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The Freshman Engineering Program at the State University of New York at Binghamton

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Abstract

The mission of the freshman-engineering program at the State University of New York at Binghamton is to provide incoming students the skills necessary to succeed in engineering. The program has four main thrusts: academic instruction in the two semester introduction to engineering sequence, an evening tutoring effort, an ongoing collaborative review of the freshmen year experience with faculty from mathematics and the sciences and linkage with the Binghamton Success Program, a federally funded effort to support students from underrepresented groups in engineering. Each of the four elements will be described with attention paid to assessment and planned future directions and developments. The program has changed dramatically over the course of the last two years and has witnessed both successes, and to a lesser extent, several failures.

Introduction

One of the innovative features of undergraduate engineering education at the State University of New York at Binghamton is the common freshman year program, administered by the Division of Engineering Discovery and Design. Students are not required to select a major area of emphasis (i.e. bioengineering, computer, electrical, mechanical, system or industrial engineering) until the end of the freshman year. The mission statement of the freshman-engineering program is to provide incoming students the skills necessary to succeed in engineering. The program has four main thrusts: (a) academic instruction in the two semester introduction to engineering sequence; (b) an evening tutoring effort; (c) an ongoing collaborative review of the freshmen year experience with faculty from mathematics and the sciences; and (d) linkage with the Binghamton Success Program, a federally funded effort to support students from underrepresented groups in engineering.

The present work will provide detailed information and a careful assessment of the various elements of the freshmen year efforts over the past two years and end with a description of the planned future directions and developments.

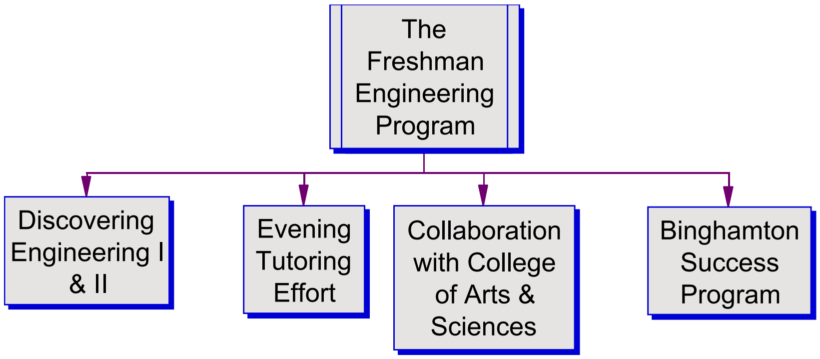


Figure 1. The Freshman Year Program at the State University of New York at Binghamton

Literature Review

Freshman engineering programs can be categorized using many different schemas. For the present work, the following model is offered: (1) Introductory lecture or seminar format; (2) "Skills-based" program housed in a separate department; and (3) "Project-based" model, typically placed in the context of a common freshman year enrollment. Each approach has its own set of strengths and weaknesses. As the State University of New York at Binghamton's engineering program has responded to the challenges of ABET EC2000, we have elected to take a slightly different approach with the focus on projects but with additional emphasis on developing the critical and creative thinking skills that will enable our students to stay enrolled in engineering and be successful in the upper-level required discipline specific engineering courses.

An integrated approach similar in some respects to the present work has been described by Watret and Martin [1]. They sought to connect mathematics and physics, incorporate common technology into each course, incorporate integrated exams that require the use of mathematics and physics to solve engineering problems and incorporate more writing and presentations by students in class. Results from the approach suggest that there was a high level of success in achieving the goals set out by the program including higher retention rates. Ohland and Sill [2] describe an introduction to engineering course focused upon helping students decide if they want to major in engineering or science, and weeding out many students who eventually choose a different major. They found that the course resulted in students changing their majors to some of the lesser-known engineering disciplines such as industrial, biosystems, ceramic and materials engineering and that the course was useful in familiarizing students with the different facets of engineering without them having to take a large number of introductory courses to determine which they finally preferred the most. Mourtos and Furman [3] recently offered an introductory engineering course that included the following set of goals: (a) educate students about the engineering profession and expose them to the different disciplines through problem solving;(b) provide students with a basic understanding of engineering methods, including experimentation, data analysis, and computer skills; (c) introduce students to design through a variety of projects; (d) provide opportunities for students to develop communication and team skills; and (e) provide support in academic success strategies.

