IMPEC: AN INTEGRATED FIRST-YEAR ENGINEERING CURRICULUM

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Introduction

Traditional engineering curricula are highly compartmentalized. Fundamental mathematics and science courses and engineering courses are generally self-contained, with few connections being made to related courses in other disciplines or even the same discipline. Real engineering problems, on the other hand, invariably involve information and skills associated with a variety of engineering, mathematics, and physical science courses. When students do not understand the interrelations between different subjects, they tend to be less motivated to learn new subject matter and consequently less able to solve realistic problems.

Recognizing this problem, several universities have recently developed first-year engineering curricula that include multidisciplinary integration. This paper reports on one such effort currently under way at North Carolina State University sponsored by the National Science Foundation SUCCEED Coalition. In the new curriculum, designated as IMPEC (Integrated Mathematics, Physics, Engineering, and Chemistry), elements of engineering design and operations are brought into the first year and integrated with introductory calculus and science courses. The goals of the curriculum are to provide (1) motivation and context for the fundamental material taught in the first-year mathematics and science courses; (2) a realistic and positive orientation to the engineering profession, and (3) training in the problem-solving, study, and communication skills that correlate with success in engineering school and equip individuals to be lifelong learners.

Curriculum Structure and Instructional Approach

In the fall semester of 1994, IMPEC students took the first courses in calculus and physics (mechanics) as well as a one-credit engineering course. In the spring of 1995, students continuing in the sequence took the second courses in calculus and physics (electricity and magnetism) and a second one-credit engineering course. This sequence of science and mathematics courses did not parallel the one taken by most engineering freshmen and created serious scheduling problems for some of the IMPEC students. The 1995–1996 sequence parallels the one followed by most engineering freshmen: general chemistry, calculus, and engineering courses in the fall and physics (mechanics), calculus, and engineering courses in the spring. The one-credit fall engineering course replaces the standard zero-credit freshman orientation course, and the one-credit spring engineering course is an add-on to the standard curriculum.

The principal features of IMPEC are as follows:

- The courses are team-taught by mathematics, chemistry, physics, and engineering professors. Fundamental scientific and mathematical material is presented in the context of real-world engineering problems.

- With the exception of a chemistry laboratory, the courses are taught in a single classroom equipped with PC's that have real-time data acquisition capability. The classroom holds 36 students, which limits the enrollment in the curriculum.

- The calculus instruction follows the Harvard Calculus format, emphasizing a true understanding of concepts as opposed to learning drills and prescriptions. The "rule of three" is followed, which states that every topic should be presented geometrically, numerically, and algebraically. A symbolic mathematics application program (MAPLE) is used for complex calculations and graphing.

- Multimedia instructional packages—*Exploring Chemistry* and *Introduction to General Chemistry*, distributed by Falcon Software—supplement the standard chemistry textbook. The lecture and laboratory components of the course are integrated to a much greater extent than in the standard curriculum.

- A "hands-on" approach that emphasizes in-class experimentation provides the basis for the physics instruction. Computer simulations complement physical experiments. The physics text has a workbook-like style that requires extensive student input.

- The first engineering course substitutes for the standard freshman orientation course. The students learn about engineering disciplines and job functions from the text *Studying Engineering*, by Raymond B. Landis, and by attending orientation sessions given by representatives of different engineering departments. They receive training in mathematical computer applications (including spreadsheeting and symbolic mathematical operations), technical writing (including word processing), oral presentation (including PowerPoint presentation graphics), time management, teamwork, and various study skills. They also receive supplementary instruction linking chemistry and calculus principles to engineering applications.

- The second engineering course uses the automobile as a theme to link the calculus and physics material. The students take a field trip to the shop of a local race car driver and solve numerous statics and dynamics problems dealing with automobiles. They also receive additional training in the skills enumerated above in connection with the first engineering course.

- Both engineering courses culminate with design projects done by teams. In the first semester, the students design a propane-fired water heater and shower for a recreational vehicle, itemizing engineering specifications and carrying out some basic material and energy balance calculations for the heater. In the second semester, they design and build a model of an automobile steering and suspension system and carry out stress analyses on their design. The teams produce written and oral project reports which include explicit statements of how they used principles and ideas from calculus, chemistry, and physics in their work.

- A nominal schedule states which courses meet during which hours, but the actual schedule changes every week according to which topics are to be emphasized. Most class periods are taught by individual IMPEC faculty members, but several times during each semester "workshops" on specific topics (e.g. statistical analysis and angular motion) are team-taught by the full faculty.

- The course instruction makes extensive use of active (experiential) and cooperative (team-based) learning, de-emphasizing but not completely eliminating formal lecturing. All laboratory experiments and most homework and in-class activities are done by teams of students. Exercises are set up to provide for positive interdependence, individual accountability, and periodic self-assessment of team functioning.

