Abstract

Engineering freshman seminars at Vanderbilt University incorporate several features that make them attractive to faculty and students: (1) they are limited to one-semester hour; (2) they are optional for students and for professors; (3) they are staffed entirely by full-time professors; and (4) the faculty may teach anything they please within their own area of expertise. These seminars were developed in response to student requests for more intimate intellectual contact with senior professors and for earlier exposure to engineering thought. During the first year of experimentation, 11 sections were taught to 85 of our 320 freshman. In 2000-01 12 sections are taught to 173 of 360 freshman. Perhaps not surprisingly in view of the volunteer nature of the courses, objective student ratings of these course are the highest in the School of Engineering, and faculty satisfaction is high. Everyone takes credit for our one-year increase in freshman-sophomore retention from 89% to 94%, but these seminars have surely played a role. Our recent initiative in the use of wireless laptop computers in the classroom will further enrich the freshman seminar experience. Other planned improvements include team-taught freshman seminars in conjunction with the colleges of arts and science, education, music, and business.

I. Introduction: Challenges of the Freshman Year

The self-examination urged on us by the expectations of Engineering Criteria 2000 made it clear that the Vanderbilt University School of Engineering, like many of our counterparts elsewhere, faces challenges in the engineering freshman year. Our objectives for the freshman year -- (1) to illustrate the practice of engineering as an iterative process of synthesis and analysis, (2) to help the student make career choices, (3) to provide tools prerequisite to further study, (4) to develop learning skills, (5) to illustrate the role of ethics in the professional practice of engineering, (6) to develop teamwork skills, and (7) to develop communications skills – were not always being achieved. In particular, objectives (2), (4), and (7) were not being realized in our rather standard first year, which consists of mathematics, science, liberal arts electives, a slate of “technology-society” electives, an introductory engineering course emphasizing team projects and basic computer skills, and a C++ programming course.

Many of our freshmen made it clear to us in our constituent polling that they felt they were getting insufficient help in career choices and that they were sometimes disappointed in their...
lack of ready access, in small groups, to senior professors. They felt that their $24,000 yearly tuition should buy such access. Vanderbilt students arrive with high expectations, and they find themselves in an environment in which small classes and close personal attention are the expectation.

Our polling of freshmen disclosed an additional challenge --- they are relatively uninterested, they say, in developing the skills of lifelong learning, in developing communications skills, or in ethical studies. Our faculty are therefore faced with the uphill task of inculcating to a reluctant audience skills we know to be important.

Our final challenges have to do with our organizational structure and our faculty. Our school is too small to justify a department devoted to freshman studies. The freshman program is operated rather informally out of the Dean’s Office, and faculty members must be recruited or conscripted each year to teach our standard Introduction to Engineering. This course, which has been developed and improved over the years, offers relatively little freedom for innovation and little intellectual challenge to the faculty. It is no surprise that professors are for the most part reluctant to participate. So our freshman course is taught by a mixture of a few dedicated senior professors and an ever-changing corps of underpaid adjuncts and postdoctoral fellows. Some of these are effective teachers and others are not.

A rational response to these challenges might be to immediately reorganize the entire freshman year to attain our desired outcomes, but rationality and expedition are not always found together in the academic environment. As an incremental approach, we undertook the series of engineering freshman seminars described in this paper.

II. Description of the Freshman Seminar Program

For the past two academic years we have experimented with a series of optional freshman seminars taught by engineering faculty to engineering students. These seminars have the following features:

- They are entirely optional for students and for teachers. If a student elects a seminar, he or she takes it on top of the usual load. The seminars carry only one semester hour of credit, usually meet for one hour a week, and rarely pose an overload problem for the student. Faculty members who choose to teach a seminar usually do so in addition to their regularly-assigned teaching load.

- The professor may teach anything he or she wants to teach as long as it is within their area of expertise. A syllabus is reviewed by a curriculum committee before the seminar is approved, but in practice people do not volunteer to teach something inappropriately far removed from their engineering expertise. The fact that people may teach what they please is a key to their voluntary participation. Faculty members enjoy teaching freshmen if they are free to teach what they like in ways that appeal to them.
• There is an expectation of accountability on the part of students and faculty. Each seminar is expected to include assessment of the students’ progress, some exercise of communications skills, and formal evaluation at the end of the semester.

• The teacher must be a full-time, tenured or research professor in the School of Engineering. Some seminars do involve team-teachers from other units of the University.