Where the present effort differs from these successful freshman-engineering programs at other universities is, in my view, a significantly increased emphasis on engineering ethics, a significant focus on the societal and global implications of the engineering profession today and careful study and reflection upon the profound impact engineers have upon the natural world. In addition, the Watson program has, in many ways, fully integrated the freshman program with our minority-engineering program. The distinction between these two efforts often seems non-existent.

Freshman Courses

The focus of the freshman year program is centered on the courses entitled *Discovering Engineering I & II*, a two-semester sequence that integrates instruction in engineering graphics and design, computer applications and tools, oral and written communication skills. Considerable attention is also given to the development of problem solving skills (including both critical and creative thinking skill development), and academic survival skills (i.e. time management, test taking and test preparation). Additionally students confront the value-laden nature of the engineering profession through a careful consideration of professional and engineering ethics, and an examination of the impact of technology in societal and global contexts.

The first offering of the newly revised form of the freshmen engineering course sequence occurred in academic year 2001-2002. Assessment of the previous freshman program's courses pointed to several issues, which demanded serious reflection and subsequent action. First, the structure of each of the courses with a common, brief general session and subsequent breakout into three different classrooms had created enormous confusion among students. Students perceived the course to be three separate courses rather than one integrated one. Secondly, students were sent mixed messages concerning the required professionalism in formal engineering presentations. While their presentation skills improved generally, the technical focus was often lacking. Students writing skills also increased but here too there was a problem in appropriate technical style for engineering reports. Students were not challenged to prepare formal laboratory reports nor formal engineering design reports. Perhaps the most apparent weakness of students after finishing the sequence was the lack of ability to construct simple computer programs. The software package *Matlab* was introduced yet it seemed to distract students from learning the fundamental skills required to program.

Many substantive changes were been put in place for the first effort at revision. The old structure had been abandoned and in its place was a fully integrated program. The incoming freshman class of approximately 200 was divided into five separate sections of 40 students each. Each class section was independent and taught by a multi-disciplinary team of instructors with graduate student support. Oral and written communication skills were more sharply focused in an engineering context. Students had opportunities to demonstrate their expertise in formal engineering design presentations, formal engineering design reports and formal laboratory reports. The lack of acceptable computer programming skills also was addressed with a movement away from specific program instruction (i.e. *Matlab*) to an emphasis on numerical methods with flow charts.

During the fall term, the course integrated instruction in engineering graphics and design, computer applications and tools, and oral and written communication skills. (Figure 2) Considerable attention was also given to the development of: (a) problem-solving skills including both critical and creative thinking skill development; and (b) academic survival skills (i.e. time management, test taking and test preparation). Additionally students confront the value-laden nature of the engineering profession through a careful consideration of professional and engineering ethics and an examination of the impact of technology in societal and global contexts. By the end of the semester students are expected to be able to: (a) utilize the internet as a valuable tool in conducting research; (b) construct mind-maps as an effective tool to organize information; (c) set short-term and long-term goals and strategies; (d) take effective notes; (e) describe the different engineering disciplines; (f) solve technical problems using an effective problem-solving technique; (g) use an engineering design problem-solving schema for open ended design problems; (h) describe the value-laden nature of the engineering profession; (i) define and describe moral reasoning theories used in engineering contexts; (j) develop writing skills required to argue for an ethical position or perspective; (k) use effectively standard engineering graphical techniques and produce an engineering quality drawing; (i) use spreadsheet tools to calculate solutions to problems display and analyze experimental data; (j) write a formal engineering laboratory report; (k) make an effective oral presentation; (l) write a formal engineering design report; and (m) effectively work in teams.

