterprise.

The NSF ERC at Ohio State has been successful in attracting undergraduate students to participate in research activities. Students were first employed during the summer quarter as research interns. Graduate students served as their direct mentors on projects and the undergraduate students became part of a professor's research team. The research teams found that the undergraduates were contributing to the projects' successful completion. As success was achieved additional programs were added to the ERC's annual activities.

These included Research Experience for Undergraduates, a formal NSF program, that provides funds which the ERC uses to attract students from schools other than Ohio State to be part of the manufacturing research. The ERC also sets aside its own funds to hire Ohio State students to participate in research. Both groups become summer interns who work full time for approximately 10 weeks. They are assigned to projects and write progress reports every two weeks. At the conclusion of the project, they write a paper and create a poster 2' by 3' that provides details of the project results in a condensed form. These posters are then framed and hung in the hallways and rooms occupied by the ERC.

The ERC has additional programs for undergraduates. These include undergraduate fellowships and academic year undergraduate internships. The latter require the students to work 20 hours per week with the same requirements as the summer interns with respect to reports. Again the graduate students serve as mentors and the undergraduates become part of the research project team.

At the end of summer quarter, the ERC assembles a resume book with resumes of the current graduate and undergraduate students. This resume book is provided to the 68 companies who are industrial members of the ERC. This affords students and companies with an opportunity to arrange an industrial internship so that the students can take their research experience and apply it to real world problems.

Video Project

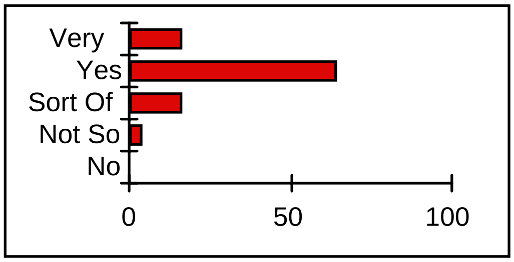
In order to capture the interest of the students and faculty of the Gateway Coalition and the engineering education community in general, the project team proposed that a video be created which would chronicle the success at the Net Shape Manufacturing ERC and at the other colleges in the Coalition.

Video footage and still photographs from the Gateway Coalition members were assembled into a ten minute video. The video shows faculty and students working together, shows research facilities, and provides faculty comments on the importance of undergraduate research for student educational growth.

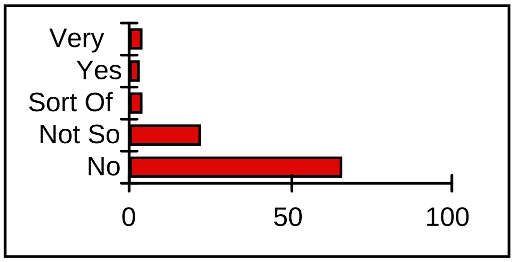
When the video was completed, it was shown to an assembly of undergraduates, graduate students, faculty, and staff. After the showing, the project investigators provided a questionaire which was used to assess the responses of the attendees.

There were 14 undergraduates, 14 faculty and staff, and 16 graduate students in attendance. The first four bar charts below show the question and the percentage responding with Very Much So, Yes, Sort Of, Not so Much, and No.

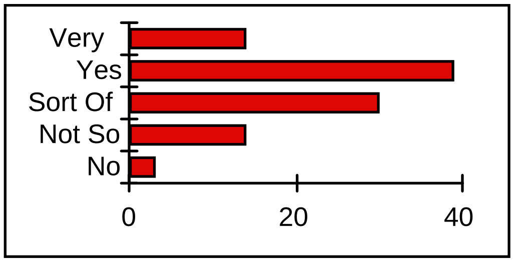
Did The Video Keep Your Interest?



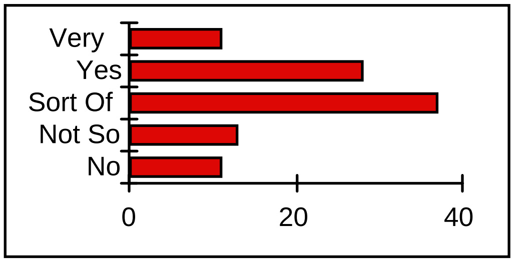
Was The Video Too Long?



Did the Video Represent Student Diversity In Engineering Education?

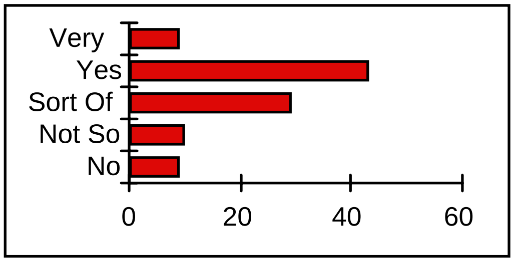


Did the Video Represent Diversity In The Engineering Profession?

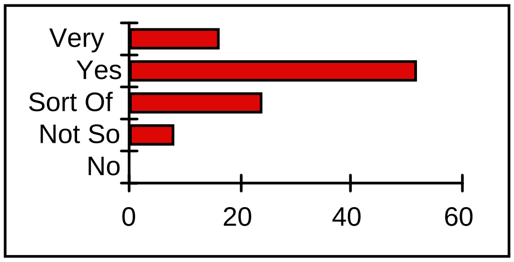


This message was read to the group prior to answering the last three questions. 'The video's primary message was to inform undergraduates that involvement in research during their undergraduate study is important and offers great opportunity for exposure to graduate education.' The last three questions and the responses are shown below.

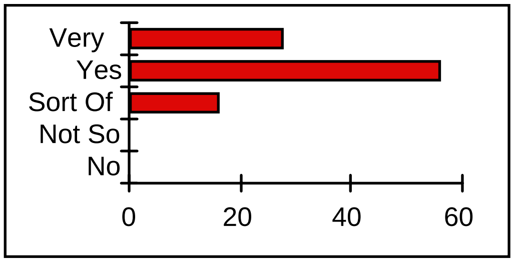
Was the Primary Intent Clear? (26 Responses - UGs + F/S)



Is The Importance of UG Research Clear?



Is The Importance of Graduate School Clear?



Summary

The video is to be distributed to the Coalition schools along with the documentation used by the ERC for advertising their programs, for keeping track of the student data base, for the reporting requirements including the project report and the poster. In addition, selected pages from the resume book are included in the materials distribution so that the member schools can see examples of student projects and typical qualifications. The NSM ERC will be sending the announcements for summer interns to all of the Gateway Coaltion institutions. The NSM ERC has stated that the ERC facilities are also available to the Coalition for activities beyond the formal intership programs. The ERC welcomes cooperative ventures in faculty sabbaticals and short term assignments for faculty, staff, graduate and undergraduate students for manufacturing familiarization.

TEAM Dynamics

Prepared by:
R. B. "Sam" Hilborn, University of South Carolina

Introduction

The major thrust of this program is to augment the classic concepts of Mastery Learning with currently available technology in order to make the instructional process, not only more cost effective, but also more efficient and effective from the learner's perspective. In addition, the basic concepts of Mastery Learning are to be modified for use in a class that has been divided into groups of Learning Teams for the purpose of fostering the cooperative learning process. An additional benefit of this structure is that it affords the students some opportunity to become acquainted with the basic principles of team dynamics, so widely used in industry.

Goals

1. To develop procedures for the effective utilization of technology for Mastery Learning.

2. To develop principles for establishing an environment conducive to the effective nurture of a team culture in the classroom.

3. To develop methods for the rapid and effective evaluation of individual student progress.

Evaluation Approach

Heuristic

Schedule

Event	ecd[6]	Status
• Develop class syllabus	5/15/93	Completed
• Develop criteria for TEAM formation	5/15/93	Completed
• Implement e-mail for: (i) intra- and inter-team communications (ii) student-instructor communications	5/15/93	Completed
• Develop & implement rapid assessment procedures for evaluating student mastery of topics	8/15/94	First principles developed
• Develop application software utilization for maximum contribution to Mastery Learning	8/15/94	Working, but needs tweaking
• Develop procedures	8/15/94	Being studied

[6] Estimated completion date

for the nur ture of a TEAM culture

• Develop methods for student performance evaluation	8/15/94	In progress
• Extrapolation to other classes in 1994	8/15/95	To be initiated
• Project evaluation	8/15/95	Continuous

Project Description

The major program has been divided into three separate, yet interdependent, sub-programs, namely: (i) mastery learning in a team framework, (ii) technological environments, and (iii) evaluation. All three sub-programs will be developed in parallel, as the results in each are highly dependent on the results in the other two.