- Homework and examinations contain a mixture of closed (single-answer) problems designed to test understanding of specific methods and skills as well as open-ended multidisciplinary questions to test the students' creativity and ability to integrate the full range of course material.

- Course handouts, assignments, and revised schedules are delivered via an IMPEC home page on the World Wide Web. Most students feel no need to print the materials, since they can consult the web site for a current version from computers in the classroom or their dormitories at any time. Distributing the course materials in this manner is no more time-consuming than the traditional process of making paper copies, and the inevitable last-minute changes are effortless.

Recruitment and Registration

Early in the summer, a description of IMPEC is mailed to several hundred entering engineering freshmen, and an hour-long session takes place at the campus freshman orientation program in July. In that session, the IMPEC faculty members describe the principal features and requirements of the curriculum. Students who wish to participate sign forms expressing their desire to do so and at the same time giving permission to access their records for assessment purposes. The forms also contain demographic information and ask whether or not the students expect to receive advanced placement credit for any of the subjects included in IMPEC. (If advanced placement credit has been received for any IMPEC course, the student must forego the credit to participate.)

Enrollment and Retention Data

In the summer of 1994, 52 students came to the IMPEC orientation session, 38 enrolled for IMPEC, and 36 appeared on the first day. Nine students got D's or F's in at least one of the sequence courses; seven passed the first semester but chose not to enroll in the second one, primarily due to the nonstandard nature of the course sequence; and 18 successfully completed the two-term sequence, for a 50% completion rate for the year.

Several problems were encountered in the first year of IMPEC. One was that the orientation session conflicted with a session for minority students, so no minority students enrolled. Another was that the number of students who volunteered to participate was essentially the number we could admit, which meant we did not have a legitimate control group of non-selected volunteers with whom to compare the IMPEC registrants. Making comparisons even more difficult was the fact that we only invited applicants whose predicted grade-point averages were 3.0 or higher so as not to jeopardize students who were at risk academically by enrolling them in an untested program. For these reasons, we decided to use the first program year primarily for course development and to focus our assessment and evaluation on the second year.

For the 1995–96 academic year, no restrictions on predicted grade-point average were imposed other than the 2.6 cutoff used by the College of Engineering. In July of 1995, well over 100 students came to the IMPEC summer orientation session, including four African-American students. Most expressed a desire to participate in IMPEC. Thirty-six students were selected, including all of the African-American students. Forty of the volunteers who were not selected were designated as a control group. Except for the absence of minority students, the demographic profile and pre-admission credentials of the control group matched those of the IMPEC class reasonably well.

Of the 36 students who enrolled in the Fall 1995 semester, four earned grades of D or F in one of the sequence courses, two decided to switch out of engineering, and 30 re-enrolled in the spring, for a one-semester completion rate of 83%. Judging from their first-semester performance, our expectation is that all of these students will complete the second semester successfully.

Assessment and Evaluation Plans

The performance and attitudes of three groups will be compared to the greatest possible extent: the Fall 1995 IMPEC students, the control group of non-selected IMPEC volunteers, and the roughly 1000 College of Engineering (COE) freshmen who did not volunteer for IMPEC. The following assessment data will be collected by the end of the Spring 1996 semester except for the data of Items 8–10, which will be collected at the end of each of the next four years.

1. *Pre-admission predicted grade-point average, SAT scores.*
2. *Attitudes to Engineering Survey Responses*— pre-semester and post-semester (IMPEC, control, COE freshmen). This survey, developed at the University of Pittsburgh, assesses (i) attitudes toward engineering as a curriculum and career, (ii) self-reported confidence levels in core freshman-year subjects, and (iii) (in the postsurvey) attitudes toward the freshman year experience. It is also being administered to students at the University of Pittsburgh and elsewhere, making inter-institutional comparisons possible.
3. *Myers-Briggs Type Inventory Profiles* (IMPEC only).
4. *Hestenes Force Concept Inventory scores*—pre-semester and post-semester (IMPEC, regular physics class). Assesses conceptual understanding of mechanics.
5. *Hestenes Mechanics Baseline Test scores*—post-semester (IMPEC, regular physics class). Assesses mechanics problem-solving ability.
6. *Performance on common final exam problems in calculus, chemistry, and physics courses.*
7. *Written and oral engineering project reports* (IMPEC).
8. *Overall GPA* (IMPEC, control).
9. *Retention in engineering* (IMPEC, control).
10. *Graduation rates at 4 and 5 years* (IMPEC, control).

Preliminary Results

The 1994-95 student evaluations were on the whole positive, although some aspects of the instruction, notably the time demands on the students, were criticized. Fall 1995 student evaluations of both the courses and the instructors were overwhelmingly positive in every respect, with many of the students singling out group work, subject integration, and the personal attention from the professors as aspects they particularly appreciated. At the beginning of the Spring 1996 semester when this paper was written, we had just begun to analyze the fall semester assessment data quantitatively. A full report will be given at our conference presentation.

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