The thrust for the spring term was integrated instruction in engineering principles and problem solving, numerical methods, symbolic software, computer-aided design and oral and written communication skills. (Figure 3) The engineering principles and problem solving were presented in the context of the impact of technology upon the natural environment. Engineering as a profession with an ethical dimension was again carefully considered.

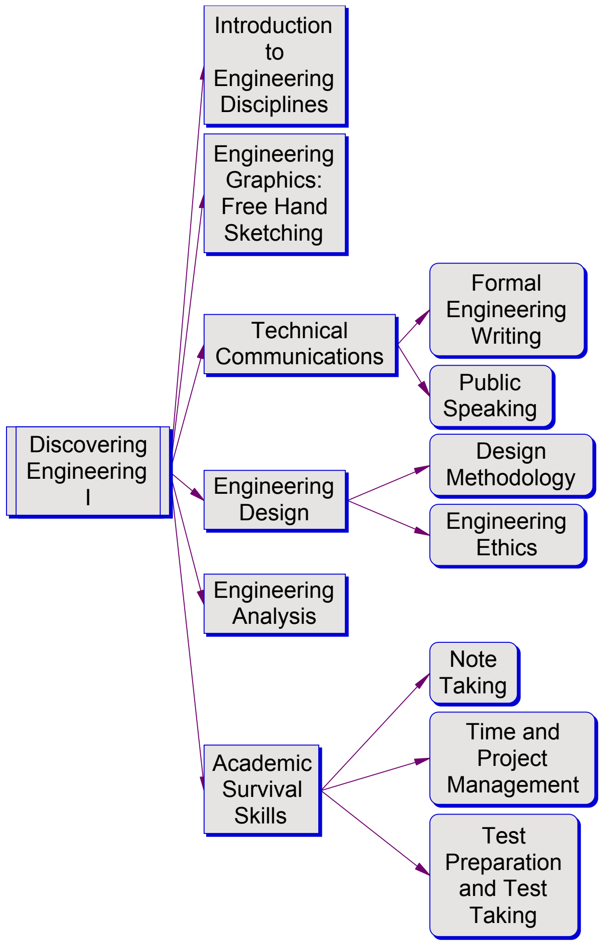


Figure 2. Concept Map Describing Discovering Engineering I

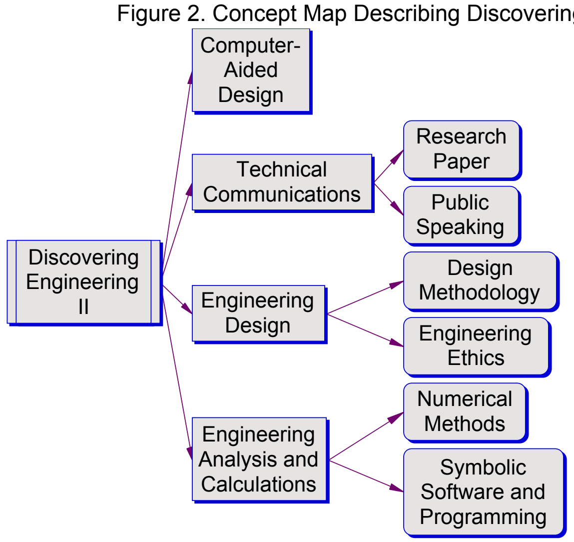


Figure 3. Concept Map Describing Discovering Engineering II

By the end of the semester students are expected to be able to: (a) describe the important principles that serve as the foundation for modern engineering; (b) use the Conservation Laws to solve real-world engineering problems; (c) develop writing skills required to produce an effective research manuscript; (d) write a formal research report; (e) develop public speaking skills; (f) make effective oral presentations; (g) use numerical methods to solve real-world engineering problems; (h) develop basic skills in computer-aided design; (i) work in design teams; and (j) solve an open-ended engineering design problem

During the first offering of the revised course, strengths and weaknesses of the incoming students and the program became readily apparent. Students struggled greatly with both formal writing and oral presentation skills. This observation has led to a significant second revision in the freshman year, which will be documented later in this report.