The following is an outline, by task, of the anticipated effort:

I. Mastery Learning in a Team Framework

A. Create a newly structured junior course in electronics based on the principles of Mastery Learning within the framework of students working as teams.
B. Develop criteria for optimization, from the point of view of learning potential, of team member selection.
C. Develop a data base of diagnostic tests to cover all aspects of the subjects to be learned.
D. Develop motivational tools to promote student interest in pursuing the learning problem within a team framework, as opposed to individually.

II. Technological Environments

A. Development of the pedagogical skills required to most effectively utilize the available technology in a classroom environment.
B. Develop a PLUS, hyper-card like, relational information database as a repository of exams, problems, examples, references, progress reports, demographic information, etc.
C. Develop interactive, computer-based, in-class assessment procedures.
D. Investigate the use of additional technology, such as video tapes and discs, for adoption into the Mastery Learning process.
E. Develop out-of-class modem-based network communications between students and instructor, between students within a team, between different teams, and between everyone and an informational data base that may be networked to a world-wide network.

III. Evaluation

A. The evaluation of this project is to be performed by a quality assessment of its effectiveness in:
   (i) Stimulating student interest
   (ii) Developing student potential
   (iii) Improving student performance

B. The procedures to be used for this evaluation consist of the following:

(i) *Stimulating student interest*: Develop a questionnaire to ask students graduating from this class to compare it with all other UG engineering classes they may have had.

(ii) *Developing student potential*: Compare grades students receive in this class with cumulative, as well as semester, grades they made in other classes.

(iii) *Improving student performance*: Establish competitive inter-institutional design/problem solving competitions, via Internet, as a peer benchmark assessment.

Discussion

The project has been implemented, to date, within the framework of one junior level electronics course. A brief description of this course, including the efforts of this project, follows:

ELECTRONICS II

A Summary of the Course

This course, which has been developed to provide its graduates with sufficient technological and interpersonal skills so as to be highly competitive in today's job market, is structured around a four-fold agenda consisting of:

Advanced Electronics Design Projects
Use of PSPICE as a Design Tool
Development of a Team Culture
Cooperative Learning within a Team Environment

Teams of 4 or 5 students are formed on as equitable a basis as possible using their GPAs and Myers-Briggs personality type indicators as criteria. Although each student is assigned a personal computer in the classroom, all homework and design projects are team efforts producing a single product to be evaluated. Every attempt is made to encourage and promote cooperative learning between the members of each team. Although examinations are taken individually, every student's grade is affected by the success of every other member of his or her team. This is done to help promote the concept of cooperative learning in students coming from a culture based on the competitive development of the individual.

The use of PSPICE permeates throughout in an innovative manner developed for this course at the University of South Carolina. In addition to its use as an effective tool for clarifying the often very abstract physics governing the operation and characteristics of semiconductor devices, PSPICE is uniquely used as a design tool enabling students to perform electronic designs of rather advanced complexity in a very short time.

The extensive use of technology, including telecommunications via e-mail between student team members and between students and instructor, as well as the promotion of in-class team design competitions, has produced a learning environment that tends to develop the student's learning capacity to its full potential. Student graduates of this class appear to be fully competitive with their peers from around the world.

Conclusions

Although not enough feedback has taken place to assess this program, preliminary dialog with the students and with prospective employers indicate a great deal of satisfaction with the implementation of this kind of a course. In addition, early data indicates improved performance for the students graduating from this class over those who have taken the same material in a more conventional course.

Actions Speak Louder Than Words: A Retreat to Promote Community Building

Prepared by
Margaret E. Boulding, Case Western Reserve University
and
William Patterson, Procter & Gamble

In our technological world, the need to have a well-trained competitive work force in the science and engineering areas is critical to our continued success as a world leader. In order to do this, we must identify the best minds and encourage them to work together. This sounds very elementary but it is not easy when you have a population that is a melting pot of different races and nationalities often reluctant to work together.

What are we doing to prepare ourselves and all students to work together in the year 2000? Many of us spend a great deal of time discussing what should be done. Others attend workshops that continue the dialogue about the need for diversity in all levels of the work force. And finally, there are those who just complain about the difficulties the United States is having in managing its changing work force. The most distressing aspect of this situation is that these activities do not give all students, faculty, and staff the opportunity to actually work together and experience true diversity.Why are people reluctant to participate in diversity training with individuals from other racial groups? Are they hesitant because (1) they do not understand or are uncomfortable with cultural differences, unusual customs or actions, (2) they question the benefit or return on the investment of time and money to implement diversity workshops, (3) they doubt that when they return to the work place, they will have gained enough knowledge about people from other races to feel comfortable in working with them in a productive manner? Biases and preconceived beliefs that are based on misinformation create problems that prevent people from working together. For all of these reasons many individuals are reluctant to make a commitment to participate in diversity training.

Another reason that prevents people from participating wholeheartedly in diversity programs is that they may get a negative attitude when asked to attend such an activity. They may feel coerced by their employer and they may think someone is implying that they are racist and need to change.

One suggestion to avoid this type of misunderstanding is to use an activity that is (1) not described as a diversity program. (2) does not just discuss what should be done, but offers all of the participants something that will benefit them, e.g. leadership skills, effective teamwork, unity, trust and respect for each other. Offering a program that focuses on any or all of the above will encourage people to work together as they acquire skills beneficial to each of them.

The following program is a Minority Retention/Development Project that was designed to provide useful training for all students. The students are focusing on skills that corporations want and need. The students are learning (1) to function as team members, (2) to develop leadership skills, (3) to handle stress, and (4) to work with any person to get the job done. The program design includes an industrial partner who helped us with the project structure and will continue to participate in the training programs on campus. The sponsor will invite the students to visit their site and engage in developmental activities that will prepare them for summer internships, co-op, or perhaps a position after graduation.

The corporate representatives working with our program are Mr. William Patterson of Procter and Gamble and five other staff members from P.& G. In addition to the manpower, Mr. Patterson designed the retreat project, recruited the other P & G members to serve as group facilitators, and provided video capability, supplies, and certificates for all of the participants. The P & G support was critical to the success of this activity because the students involved took the project VERY SERIOUSLY.

Mr. Patterson stressed that students must learn to cooperate as well as work independently to maximize effectiveness. It is essential that they start practicing these concepts as a part of their educational curriculums.

CWRU Minority Retention /Development Project

Description: As the enrollment of minority students has increased at CWRU, a variety of sub-groups has emerged. Some of those smaller groups, those based upon students' majors or their current classes, are positive and productive. Others are cliquish and competitive, and they can negatively affect the operations of the Minority Scholars Program and the student associations. Because students who are part of a strong, cohesive support group tend to be more successful in college, we want to help our minority students to become unified and to work together more effectively.

The purposes of this project are (1) to promote community building, encourage friendships, open communication and to develop a sense of unity and shared purpose among participants in Case Western Reserve University's Minority Scholars Program (MSP); (2) to promote teamwork between minority and other students at CWRU.

Objectives: The project will consist of an off-campus, 3-day workshop followed by monthly discussions and activities which will strengthen the concepts developed during the workshop sessions. A second workshop will be held and will include majority and minority students to further expand the concept of unity and community building skills and attitudes developed in the first workshop.

The knowledge gained from this project will show students how they can work together more effectively within their own group and with others. This project should not have any risks for students beyond those encountered in daily living.

Every precaution will be taken to make sure that any information observed or discovered about students will be kept confidential. The workshop will be videotaped for faculty and students' learning purposes in order to observe participants' interactions while engaging tin team work exercises. Prior to participating in the workshop, students will be asked to sign a form giving their permission to be videotaped.