The following seminars have been offered during the academic years 1999-2000 and 2000-2001. In each case we indicate the semesters in which the section was offered and, in parentheses, the enrollment during that semester.

- “High-Fidelity Sound Reproduction”. Taught by electrical engineering professors, this seminar takes advantage of the interest many young people have in recorded music to teach circuit theory. It includes laboratory demonstrations and work at Nashville sound studios. [Fall, 1999, 15 students; Fall, 2000, 16 students]

- “The Second Law of Thermodynamics”. With the aid of a textbook and web-based resources, the students spend the first half of the semester coming to grips with the historical and mathematical underpinnings of the Second Law, then embark on individual or team projects examining efforts of people to apply this concept to topics ranging from black holes to the reflection of entropy in certain branches of Hindu theology. [Fall, 1999, 14 students; Fall, 2000, 13 students]

- “Engineering Careers --- Web-based Data Collection and Conferencing”. Taught almost entirely on-line, this seminar develops electronic means to contact and conference with hundreds of Vanderbilt engineering alumni to learn more about engineering practice today. [Fall, 1999, 11 students]

- “Frontiers in Mechanical Engineering” studies engineering problems and challenges presented by visitors from local industry. Topics have varied from Hot Chips and Salsa to Contradictory Regulations for Car Engines. [Fall, 1999, 14 students; Fall, 2000, 25 students]

- “Frontiers in Chemical Engineering” uses current research topics to illustrate basic chemical engineering principles. [Fall, 1999, 9 students; Fall, 2000, 11 students]

- “Electrocardiogram Capture and Analysis” looks at the heart from an engineering viewpoint. The role of engineers in developing the science and art of electrocardiology is examined. [Fall, 2000, 18 students]

- “Moore’s Law: The Incredible Shrinking Transistor” applies the idea of Moore’s law not only to decreases in the dimensions of electronic devices but also to the stock market. [Fall, 2000, 27 students]

- “Biochemical Engineering Process Development” is an open-ended laboratory course in which students work together to develop a biochemical process such as
removal of valuable proteins from pineapples or okra. [Fall, 2000, 5 students; Spring, 2001, 2 students]

- “Readings in Contemporary Technology”. In this seminar, students come to grips each week with an article from the current *Scientific American*. The goal is to develop a better understanding of and appreciation for contemporary technologies [Fall, 1999, 4 students; Fall, 2000, 9 students]

- “Modeling Plumes from Chimneys”. Vanderbilt’s power plant is used as a laboratory for the study of environmental regulations and modeling processes. [Spring, 2000, 2 students]

- “Microsensors and Microsystems”. This seminar involves many disciplines in coming to grips with modern approaches to fast and accurate measurement. [Spring, 2000, 8 students; Spring, 2001, 8 students]

- “Clinical Biomedical Engineering” meets in the patient environment of the Clinical Research Center of Vanderbilt Hospital. Students are able to study details of medical instrumentation in a highly motivational context. [Spring, 2000, 18 students; Spring, 2001, 19 students]

- “Exploring Computing and Engineering in the Context of Diabetes Management” illustrates the use of computer science in medical informatics. [Fall, 1999, 3 students]

- “Engineering Entrepreneurship”, team-taught between the School of Engineering and the faculty of Human and Organizational Development in Vanderbilt’s Peabody College of Education, this seminar explores principles and practices of entrepreneurship, a topic of great interest to some young people today. [Spring, 2001, 20 students]

III. A Sample Syllabus

To provide a more detailed sense of the content of a typical seminar, here is an abbreviated syllabus for the course, “High Fidelity Sound Reproduction”, taught by electrical engineering professors Ron Schrimpf and Lloyd Massengill:

1. Preparation. Students entering this course should have an interest in music and its electronic reproduction. Familiarity with basic mathematical and physical concepts (e.g., wave propagation, pressure, mathematical series) is assumed.

2. Course outline.
   a. Sound waves
   b. Attributes of recorded music
   c. Digital audio
   d. Data conversion and storage
These topics are used to introduce some engineering principles and methods using music reproduction as a vehicle. While the material is not required for later courses, it helps the students to understand the broader context of the methods they will learn in future courses. Examples of topics that are useful in later courses are Fourier series, non-linear circuit elements, transducers, digital signals, amplifier design, and data conversion.