The inclusion of moral reasoning has provoked an immediate strong reaction. Several students have argued that they chose to go into engineering to avoid such material, particularly to avoid preparing formal written analysis of engineering ethics case studies. Perhaps the segment of the course that helps students best understand the importance of ethics in the engineering profession and provides the unifying element is the term design project. For academic year 2001-2002, the class was divided into teams of three or four students and asked to design a chicken coop for a farm cooperative in Guatemala. Both a final presentation and a final report were required. The project was chosen as it involved many important components of the class: working in a design team, graphical representation (freehand or computer-aided) of the design, a formal engineering design report including an ethical analysis. Though no model was required approximately 50% of the teams did construct a prototype. The final presentations were held in a professional conference format with each team given 12 minutes for their presentation and an additional three minutes for questions and answers.

Lastly, students continued to struggle with the computational segment of the course. Though the emphasis was shifted from specific software to more general numerical methods, a great deal of frustration among the students remained. Student feedback was still quite negative and their understanding of simple algorithms used in numerical methods and programming remained weak.

After considerable discussion with faculty from the mathematical sciences and engineering both locally and internationally, the software package *Maple* was chosen for the next offering of the freshman engineering sequence.

The Tutoring Program

Perhaps the most difficult challenge in developing a successful tutoring program is overcoming students' reluctance to participate, particularly in a peer-tutoring remediation plan. The work described by Henderson et al [4] suggested four general positive outcomes of tutoring programs: (a) Improvement in students performance and skills; (b) Improve the learning of both the tutor and the tutee; (c) Relieve the strain of teachers trying to teach large, often mixed ability classes; and (d) though relatively inexpensive, it can greatly enrich the educational process. Significantly, their research also showed that the program must be highly structured with well-trained tutors if the program is to be successful.

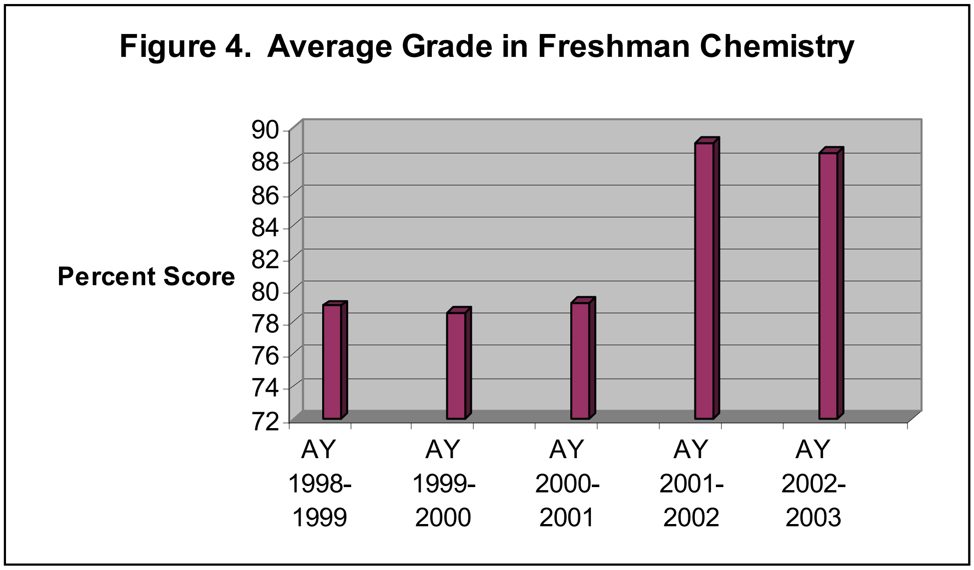
With the development and implementation of the evening tutoring program, our goal was to establish a true engineering learning community wherein students would be able to find help in courses from across the university not only in the required engineering courses. On any given evening, there is help available in calculus, analytic geometry and differential equations, inorganic and organic chemistry, engineering physics, engineering problem solving, engineering graphics and computer aided design as well as public speaking and writing.