All participants will be CWRU undergraduate students, MSP staff members and other university representatives, e.g., faculty, representatives from Student Affairs. The evaluation process of the workshop will begin during the workshop and will continue throughout the academic year through questionnaires and open discussions.

Project Design Overview

The design basis for the retreat will be experimental with selected cognitive components; that is, the participants will be called upon to "live" the experience and learn from doing versus typical lecture education. The following is a design overview.

Upon arrival at the learning site, participants will be divided into groups of twelve. Each group will be given the same assignment. The assignment is to develop a plan to attract and retain young minorities in engineering curricula. The plan should be detailed and professionally presented. Each group must be ready to give a presentation during the final two hours of the conference. Thirty minutes will be allotted for each presentation. The presentation should represent a consensus of the total group and all group members must play an active role in the presentation.

Each group will have a trained facilitator/observer that will offer comments at "teachable moments" while the groups are working away from the main group. Each group will also be video taped while in session and excerpts from the tape will be used to facilitate learning of the small groups as well as the total community.

During the course of the groups working on their project, planned disruptions will occur. These disruptions will take the form of:

- Selected individuals being temporarily removed from the team if they become too dominant in their leadership style of the group.

- Unscheduled meetings that have mandatory attendance for all group members. These meetings will consist of formal lectures on pertinent topics.

During the final critical stages of the project execution, key team members will be removed from another group. This will give the team members an opportunity to experience loss of leadership as well as the experience of bringing new members on board at the critical phases of a project. The members that are displaced will have an opportunity during the debriefing to share what it is like to join a new group that has established norms. The morning of the final day will be spent debriefing the exercise and extrapolating learnings from the total community.

The afternoon and evening of the final day should be reserved for a recreational activity. FUN!!

Evaluations to determine the effectiveness of the workshop will be conducted in three phases.

- At the conclusion of the workshop
- At mid-term of the first semester
- At mid-year

The students completed evaluations at the end of the retreat. Ninety percent of the participants stated that the activity was excellent or very good. Some of their written comments about the retreat were:

- I learned things about myself that surprised me.

- I learned about others, team, development and leadership roles, I have good ideas. They just need to be expressed more.

- Team development was a lot harder than I thought.

There were three observers at the retreat, Dean Minnie McGee and Ruby Smith of Ohio State and DuWayne Brooks of The University of Illinois at Urbana-Champaign.

The students attended open discussions in November 1992 and December 1992. as a result of the Fall reviewing sessions, the students searched for other projects that would allow them to work together and utilize some of their newly acquired teamwork skills.

The second phase of the Unity Project took place in February 1993 as our students were preparing for Engineers Week. A group of students who had participated in our "Retreat" last fall met in order to plan and implement two projects related to Engineers Week. The first assignment was to make the arrangements to sponsor an engineering competition open to all CWRU students. An appropriate design project had to be identified, publicity had to be arranged, and project materials and prizes had to be purchased. The group's second task was to promote interest among CWRU minority students in Engineering Week activities. In an attempt to encourage minority students to enter different competitions, money for any necessary supplies was made available. The planning group had to decide how to publicize this information and how to distribute the funds provided by industrial sponsors for this purpose. The group's tasks included (1) planning strategies, (2) developing teams, (3) selecting team leaders, and (4) recruiting additional workers with certain skills.

The objective of this activity was to see if the students would use any of the teamwork and leadership skills that they learned during the Unity Retreat.

The students experienced the storming and forming as before. But this time it took less effort to get organized and to select leaders and students who had skills in the technical areas, marketing, and making presentation. There was less friction in forming subgroups and working together. We are eager to develop and implement the next activity with an integrated group of students.

Engineering Education Excellence

Prepared by:
Edward W. Ernst, University of South Carolina

Engineering Education Excellence is our quality first program for the College of Engineering at the University of South Carolina.

The program has been steadily evolving but our idea about what the program should be seems to change even faster. As with most new areas, the more we learn, the more we need to know and the greater the change in what we think and what we do.

The stimulus to pursue a quality first approach to improvement of engineering education came from the College of Engineering Partnership Board, a group of industry executives who advise the dean. There were in various stages of implementing TQM programs in their organizations and were excited about what these had done for their companies. As they felt the approach could help the college, they offered several comments and suggestions that have proved to be very helpful. First, the primary ingredient is education of the people involved. The education should start with those charged with directing the college. For us, that was the deans and the department chairs. Second, although the programs at the various companies have a lot in common, they are also different. You must tailor a program to fit the particular organization and the particular people involved. Don't expect to find an "off-the-shelf" solution you can apply to your organization. Third, one member of the Partnership Board offered to have his company organize a two-day workshop for the deans, department chairs, and a few selected faculty. This was our initial education in quality first programs.

Since that time the faculty involved in this workshop have organized and facilitated several workshops for faculty to help them learn about our quality program. These have been critical in the development of the Engineering Education Excellence program. A separate workshop was organized for the classified staff of the college.

These workshops were intended to develop a common consensus vision of what we were about in the college and to identify some of the major things that must be done if the vision is to be achieved. The specific products of the workshops illustrate these points. (Attachment 1)

The next steps involved recognizing what each of us do, or should do, in each of the key result areas. Discussion of these among the group raises the issues, that is the specific items or problems that must be addressed. From these we select those that are both important and those we can control. For a selected set of these (*high* in importance and *high* in ability to control) we have appointed action teams.

- Recognition and reward
- Focusing our resources
- The design and delivery of the freshman/sophomore program
- Develop and implement metrics for quality in what we do

Each action team included four to six faculty, administrators and, for two of the action teams, a classified staff member. Each action team was asked to:

1. Define the issue

2. Determine what needs to be accomplished within this issue to help achieve the vision of the USC College of Engineering.
3. Develop a plan for resolving the issue and accomplishing what needs to be done
4. Gain approval for the plan from those who must participate
5. Implement the plan.

This was in place by the end of 1992. Since then the action teams have been struggling and making some progress. The plan implemented by one action team was to disband four separate committees and appoint a single committee in the area.

During the past year we have begun to recognize the importance of the customer and meeting the customers needs. However, getting there has been difficult for some. That faculty should seek to understand what students need or what the employer's of our graduates think they want from a new graduate is not easy for some of us to accept. Equally difficult is knowing what to do with the information gained in this process.

As we learn more about how various companies have implemented TQM, we gain new insights into what we can do in the engineering college. For example, Deming, Juran and others note that whatever is done is a process. Each process involves customers, suppliers, and those doing the process. Engineering education is the process and a very important sub-process is learning. In this sub-process knowledge or a skill is gained or a competency is achieved. The primary customer for this is the student. One of the inputs for the process is the student--without the specific learning. Further, the learning is that accomplished by the student. The faculty role in the process is to help the student learn. Using this model for engineering education leads us to recognize that many engineering students have learning capabilities that can and should be improved.

We plan to explore this idea during the current academic year by offering a course to second semester freshmen designed to teach students how to learn engineering material including science and mathematics. The structure planned for this is to introduce students to quality first concepts, identify their learning as a critical sub-process in their education and guide them in finding ways to improve that learning process. Action teams will be formed each composed of students taking the same course. Their goal will be to find ways to improve their learning in that course. Each student will participate in three action teams: one for a math course, one for a physics or chemistry course, and one for an engineering course.

Our Partnership Board noted we should expect no off-the-shelf prescription for TQM that would work for all organizations. However, there are some concepts that our friends in industry have developed that seem useful for engineering education.

1. The focus for quality is satisfying customer needs. This requires that we determine who our customers are and what their needs are.
2. Quality many have several meanings but two of particular importance are that the features of a service or product meet customer needs and that products and services be free from deficiencies.
3. The goal of quality first programs is continuous improvement in what is done in each of the processes and sub-processes.
4. Avoid re-work: do it right the first time.
5. Develop metrics that can be used by those involved in the various processes to determine how well they are doing, and whether or not they are approaching the goals that have been established.

6. Undergraduate engineering education is a process, composed of many sup-processes. Each process (and sub-process) has suppliers and customers. Some processes are internal, in that they serve customers internal to the organization.