3. Lab exercises. While the course does not have a formal lab, in-class demonstrations and field trips are used to illustrate important principles. Examples from Fall 2000 are:

   a. Spectrum analysis of audio signals
   b. In-class music demos to illustrate various sound properties
   c. Visit to recording studio

IV. Results and Evaluation

During the first year of experimentation, 1999-2000, eleven seminars were taught to 85 of 320 engineering freshmen, or 27% of the class. No strong effort was made to recruit students, and prospective seminar participants were warned that an overload might be involved.

In the second year, 2000-2001, twelve sections were taught to 173 of 360 freshmen, or 48%. Almost twice as many students wished to enroll, but limitations of class size and numbers of teachers made it necessary to choose the students by lot. Typical class size is 10-15 students, although two sections had two participants and another had 27.

As might be expected from a purely voluntary program, objective student ratings of the freshman seminars are quite favorable. On a scale in which 1 is bad and 5 is good, the “Overall Instructor Rating” for freshman seminars in the fall of 2000 was 4.33 ± 0.55 (mean ± standard deviation) compared with a school-wide average of 3.89 ± 0.54. The “Overall Course Rating” for freshman seminars was 4.20 ± 0.59, while the corresponding figure for the school as a whole was 3.64 ± 0.59. The freshman seminars included the three highest rated courses in the School of Engineering. “Intellectual Challenge” for the freshman seminars, 3.73 ± 0.69, was comparable to the school average of 3.76 ± 0.47

After the academic year 1999-2000, our freshman-to-sophomore retention rate increased from 89% to 94%. No one knows for sure, but it is reasonable to hope that the freshman seminars had something to do with that.
V. Conflicts, Problems and Rewards in Freshman Seminar Instruction

It has not been possible, in the one-hour freshman seminars, to achieve all the objectives listed earlier in this paper. In some senses, the objectives can be in conflict. For example, it is hard, in a one-hour course, to simultaneously meet the students’ hopes for career guidance and our wish to encourage the habits of lifelong learning. Small, focused seminars like “The Second Law of Thermodynamics” or “Readings in Contemporary Technology” placed great demands on individual learning by students, but they did not expose the students to a wide range of contemporary engineering practice. Larger, perhaps more general, seminars such as “Frontiers of Mechanical Engineering” and “Frontiers of Chemical Engineering” exposed participants to a helpful range of engineering practice, but were less demanding in terms of individual student initiative and thought. It should be possible, by close and demanding study of examples from current engineering practice, to help with career choice and at the same time place intellectual demands on the students, but we have not been able to do that in a one-hour course.

Recruitment of professors from some disciplines, in particular from civil engineering, has been difficult. The volunteer nature of the program fuels enthusiasm among participants, but in the steady state volunteerism may not be viable. Alternatives to volunteerism include direct assignment (which might or might not undermine the quality of the program), additional incentives in the form of discretionary funds for research, or abandonment of the program.

But for those who have participated, the engineering freshman seminars have provided a deep sense of reward for both teachers and students. “It’s the sort of thing I hoped to get out of college,” is a typical freshman remark.

VI. Future Prospects

The seminar series is no longer experimental, but has been approved as an official curriculum offering, published in the catalog. It remains a one-hour, voluntary course. At least for the near future, I believe we can meet the immediate challenge of offering seminars to all who wish them. In the long run, a more complete overhaul of the freshman year will be needed, but it is anticipated that seminars will be a part of that.

Effective in the fall of 2002, the Vanderbilt University School of Engineering will require each entering freshman to have a particular wireless laptop computer, configured to our specification. For the past year we have experimented with wireless laptops and believe that the machines can help us achieve the best balance between the power of asynchronous learning and the importance of personal interaction, in groups, with fellow students and experienced professorial guides. The laptops will be important in our freshman seminars. They will provide immediate reinforcement of the requirement (i.e., show the students that their money was well spent and that the machines are, indeed, important to their engineering education). The computers will be used to provide immediate feedback to the teacher on how points are getting across, in in-class testing, in common exploration of design calculations, and in classroom access to data from the World Wide Web.
Other improvements contemplated for the near future include an increased emphasis on team teaching with colleagues from living state physics, management, education, and music.

Finally, we anticipate that the freshman program will benefit from the work of the Engineering Research Center for Bioengineering Education. Funded by the National Science Foundation, this consortium among Vanderbilt, Northwestern, Harvard/MIT, and the University of Texas at Austin joins engineers and learning scientists in the development of disciplinary taxonomies and in the delivery of pedagogic tools designed to accommodate different learning styles and needs. The Center concentrates on bioengineering, but the fruits of their work will be available and applicable throughout our freshman curriculum.

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