Tutoring is provided through a combination of efforts by both undergraduate and graduate students under the supervision of members of the engineering faculty. In addition at the beginning of each term, a two-hour training workshop is held for all student participants. The undergraduate and graduate student mentors are from all engineering disciplines available at Binghamton. In addition there are student mentors, majoring in rhetoric and English who provide assistance in oral and written communication.

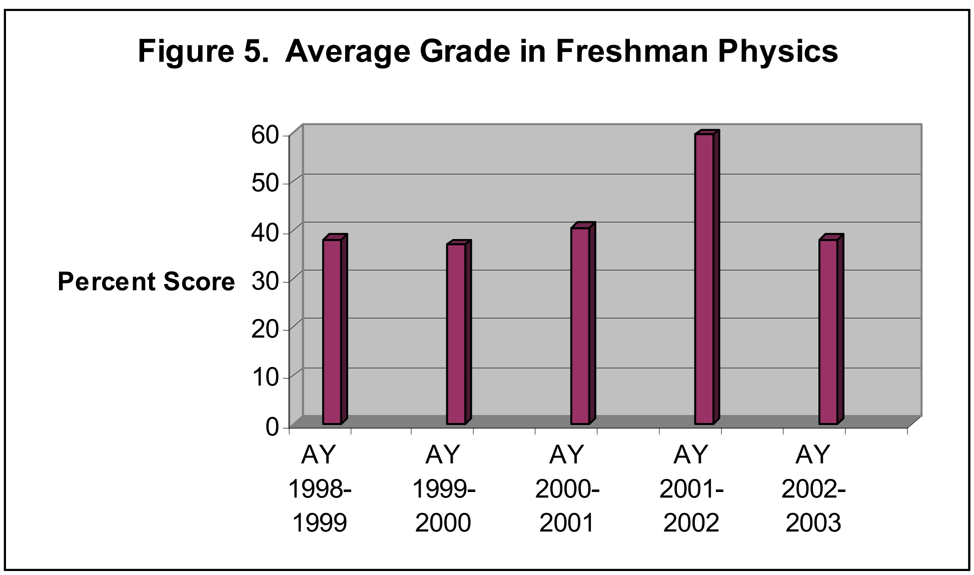
Tutoring is held during the evenings, Monday through Thursday, with the sessions held in various classrooms located throughout the Engineering Building. The sessions are organized in a learning community format, that is, the student mentors place students seeking help in groups with the mentors' responsibilities to then guide students to the answers rather than to simply provide the approved solutions.

Attendance in the tutoring effort averaged at about 50% of the freshman class enrollments (i.e. approximately 100 students per evening) with large increases in attendance linked, not too surprisingly, to impending major exams in the various courses. Interviews conducted by visiting faculty (a visiting *ABET* team) confirmed the importance of the tutoring effort. Not only did the students feel that they were getting needed help with their courses but they identified the sense of belonging to a community wherein the engineering school and the university did genuinely care about their well-being and success. The tutoring generated a groundswell of good will among students and parents alike.

Term end data from the required chemistry class points to the improvement of students' performance during the fall term. (Figure 4) The overall distribution of grades was significantly improved over any of the previous years by the chemistry department.



Data from engineering physics suggests a significant improvement over the results from the past during the first year of the revised effort. (Figure 5) The results from the second year have been disappointing. Part of the reason for the increase in both the chemistry and physics results is the available and highly used tutoring effort. Other factors, such as the close collaboration with the various math and science departments also played a role in the improvement. More details of this ongoing collaboration are given in the following section of the present work.



Another aspect of the revised freshman engineering program has been the strong effort made to work cooperatively with academic departments outside of the engineering school including the mathematical sciences, chemistry and physics with the stated goal being to reinforce the linkage between engineering and the pure and applied sciences. This collaborative effort included "guest" visits to the classroom where for example the freshman-engineering professor participated in the presentation of material in the physics class. Additionally, a laboratory exercise from chemistry provided the data for an engineering classroom activity focusing upon data analysis and presentation. A common template for problem solving and presentation in engineering and physics has also been developed. Students are asked to complete their homework assignments using the same format in both courses—engineering and physics.