An additional insight we have gained during the year is that many of these concepts are not new to engineering educators. Some of them are practiced by faculty judged by their students as excellent or outstanding teachers. It appears we depart from those practices at our risk and the risk of our students. Our best teachers are concerned about what their students need, what they (the teachers) can do to help the students learn. Similarly, they provide the student with ways to evaluate how well the learning is proceeding. They urge and guide the student to do it right the first time. Continuous improvement--the urge to do your best seems always there.

What then, can our quality first programs do for us? Fundamentally, a quality first program is the engineering educator's continuous improvement program. Several of the concepts may be used by a faculty member independent of any knowledge of quality first as it is practiced in other environments or in other colleges, but the record of quality first programs will suggest other concepts with which to develop new approaches to improve further the quality of the engineering education offered.

Evaluation Of The E4 Program - Notes On The Process

Prepared by:
James E. Mitchell, Drexel University

Abstract
A chronology of the evaluation methods used in Drexel University's E4 curriculum revision experiment allows an appraisal of evaluation's impact. Most attention was given to Formative evaluation over the five year duration of the experiment resulting in a faculty desire to continue the process after the completion of the experiment. Quantitative Summative evaluation, performed mostly at the end of the experiment, had its major effect on constituencies outside the E4 faculty group, those deciding whether to adopt the curriculum for the entire College of Engineering. Evaluation of retention, not an original experimental goal, became particularly important in the program's adoption. Journal analysis, having both Formative and Summative roles, gives an excellent "feel" for the impact of the program.

Introduction
Drexel University's E4 program is widely known in the Engineering Education community for its drastic reformulation of the first two years of the Engineering Curriculum. The goals, curriculum changes, and evaluation of the results have been reported elsewhere.[7] [#65] A more detailed look at the process, evolution and uses of E4's evaluation methods may be beneficial for others engaged in similar experiments. The perspective I bring is of a latecomer to the E4 team. My charge was to lead the adoption of a modified E4 Curriculum by the entire College of Engineering.[8] In that role I had to review the evidence addressing not only the program outcomes, but also the costs. I also now teach in the program.

E4 Evaluation Efforts
The E4 experiment is five years old(Table 1). Evaluation of the experiment was planned from the beginning. The actual evaluation process, however, has changed and developed greatly over that time.
External evaluation was planned in the original proposal and carried out throughout the experiment. The major technique was a yearly analysis of selected journals kept by students as part of their humanities course requirements. This analysis was supplemented by interviews with students at intervals during the life of the program, particulary those leaving the program. Broader external evaluation using a variety of standard measures was initially envisioned but was not completed.[9]

Internal evaluation, usually thought of by the participants as "feedback", began with the first group of students. Most important undoubtedly were the weekly meetings instituted and continued throughout the life of the experiment. Faculty and students attended the meetings with conscious intent to evaluate what was happening, to coordinate, and to modify the progress of the courses being taught. End-of-term meetings reviewed overall progress and planned modifications for succeeding terms. Summer planning teams drew on the prior year's

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[7] R. G. Quinn, *Engineering Education (Journal of)* **82**, 196-202 (1993).
[8] Dean Y.T. Shah is the overall leader of the adoption effort. He formed a committee composed of Dr. R.G. Quinn, leader of the E4 experiment, R.E. Woodring, former Dean of Engineering, and the author to carry out the implementation. The author was chair of that committee, with particular responsibility for resource issues and preparation of the plan to be considered by the Provost and Faculty Senate.
[9] The original group of external evaluators parted ways with the development team before any students entered the program. A second external evaluator began work immediately and continued for approximately a year, but then ceased participation as well.

experience to modify the curricula for succeeding years.[10] Humanities professors read the student logs in progress and contributed the insights drawn from those readings to the evaluation process. Term-end student questionnaires provided way-point evaluations of the process and the faculty involved - and led to changes in both.[11]

Faculty also evaluated student performance in terms of project goals through "measurements of laboratory skills; evaluation of performance in several design projects; critiques of written and oral presentations; evaluation of performance in using the computer as an intellectual and professional tool; and the normal evaluations using homework, quizzes and examinations."[12] Quantitative measures of performance were compared to a matched control group. These measures included comparison of retention rates within the university, "on track" progress, and GPA in upper level courses once E4 students rejoined the control group in post-E4 courses.[13] Finally, a comparison of faculty resources required to teach in the "traditional" curriculum and the "E4" curriculum was developed using a detailed model of course credits, contact hours and actual time required per credit taught.[14] This led to a generalized model of the entire five year "traditional" curriculum which could be compared to the new curriculum. FTE faculty requirements for each curriculum, derived from that analysis, were key data for the financial analysis of the impact of the shift from the "traditional" to the new curriculum.

Uses of The Evaluation Efforts

Evaluation is usually categorized as either *Formative* or *Summative* rather than the *Internal* and *External* terminology used above. For an administrator coming fresh to the field, the terminology was initially confusing, but soon made great sense because of its different uses.

Formative Work

The majority of the efforts described above are clearly *Formative* . The major effort during most of the E4 experiment's life was to continually improve it by listening to all participants, then revising the curriculum as appropriate. The weekly meetings, term surveys, planning meetings and understanding of the journal contents were all of a formative nature.[15] [16]
A key, unexpected, outcome of this process is that the faculty involved came to value the formative measures for themselves. In the Spring of 1993 they developed a statement that was unanimously agreed upon by all participating faculty. Amongst other recommendations it strongly endorses the continuation of the formative evaluation steps defined above as a necessary ingredient for the continuing health of the curriculum and involvement of the faculty.[17] This

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[10] Faculty new to the experiment were carefully mixed with veteran faculty to insure continuity of experience.
[11] Op. Cit.
[12] Ibid.
[13] Ibid.
[14] The time analysis was developed by comparing two-week faculty time logs for faculty in the E4 program against faculty teaching in an Engineering department. The data was collected and tabulated by J.R. Weggel, with the comparison drawn by the author.
[15] A similar measure not explicit in Quinn's paper, but often remarked on in his presentations, was the importance of the support staff member, Mrs. P. Christie, who worked closely with all the students. She provided immediate, invaluable feedback on developing issues as well as often resolving the inevitable difficulties of a new and changing program.
[16] Additional formative steps could be undertaken building upon this committment. Outside Evaluator for the E4 Experiment, Elizabeth Haslam, suggests (10/11/93 Memo) that "structured evaluation" take place via "regularly scheduled meetings where faculty, students and administrators reflect on student learning, integrated course work, design projects,logs, etc." These meetings would be different in kind from the regular feedback meetings in their explicit focus on evaluation as opposed to resolving current difficulties. They would beneficially involve an outside evaluator as a participant/observer.
[17] E4 Faculty, Drexel University, E4 Consensus Statement (1993).

conclusion is also born out in the 1993 outside Evaluator's report on Journal Analysis and Faculty Interviews.[18]

Summative Work

Summative evaluation is, in contrast to the dynamic nature of Formative evaluation, a static measure of achievement. It asks "what happened", not "what is happening". The Summative work was indeed performed primarily during the last year of the E4 experiment. Quantitative summative measures were primarily derived from University-kept statistics on student enrollment and Grade Point Averages (GPA's) comparing the E4 students to matched control groups on those measures. Qualitative summative work drew from the four years of journal analysis by the external evaluator as well as structured interviews with selected students and faculty. What follows are comments on the generation of these results rather than their interpretation.

Student Retention Analysis was arguably the single most important quantitative measure of the results of the E4 program. That number was first computed in the third year (1991) of the program. It showed considerable improvements in retention within the university for students who started in the E4 program - whether they remained in it or not. In a private, tuition-driven university that result immediately drew the attention of the Senior Administration and led to their continuing support for expansion of the program to the entire College of Engineering.[19] Of particular note is the fact that retention was not a key element of the original E4 proposal.[20] It is possible that, if the quantification of expected results from the E4 experiment had been firmly defined initially, the retention improvements might have been missed.

GPA Analysis was the second major quantitative result developed. It used the pool of students who volunteered but were not picked "from the hat" as a control group. This measure was extremely important to faculty within the College of Engineering in their consideration of whether to support expansion of the program for all students. Only when the analysis showed similar or mildly superior performance in their "post-E4" years were many of the faculty convinced that the unquantified aspects of the program (superior communication skills, teamwork, laboratory experience, problem solving) justified the change in curriculum. For those embarking on similar efforts it is worth noting the benefit of keeping good records and planning the analysis from the beginning. Considerable extra effort was necessary to document the control groups when the GPA analysis was performed in the final year.[21]

Journal Analysis was probably not highly important as a Formative evaluation tool, though that possibility existed since the analysis was prepared yearly. Its appearance during the summer, when faculty minds were on other matters, probably contributed to its relative lack of impact. However, the impact on faculty and others not involved in the E4 program of the student experiences, thoughts, fears and triumphs was extraordinarily potent. Experiment Leader Quinn repeatedly used these quotations to illuminate concepts such as *curriculum integration* or *laboratory experience* by direct quotes from student logs. For those few willing to devote the necessary time, reading the evaluation report's carefully organized themes (presented primarily in the students own words) conveys, as no statistic can, the impact of the program.

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[18] E. Haslam, Drexel University, Outside Evaluation Report for the E4 Program 1992-1993 (1993).

[19] The University has formally adopted, as part of its strategic plan, expansion to all Colleges of the "E4 Principles" .

[20] E. Fromm, R. Quinn, An Enhanced Educational Experience for Enginnering Students (perspectus for a program funded by NSF) (1988)

[21] A related issue is that when the program expanded to 200 students in 1992, there was not a sufficient control group. A valid group had to be created retroactively by defining a pool of students with comparable SAT's and HS GPA's. They were not, however, volunteers as were all prior control groups.

Faculty Load and Financial Analysis . The original E4 proposal made no projections about cost, expandability or other issues. Proof of the concept was sufficient. Nonetheless, when the academic and retention success of the program was becoming apparent, these issues needed to be addressed. As mentioned above, this was achieved by modeling the program - using class size, faculty teaching load, and teaching assistant requirements compared to those of the "traditional" curriculum. In addition, the E4 faculty generated workload data that allowed preparation of a plausible analysis of the additional effort to teach in the new mode. In combination with the retention statistic this allowed development of a financial model showing the net revenue effect for the university created by shifting to the new curriculum.[22]

Evaluation Efforts Not Carried Out

A number of evaluation efforts considered as desirable during the initial planning were not carried out. In particular, no standardized tests of any sort were given to the E4 and their control groups. There were initial plans to use such tests as the Torrance Tests of Creative Thinking (TTCT) as well as other measures to evaluate changes in appreciation of social issues etc. These hopes were not carried out for two reasons. In the single effort to carry out such a comparative test, no way was found to involve the control group students. Secondly, the working relationship with external evaluators skilled in these areas did not develop fruitfully.

Consequences of Choices for Evaluation Efforts

As mentioned above, less attention was devoted throughout the E4 project on Summative than to Formative work. Given the extraordinary effort necessary to define, organize, commence, modify and then expand the curriculum this balance is unsurprising. Nonetheless, there were consequences to the decision which are worth noting.

With an innovative, expensive program which was assumed to require considerably more faculty effort than the "traditional" mode of teaching, there was bound to be a high level of questioning about the merits of the new curriculum. These questions naturally led those not immersed in the program to say "show me". In an engineering school particularly, the desire is for "numbers" to prove the worth of the experiment. For most of its life the E4 program produced few generally accessible numbers. Faculty involved were enthusiastic, but couldn't document the basis for their enthusiasm. The outside evaluator's yearly reports analyzing journals and interviewing selected students bore out the promise of the program, but produced no "hard numbers" to allow comparison to the traditional program. This lack of numbers, combined with a minimal general communication to the university community about the program, led to mistrust both within the College of Engineering and the wider university. Only in the final year of the program, as expansion to the entire university was contemplated, was a major effort made to generate numbers that could convince those wanting quantification. Those numbers indeed bore out the more qualitative conclusions and greatly aided adoption by the entire College of Engineering.

Conclusions

Coming late to such a large undertaking as the E4 program I struggled to understand what it accomplished. In the process I learned that evaluation was far more than a "final grade". Careful formative and summative work were vital first to the creation of a new curriculum and then to its formal adoption. I also learned that it is probably impossible to predict the final outcome well enough to fix the evaluation measures firmly before the process begins. Using open-ended processes such as weekly meetings and journal evaluation allow the unexpected to emerge and become accepted. That these are non-quantitative measures does not belie the importance of

[22] In fact three scenarios were considered, for "Maximum", "Medium" and "Minimum" additional effort required. All three showed a net increase in University revenue.

quantitative measures as well. Those, I realized, can justify the program to those outside it having limited time and restricted interest.

More specifically I believe the following are significant lessons which may help others undertaking similar efforts:

- Formative evaluation was essential to the operational success of the E4 program. It is perceived as so beneficial by faculty participants that it will continue as the program becomes the standard for the entire College of Engineering. It is doubtful that this degree of importance was originally foreseen.
- Student journal analysis provided both formative and summative evaluation. Its major impact, however, was probably in the vivid impressions that student writing gives to an outsider becoming acquainted with the E4 program.
- Early identification of a control group and attention to record keeping of at least standard statistics such as GPA's and university status is almost certain to be beneficial in summative work on curriculum reform. In the E4 Program student retention and GPA standings compared to control groups were vital in convincing the University community of the E4 program's success. The retention analysis was of particular importance to University Administrators, yet was not originally contemplated.
- Others engaged in similar experiments would be wise to be sensitive to unexpected outcomes which warrant changing evaluation plans or emphasis.

Acknowledgment
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Table 1 - Chronology

Fall ‘88	E4 Proposal Prepared - Including Evaluation Plan
Winter ‘89	E4 Proposal accepted
Spring ‘89	New Curriculum development begun
Summer ‘89	New Curriculum for first year completed
Summer ‘89	Advisory Board Critical of Evaluation Plan
Summer ‘89	Original external evaluator relationship terminated
9/89	Evaluation Plan proposed by 2nd external evaluator
9/89	First 100 students enter
9/89	Weekly faculty-student meetings begin & continue through entire experiment.
9/89	Control group identified from those volunteers not (randomly) selected for E4.
9/89	Students required to keep journals. Selected journals for entire year analyzed for themes by 3rd external evaluator (Haslam).
Spring ‘90	Attempt to test E4 and control groups unsuccessful due to inability to attract control group students.
9/90	Second 100 students enter. Control group, journals and meetings continue as in first year.
5/91	Survey of Freshman Opinions on Course
7/91	Journal analysis of 2nd 100 students
9/91	Third 100 students enter. Control group, journals and meetings continue as in prior year.
Summer 92	College of Engineering curriculum revision begun - based on E4 experiment.
9/92	Fourth 200 students enter. Control group formed of those with similar SAT and HS rank.
3/93	Retention & GPA Analysis
7/93	College of Engineering unanimously votes for new curriculum
9/93	Fifth 300 Students enter program.
10/93	Submit new curriculum proposal to University Faculty Senate. Resource requirements analysis included as part of proposal.
9/94	Planned date for all entering Engineering students to enter the new curriculum

References

[1] R. G. Quinn, *Engineering Education (Journal of)* **82**, 196-202 (1993).

[2] Dean Y.T. Shah is the overall leader of the adoption effort. He formed a committee composed of Dr. R.G. Quinn, leader of the E4 experiment, R.E. Woodring, former Dean of Engineering, and the author to carry out the implementation. The author was chair of that committee, with particular responsibility for resource issues and preparation of the plan to be considered by the Provost and Faculty Senate.

[3] The original group of external evaluators parted ways with the development team before any students entered the program. A second external evaluator began work immediately and continued for approximately a year, but then ceased participation as well.

[4] Faculty new to the experiment were carefully mixed with veteran faculty to insure continuity of experience.

5 Op. Cit.

[6] Ibid.

[7] Ibid.