Particularly noteworthy is the close cooperation and collaboration that is taking place among the freshman-engineering program, physics and the Binghamton Success Program. Bi-weekly planning meetings have been held which have resulted in a re-introduction of the academic survival skills presented in the engineering classes into the physics lecture and the development and offering of a physics test preparation workshop offered by the engineering faculty. Additionally, student feedback has been obtained in the physics class again using the same formal mechanism (i.e. a "Discovery Sheet") routinely used in the freshman-engineering program.

A standing university committee has been established to review the performance of engineering students in the various mathematics and science courses. The committee is co-chaired by the deans from the school of engineering and college of arts and sciences. It is the intention of the committee to establish a set of "best-practices" in the teaching of the different courses. One other idea that is being considered for adoption is an actual exchange of faculty---engineering faculty assisting in the teaching of physics and mathematics and science/mathematics faculty assisting in the teaching of freshman engineering.

Rather than an apparent attempt at academic meddling, the chemistry, physics and mathematics departments have all responded very favorably. Significantly, the physics and engineering faculty have identified their role as being part of a "team" responsible for the education of the engineering students. Physics faculty has also become an active participant in the training of student mentors and tutors, insuring a consistency of approach.

As mentioned previously, the results from the second year of the revised curriculum are discouraging. While certainly it is too soon to determine whether on not the results are an aberration or point to the need for significant change, one difference between the two years' efforts was in the degree of collaboration between physics and engineering. While the course remained the same, the instructor changed from one of the most seasoned, senior professors at Binghamton University to a brand new hire right from graduate school.

Linkage with Binghamton Success Program

A close linkage with the Binghamton Success Program (BSP has been developed. The mission of BSP includes helping students successfully make the transition to a Research 1 university, to graduate on the "cutting-edge" of their discipline and to continue their studies in a graduate program. The National Science Foundation through the Louis B. Stokes Alliance for Minority Participation funds the program.

Membership in BSP requires the student to be an American citizen or a permanent US resident and a member of one of the following groups: African-American, Latin American Native American, Alaskan Native, or Pacific Islander. Student must also be pursuing an undergraduate degree in engineering, computer science, mathematics, or one of the sciences (including biology, psychobiology, chemistry, biochemistry, physics, astronomy, and geology.)

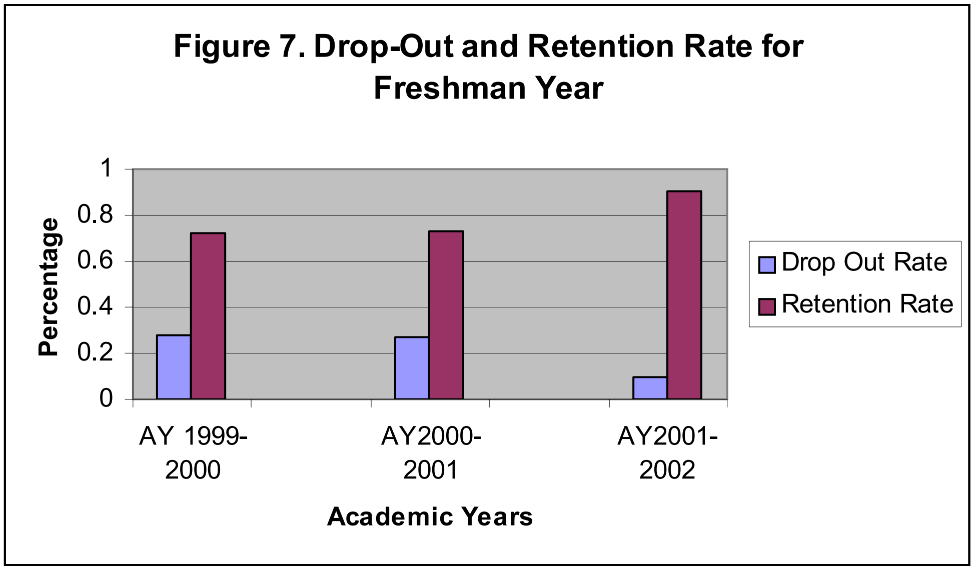
As part of the BSP effort, a new course, *The Student Success Course*, was developed and offered during the fall term. The course, taught by the program coordinator who is a learning specialist, was a one credit hour class taken on a pass/fail basis. Topics included: (a) time management and organization strategies; (b) note-taking skills; (c) the study process; (d) what to do with your notes; (e) learning strategies for mathematics, science and engineering; (f) test preparation; (g) test taking; (h) sleep: how it affects success; and (i) coping with stress and pressure.