[8] The time analysis was developed by comparing two-week faculty time logs for faculty in the E4 program against faculty teaching in an Engineering department. The data was collected and tabulated by J.R. Weggel, with the comparison drawn by the author.

[9] A similar measure not explicit in Quinn's paper, but often remarked on in his presentations, was the importance of the support staff member, Mrs. P. Christie, who worked closely with all the students. She provided immediate, invaluable feedback on developing issues as well as often resolving the inevitable difficulties of a new and changing program.

[10] Additional formative steps could be undertaken building upon this committment. Outside Evaluator for the E4 Experiment, Elizabeth Haslam, suggests (10/11/93 Memo) that "structured evaluation" take place via "regularly scheduled meetings where faculty, students and administrators reflect on student learning, integrated course work, design projects,logs, etc." These meetings would be different in kind from the regular feedback meetings in their explicit focus on evaluation as opposed to resolving current difficulties. They would beneficially involve an outside evaluator as a participant/observer.

[11]E4 Faculty, Drexel University, E4 Consensus Statement (1993).

[12] E. Haslam, Drexel University, Outside Evaluation Report for the E4 Program 1992-1993 (1993).

[13] The University has formally adopted, as part of its strategic plan, expansion to all Colleges of the "E4 Principles" .

[14] E. Fromm, R. Quinn, An Enhanced Educational Experience for Enginnering Students (perspectus for a program funded by NSF) (1988)

[15] A related issue is that when the program expanded to 200 students in 1992, there was not a sufficient control group. A valid group had to be created retroactively by defining a pool of students with comparable SAT's and HS GPA's. They were not, however, volunteers as were all prior control groups.

[16] In fact three scenarios were considered, for "Maximum", "Medium" and "Minimum" additional effort required. All three showed a net increase in University revenue.

Sunday, October 17, 1993

Session III Discussion

John Demel, The Ohio State University & Jacob Abel, University of Pennsylvania - Facilitators

John Demel, OSU: One of our faculty members left Ohio State for six months and went to work at Honda. When he came back he said: "I have learned something. The only Accords that leave the line are "A"s. They are not "B+"s or "A-"s or "C"s. They do not leave unless they are "A"s." Is that a challenge for us? Right now we are on a time-based learning mode. What I have heard today in the areas of Human Potential Development and Educational Technology & Methodology is a chance to move from a time-based to a content-based approach. Those are my comments to start off with. Dr. Abel, it's all yours.

Jacob Abel, U. of Penn: John and I, being the last provocateurs, will try to be provocative and take advantage of the fact that we are at the end of this meeting. I would like to make some observations about everything that I heard and saw during these last three days. Some of it is evaluative and I hope all is provocative.

It seems to me that the connectivity of our activities is improving. It needs to continue to improve. In some respects we have moved from "not invented here" to "do it my way" and that is a little growth but I don't think it is enough.

People have heard me say this and I am going to take the opportunity to say it here publicly: we need to get something "on the rails" in Human Potential Development.

With respect to all of the curriculum development activities, the issue of how to evaluate is still dogging us. I am the first to confess that I was not trained in the evaluation of educational development projects. I was not even trained in how to teach, as I think most of us will admit. Evaluation is still a big challenge for us.

Looking at the first year activities, because of the way we were formed and the kind of activity range that grew and developed, the projects tended to be single school projects with few exceptions. Yet, if you look at all that was done in the first year, there is a coherence of vision that is very clear. There is very strong agreement, that goes beyond the borders of Gateway, that design in the first year is extremely important, effective and valuable for our students. Rediscovering the "hands-on" laboratory and providing more opportunity for true discovery rather than obeying dogmatic, dictatorial protocol has proven to be a better experience .

From a structural, managerial point of view, we launch our projects at the beginning of each anniversary year. I spent my first ten years in the Space Industry and I learned about mid-course correction. When planning Apollo missions, for example, we often had to ask: "What are the possibilities for mid-course correction?". It seems to me that in a project of this scope, we ought to be capable of mid-course correction. We should be able to modify projects on route to cut projects on route, and to enhance projects on route. When something really looks good and our interim evaluation is positive, we should be able to strengthen it and move ahead. If there is something that you saw at this conference that is exciting and attractive and you are not a part of the multi-institutional project, there should be a way that you can get "on-board" before the anniversary. We need that kind of flexibility in our management structure.

We do not seem to capitalize on tremendous resources in every one of our schools: our undergraduate students. I do not suggest for a moment that we abdicate our authority but everyone who has experience with bringing undergraduates into the process of developing material, creating courseware, et cetera. knows that they provide a tremendous energy and they are a good, low-cost resource that could be brought into these developments. Some of that is going on but I think we have been missing the boat. My own experience is anecdotal but it appears that once you get undergraduates to do more than tell you what is good or bad about a course but to help you create the new materials, it really pays off. It is, also, wonderfully cost effective.

I think we need to do more outreach. There are more community colleges in America than those located in Dade County. This is a tremendous challenge to the entire technical educational enterprise in the country. I think that every school in the Coalition should be getting organically linked with at least one community college.

Something else I heard today from the Florida people made me think. Gateway is centered in five major urban centers. The model which I found very exciting was their outreach which has percolated all the way down to the high school. Elements of that model are in place at all of our major centers but I think that Gateway could provide a template so that we are active in all five of those urban centers in much the same way as in Miami.

With regard to the NACME presentation, I am very interested in the fact that the Aston research was cited. The factors that contribute to the loss of students are, of course, known. Aston identified factors that contributed to the retention of students. On top of that list was undergraduate research, either required or optional. In regard to the Diversity Seminars, one of the problems I foresee is that they may have a negative tone ("don't do this, don't do that"). I would like to see some focus on those things that are identified as contributing to retention. I think if you do those ten factors that the Aston identified extremely well you would be avoiding the ones that contribute to the loss.

In terms of Total Quality Management (TQM), we talked about reforming the culture of the institution. People said that there would be obstacles to it. But, these are times of tremendous threats. People said that there were "barbarians at the gates". Sometimes, times of upheaval are times that we can actually make things happen.

The last comment I have is about the Daulton School experience. The Daulton School differs from our institutions, other high schools, other private high schools in ways that are innumerable. I stagger at the prospect of applying that which can be done in the Daulton environment at other places on the planet. This is not to say that it is not good, or wrong, just that I am very familiar with the school. My roommate's wife is director of admissions for Kindergarten there. They have an acceptance rate that is lower than any college in the U.S.

Elizabeth Pittenger, FIU: While this has been going on, there has been an underground movement taking place here and I would like to announce some potential results of this underground movement. Gerry Milano and I have agreed that we think that the newsletter is important enough to put our heads in the noose. We already have some ideas and before you leave we will be soliciting, in writing, your input in response to some issues that were raised at the Gateway meeting. We intend to address Gateway because we see it as a philosophy not a curriculum. We want to get an exchange going and we want to involve people from as many schools and levels at Gateway that we possibly can including the junior colleges and NACME. We see our students also being regular contributors. I will be actively after you. I have two copies of the directory and I will be soliciting for articles. You are invited and you will attend!

Eli Fromm, Gateway Central: Ms. Pittenger, your proposal is greatly appreciated and accepted. Please work through Andrea and Ed. We will see to it that the mechanical details are taken care of. Your roles clearly are beyond the mechanical details and that is really the important part. But, as I said the other day, we need to get input from everyone to be successful. Which brings me to one other point. We have heard here that things are going on at our institutions that are not known to everyone. That, of course, is one of the purposes for having this meeting. But there are also many other faculty who did not attend the meeting. Somehow, we have to communicate beyond this group.

There are, also, many of what NSF terms "deliverables" that have been accomplished. Some of those are at the point where they are second or third generation deliverables. In fact, there are some items that we could have called deliverables six months ago. I would like to see us share them, as much as possible. However, from a pragmatic point of view, and please realize that I don't want to add roadblocks or bureaucracy, we need to recognize that we must record how much sharing occurs. We must be able to report to others on how much interest there is in these activities. As I envision it, Gateway Central serves as the communication link. Please keep us informed of what you are doing. We will put together a list of materials that are available, and distribute it. Through the individual IAL, who is a central point of contact at each institution, we will then provide requested information to you. I promise that it will be very quick. Either we will make copies and distribute them or we will communicate to the source of the requested information and ask them to send it to you. Then we will be able to keep track of the activity level. This is important because interaction is one of the measures that, from a Coalition point of view, we will be evaluated by. I very much would promote the notion of direct linking if we did not need to have this accountability. I hope that you do communicate to the greatest degree that you can. However, keep us informed so that we can record the exchanges of material.

John Morse, USC: You had better start counting, because exchange is already going on.

Eli Fromm, Gateway Central: I know. On the one hand, I am pleased from a functional point of view with activity within the coalition. I am also, however, troubled by the fact that I cannot report it in the annual report.

Christine Gabriel, NSF: I am the person who has to write all the reports to Congress for the Engineering Research Center Programs. I have had quite a bit of interaction with Congress over the past few years. If I can stand up and show view-graphs that illustrate the kind of things that go on and everyone can see and understand them, I can have a great impact. One of the most important things that you can do is to prepare a presentation on what you are doing so that the people in the audience can be engaged in what you say and really understand.

Ian Davis, FIU: I think that I am a minority of one here but I would like to make what I consider to be a very important point. When I heard the word "media", my ears pricked up. It seems clear to me that we should be seeking press coverage on what we are doing. For example, we should summarize this meeting and prepare a two minute "sound bite" and attempt to inform a broader audience than our own engineers.

Christine Gabriel, NSF: It takes a great amount of time to put something like that together and have it come out well. It takes much time to put a newsletter or a talk together, if you want it to be effective.

Menburu Lulu, FIU: Regarding the issue of Quality Assurance and Evaluation, I am not really clear on how we are going to actually do evaluation effectively. Is there any intent to standardize the efforts?

Edward Ernst, USC: We are still inventing as we are going along. I don't see how it can be standardized. I think that there are some ideas that can be borrowed and suggest that you could use those to begin to develop your own standards.

Menburu Lulu, FIU: I am talking about directions, not about buying off-the-shelf, "canned" products but directions.

Edward Ernst, USC: It seems to me that we are still in the stage that we should listen carefully to what others have been doing to see if we can find somebody among them who can help us. I am not in a position to know enough about FIU to be able to tell you what things might work there, even given my experience.

Elizabeth Pittenger, FIU: There is a danger, if we have a five year period to create a new way of educating engineers, in trying, within the first year or two, to standardize some of those ideas already. We will probably stultify creativity and deny ourselves opportunity to actually do something new if we begin to standardize the very first attempts early on in the program.

John Demel, OSU: We don't want to destroy creativity. I would like to make an additional comment, as I look back over the last two and a half days. We, as engineers, tend to act upon how we sense that our students learn. It is interesting that we are supposed to be very objective, practical people and yet we tend to sense what we think needs help. We are acting upon that sense rather than really having a way of knowing. Does anyone have any thoughts on that?

John Morse, USC: I noticed that at the end of Dr. Abel's comments the last thing he said was almost identical to what John Demel said in his earlier comments. That is, it is possible for us to rip engineering education up by the roots and shake it up and say: "Maybe we are not doing any of this the right way. We are letting engineers with a "C" average out and turning them loose on the world. While Honda only lets out cars that work.". We have bandied this idea around at the University of South Carolina and I am sure that it has been talked about at other places. Are we really doing this all wrong just because this is how we have always done it? We set some period of time in which the students are going to learn X amount of material. Then, we test them on it. There is some standard that they must exceed to pass. Is there another way to do it? What if we said: "Here is the standard; this is the "A". You have to be this good to get out of the factory. If you can jump over it the first week, then you move on."?

Robert Mills, OSU: A human being is not a car. That is an important difference.

Eli Fromm, Gateway Central: On the other hand, there could be ways to evaluate the individual that are different than the ways we have been doing it. The difficulty is that, except in rare instances, the College of Engineering is not the university. Therefore, the larger community of the university must be willing to buy into a different way of making these measures, or, at least, be willing to allow segments of the university to try a different way. I think the problem with the issue is that it is not in the control of the engineering community. Certainly, if the engineering community wants to achieve that end, the first obligation is to define what they want to do and how they expect to do it before they can expect anybody else to accept it.

George Staab, OSU: With regard to John Morse's comments about the need to set up certain levels and standards, that is similar to the way that many medical schools operate. The students go in for their education and when they think that they are ready for an exam, they take it.

Mark DeGuire, CWRU: To pick up on the car analogy and maybe stretch it a little bit, we don't produce just one line of cars. Some of our products are Maseratis. Some are Yugos. Some are mini-vans. The analogy troubled me, at first, because I thought: "Why can't we produce all of our engineering students as good as an Accord car." But now I am not so troubled by it because we do produce a few Maseratis. Which is not to say that a Yugo, for the money that you pay for it, won't get you from point A to point B.

John Demel, OSU: The difference is that we produce, through the educational process, an intelligent product that continues to improve and learn. A Honda is as good as it is going to get when it leaves the factory.

Elizabeth Pittenger, FIU: I would like to make two quick points. I think that we have discovered many things here today. In fact, for engineers, you have flabbergasted me with your ability to be flexible. The first point is the same point I raised when I went to USC as an underground rebel. I am going to continue that role. Becoming an engineer is not a linear process. It is a recursive process. Engineers should be life-long learners. You want to teach people to become life-long learners. The second thing that I see here that is very important is that you are grappling with the basic issue: what is wrong with the country? And what is wrong with the country is that we do not value work. We value only dollar signs. All of the complaints that I hear, as a person who has purposely stayed out of the loop of having to be measured by the value of a dollar for what I do, is that you are shackled by the demands of the wrongness of the system. That you are identified and defined by your dollar value to the institution you work for rather than by your process value, for your teaching. I urge you to join the underground.

Sam Hilborn, USC If you change your evaluation processes you must make sure that the rest of the world knows what you are doing. Twenty-odd years ago, the University of South Carolina, for a very legitimate reason, decided to change how they were going to evaluate students. Industry could not understand it. When NCR, for example, wanted to pick a 3.2 GPA, they could not figure it out. We had to choose because the rest of the world could not understand how we were evaluating. It made sense to us but it didn't to them.

Menburu Lulu, FIU: The idea is not really to make cars. What Sam Hilburn is doing is basically designing new learning strategies. Honda has "A" cars not because of the cars. It is the manufacturing process that is "A". Our teaching and learning strategies must be "A".

Lucy Puello-Capone, DCPS: I am happy that Mr. Lulu said that. Because as an outsider here, I am an Educator and not an Engineer, I am going to ask you this question: How important is the teaching methodology in this whole restructuring process? You are changing curriculum, changing diversity, changing course design and yet, by your own admission, the faculty say, "I've done it this way for thirty years, what is wrong with it?".

John LeMee, Cooper: Perhaps we could re-think the function of the school of engineering. As a nation, do we need them?

Christine Gabriel, NSF: Yes, I think we need them.

John LeMee, Cooper: Perhaps we do but there are chief engineers in Russia and Western Europe that we could get for a small percentage of what we pay here. In fact we can have a Russian engineer for about $40/month.

Christine Gabriel, NSF: Are they going to be creating new technologies that are going to generate good high-paying jobs for Americans?

Eli Fromm, Gateway Central: I am going to interject here. We do not have too many engineers! We may have too many people who perhaps are hired for the purpose of being an engineer but we are not graduating too many students that are educated in engineering. There are many fields for them to go into. One of our problems, in this country, is that we don't recognize that.

John LeMee, Cooper: You are quite right. The more people trained in that field the better. But we have to think that we are not training engineers. We are educating people who then become engineers. But they are not just engineers. If you look at other countries (France, for example) the most prestigious schools are the schools of engineering, not the schools of law. In the school of engineering, they receive very good training in thinking, reading facts, assimilating facts, analyzing, etc. These are the people who find their place in high positions.