The linkage between the freshmen engineering program and BSP was manifest in different ways throughout the course of the year. First student who had failed to enroll in the BSP program at the beginning of the year for various reasons were identified and encouraged by the engineering faculty to explore all the advantages of membership before completely ruling membership out. Secondly, the Student Success class also enlisted a member of the engineering faculty to serve as a "guest" lecturer. Thirdly students who were struggling in the engineering, math and science classes were identified by the engineering faculty and were brought to the attention of the BSP coordinator/learning specialist. This teamed intervention in fact was not limited to members of the BSP program but was open to all freshmen engineering students.

The Binghamton Success Program has become much more inclusive than during previous years. While some financial incentives are restricted to members of specific targeted groups, the course, workshops and academic counseling are available to all members of the engineering community as well. It should be pointed out that members of BSP point with pride to the success of their program and are delighted with the inclusion of many more new students.

Retention Rates

The retention rates for the three-year period spanning the first year of implementation of changes in the freshman program are shown in Figure 7. These favorable trends in both retention rates have occurred concurrent with a significant enrollment in the incoming freshman class from 145 in Academic Year 1999-2000 to 165 in Academic Year 2000-2001 to 205 in Academic Year 2001-2002. The totality of changes have made to a significant increase in the students who stay in engineering and progress to sophomore status.



Implemented Changes

Discovering Engineering I and *II* have undergone a significant modification. The present model of two 4 credit hour courses has been redeveloped as two 3-credit-hour courses (technical and professional aspects of engineering) plus two 1-credit-hour courses devoted entirely to technical communications. It is anticipated that the separate technical communications courses will provide students even greater opportunity to develop both their oral presentation and writing skills.

Though the two course sequences are administratively separate, there is linkage within the subjects covered. For example, open-ended design projects are introduced in *Discovering Engineering I* and *II* while the technical communications courses focus on preparing the same students to write effective design reports and make effective oral presentations.

The more general approach tried last year, the concentration on numerical methods at the expense of a particular software package, did not seem to generate much enthusiasm in the students. Feedback form focus groups pointed to a lack of apparent relevance for the different engineering disciplines. Nor did students feel confident in their abilities to solve simple numerical problems. As a result, a significant change made in the technical freshman engineering program is the switch to *Maple* software as the symbolic software language of instruction. It is the author's belief that *Maple* is most appropriate for the State University of New York at Binghamton's incoming freshman class. In addition, strong connections among the use of *Maple* in engineering, and introductory calculus, and introductory physics have been easy to make.

Future Directions

With the continued growth in enrollments forecast coupled with the addition of a strong and vibrant bioengineering program, pressures will inevitably mount to cover more and more topics at the freshman level. The program will increasingly be pulled towards the buffet or assembly line approach to engineering education, one that seems at odds with the intentions of *ABET's EC2000* guidelines. It is the present author's intention to encourage the university to move towards a more fully integrated approach based upon engineering design projects and the use of an "in-the-nick-of-time" learning model. Students need experience wrestling with open-ended projects from the outset wherein each is exposed to the true analytical and creative nature of engineering. The freshman class seems to be becoming ever more impatient with the more traditional model of engineering education—simply learn a multitude of skills and being satisfied with the reassurance that someday and in some mysterious way, they might become useful.

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