Ted Scheick, OSU: My thoughts are tangential to what other people are saying. We have a pretty good reputation in this country for producing really creative engineers. I think we do. We must be doing something right. I am sure that it is not perfect. I hope we don't just throw everything out but I do like re-examining things. On the matter of teaching students, they all have their own personalities. I have my own personality. Often, I present my students with tasks or challenges and they come back when the light bulb has gone on. I am sure that they all do that in their own way. There is not one way, there are not a hundred ways, there are probably a million ways . That is something I can only try to stimulate and I cannot learn every way to turn that light bulb on. Also, there has to be something that is left to the student. For my self, I really have enjoyed this conference because I have learned new ideas, new viewpoints and many things that I want to try. On the other hand, some things suggested here will not work for me because of who I am. I cannot make myself into an expert over night. One must adapt and do sensible things.

Dario Gasparini, CWRU: I think there are other people in other professions that we should also look at. We should look at their models. What models are physicians, business persons or lawyers using? I think we have something to learn from those professions. I think we should not only be speaking about ourselves but exploring and seeing what those other professions do. I would have enjoyed a session here with an educator of physicians. Also, another aspect that we never addressed is leadership. I think we have an opportunity, an obligation and a responsibility to create leaders. I have not heard very much in this conference regarding what leadership training would give to the students. I have heard how to train them technically and how to make them good readers and writers which are very important. But, I think, engineers have a need to become leaders. Because often they compete with lawyers, medical doctors and other people for resources. So I tend to agree with the gentleman from Cooper Union that we can learn something from French education. I am not saying to be elitist. I don't like that. But, you can learn something about how they treat their leaders and how they view engineering as a possible means of preparing leaders. For example, I would be interested in hearing the viewpoint of a person from Dade County on why engineers are trained in four to five years and why physicians or lawyers are trained in seven. Why do you think that is, historically? Do you think that it is appropriate?

Lucy Puello-Capone, DCPS: Remember I am involved with K through 12. The biggest factor is that everything we have ever done in K-12 education is dictated from the top down. Much of it is dictated by what the university or post-secondary institutions want the students to be taught. What happens, when a process like the one we hope we are going to establish with FIU and Miami-Dade, is to link that knowledge. We are developing a "feeder" pattern for the elementary, middle and senior high. We hope that by the time they get to fifth grade, they are ready, for example, for Algebra II. What would that do to speed up the process? Quite a bit. Needless to say, everybody is not welcoming the Magnet Division for being so innovative. However, if we do it, maybe your question will be answered.

Sunday, October 17, 1993

Closing Remarks

Eli Fromm, Gateway Central

First, I want to thank everyone for participating and again thank Andrea and Ed for their efforts in putting it all together.

I think the discussion we have had for the last half-hour or so was a very good one. The first two days were not quite as provocative. I was not as bold as I first was going to be because I was concerned that, coming from the Director of the Coalition, my comments might offend some people. I am pleased that we had this level of discussion today. Some of the issues raised really deal with broader societal issues. The purpose of our meeting was to bring people who are working on Gateway activities together to share their efforts and to learn from one another. I think we have done that quite successfully. Some things, as I said yesterday, I feel good about and some can use improvement.

The broader societal issues are clearly there and are extremely important. To a small degree we went through this kind of a debate at a Governing Board meeting three months ago, when we had to face the issue of prioritizing activities because of limited resources. One example was coming to the conclusion that while we felt that it was extremely important to deal with human potential development (HPD), we just cannot "do it all". We cannot divide our resources (people and funds) too thinly and succeed. Therefore, we decided to narrow certain foci. In HPD, we decided that where we could probably have the most impact is in the important areas of transition from 11th or 12th grade into college, and the college environment. We also had the issue raised at our National Advisory Board meeting. Some wanted us to place some special emphasis on grade school issues but we felt that we would be in danger of trying to do too much with a limited budget. We are narrowing down in certain respects. I think that the points raised today, suggesting that we need to look at much more than curriculum, are certainly true. We have been saying that all along. I hope more and more people hear it. I hope that at the next meeting, we begin to put the presentations in the broader context of the educational experience of students rather than just what is going on in a particular course.

A question was raised about how important the teaching structure and methodology are. They are the raison d'être of our work. If you look at some of the initial work, (such as the E^4 experience in which the idea of using journals, the team work of both faculty and students teams and the concept of a team of faculty dealing with students and staying with them for the entire year) these are all different ways in which we are attempting to improve the educational experience. Also, there is the notion of integration. That is, to change from the sequential or layered concept of teaching math and science for two years and then teaching the professional disciplines to an approach that blends them together continuously. Those are all structural changes that are taking place. In different ways, they are taking place at all of our institutions. But each has a slightly different approach.

That leads me to another point I wanted to make. Jacob Abel raised the issue of perhaps standardizing the ways in which we do some of our activities. I don't

think we are ready for that yet. We are not ready to standardize a process that is still an experiment in its infancy. Maybe eventually, several standards will come out of that experiment. I think it would be a mistake to try to standardize on many processes including evaluation. I think we have to try many different ways. In fact, we may find that, due to the setting and institutional culture, certain methodologies may work better than others in specific institutions. I think we need to have a knowledge base of many potential ways to achieve a given objective. Then we can select from them, experiment and inform one another of the results. That is the important thing.

We do have the means to make what Jacob Abel referred to as mid-course correction. We have set some time on the agenda of our next Governing Board meeting. Reallocation is not a simple task but there are opportunities and at our next Governing Board meeting we should be looking at modifications to our plan for year two and beyond.

I am glad to see that we do have cross-institutional teams. We need more of them. There are still too many stand-alone projects. As Dr. Abel said earlier, most of the single institutional projects tended to be those supported in the first year and that was a function of how the first year was started. I think that there is now a widespread recognition of the need to have multiple-institution programs. The important reason for that is acceptance. It was the most difficult thing that we experienced at Drexel. It is not in the nature of most faculty to just take what somebody else has done. A textbook may be an exception but even then they don't replicate it page by page or chapter by chapter in the same order. The way around that, obviously, is for the group, collectively, to evolve the curriculum or the educational program. Then everyone has pride of ownership. That is the mode of operation that we wish to adopt.

Christine Gabriel, NSF: I know that I have talked too much today but I wanted to say a few things. I think that people are looking at the fact that this program was set up to accomplish certain goals. They are going to be looking at whether the Coalition, as a group with the money that it had, accomplished more than would have been accomplished by individual institutions with individual grants. They are probably going to be looking at what other individuals and small groups are doing across the country to determine if they are accomplishing the goals of this program better than you.

On the issue of standardization, if you look at the engineering curriculum as it exists you would say that there is a standard curriculum. Yet every school is completely different. As I understand it, ABET gives a "yes"" or a "no". There is no ranking of the school. So I think the issue of standardization is moot.

Finally, those of us who are engineers, especially experimental types who build things, realize what happens when you have some idea of what you want to do. Usually, you build it the first time and it doesn't work. You figure out why; correct it and it still doesn't work. You go on like that until it does work. I think that is what you are doing here. You are engineers and you are trying to develop a new curriculum. Rather than sitting around and intellectually deciding how to learn, bringing psychologists in, etc., you are saying: "Here is a theory, let's try it". You have assembled a group of creative people to try many different things to see what works best.

Mark DeGuire, CWRU: I am an empiricist. Rather than start with a theory, I would like to run a test and see if it works.

Elizabeth Pittenger, FIU: My training is also in science. One of the beautiful things about science is the value of negative results. I think that just because something does not work, does not mean that it has no value. We do learn from failures. Sometimes, we should be encouraged even by things that we have, as engineers, labeled failures.

Eli Fromm, Gateway Central: One final comment to clear up a matter that we discussed earlier. Deliverables are all kinds of things. Even the set of view-graphs that were used at this conference is a deliverable. The outline for a new structured curriculum is a deliverable. The deliverable for a project, to restructure the curriculum, for example, should not be defined in your eyes as only the final curriculum. Interim products should be delivered to us at Gateway Central so that we can begin to assemble the results of your efforts and to describe them in the annual report. Our results should be reported as a collective group based on the concepts and themes that our program is pursuing and we need interim deliverables to do this properly.

Once again, thank you all for your participation. I look forward to the next Gateway Coalition Conference