Int. J. Engng Ed. Vol. 9, No. 4, pp. 286–289, 1993
Printed in Great Britain.

0742–0269/91 $3.00+0.00

American Engineering Education: Current Issues and Future Directions*

RICHARD M. FELDER
Hoechst Celanese Professor of Chemical Engineering, North Carolina State University, Raleigh, NC 27695-7905, *USA*

Calls for major changes in American engineering education have been heard with growing frequency in recent years. The proponents of change call for attaching greater importance to teaching in the academic reward system, movement away from the traditional lecture format to more active and cooperative learning methods, and the use of industry-derived assessment techniques to evaluate and improve program quality. Resistance to these proposals has concurrently arisen among administrators and faculty members who believe that the present system works well and should not be changed. This paper presents a brief history of the antecedents of the debate, lists the focal issues and outlines the opposing views on each issue.

INTRODUCTION

AMERICAN engineering education is currently in a turbulent period. Recent articles, monographs and government studies have called for major changes in the ways engineering curricula are structured and evaluated, triggering opposition from faculty members and administrators who argue that the present system works well and should not be tampered with. It is a confusing time for engineering educators trying to keep up with the discussion, as many of the proposals for change involve language that until recently could only be heard at seminars on educational psychology or corporate management principles—terms like ‘cooperative learning’, ‘outcomes assessment’, ‘continuous quality improvement’ (or ‘total quality management’), ‘cognitive style models’, and ‘just-in-time education’.

The ongoing debate involves four focal issues:

- How should engineering curricula be structured?
- How should engineering faculties be constituted?
- How should engineering courses be taught and evaluated?
- How should engineering professors be trained to teach?

In this paper, I briefly review the background of the debate and then attempt to summarize the opposing positions on each of the four given issues: the ‘traditional’ position, which represents the predominant approach of the past four decades; and the ‘alternative’ position, which I believe will become the predominant approach sometime during the next two decades.

* Accepted 20 August 1993.

HISTORICAL PERSPECTIVES

In the first half of this century, engineering schools in the United States regarded the training of future engineers as their sole or primary function. Most engineering professors had some industrial experience and taught from the standpoint of that experience. Some professors did research, others did not and were not expected to.

Starting in the 1950s, the balance between research and teaching shifted heavily toward research. It became virtually impossible for individuals without Ph.Ds to join faculties and for new faculty members who did not dedicate themselves to research to keep their positions. Faculty members were discouraged from spending much time on activities that might distract them from research, such as updating undergraduate courses, developing and implementing improved teaching methods, and writing textbooks. Consequently, the quality of undergraduate engineering education began to stagnate and its relevance to professional practice declined. By the early 1980s, most professors with engineering experience had retired and been replaced by young research scientists with no experience or interest in engineering practice, and often with little enthusiasm for teaching. It became pertinent to ask, ‘Does engineering education have anything to do with either?’ [1].

In recent years the pendulum has begun to swing back toward making undergraduate education a respected function of engineering professors once again. There are several reasons for this trend. Published studies have demonstrated that an over-emphasis on academic research has hurt the quality of undergraduate education [2–4]. Legislators, philanthropic foundations, alumni, parents and students have become increasingly vocal about this situation, inclining university administrators to take remedial measures before such measures are imposed externally. On a more positive note, the National Science Foundation has provided major funding for improving engineering education, dramatically raising the level of interest of many administrators in modernizing curricula and implementing innovative teaching methods. All of these occurrences have fueled the debate about appropriate priorities and directions for the professoriate.

Before I begin my survey of the issues, I should make two observations. I am a proponent of what I will present as the 'alternative' approach, and my presentation of the opposing positions undoubtedly reflects my bias. Also, I do not mean to suggest that the ideas embodied in the alternative approach are all new; many of them have been used by teachers going back to Socrates and probably earlier. My claim is simply that these approaches represent significant departures from those used in courses currently taught by most engineering instructors. Any reader who encounters an 'alternative' method and protests 'But that's the way I've always done it!' can be assured that my response would be applause, not disagreement.

HOW SHOULD ENGINEERING CURRICULA BE STRUCTURED?

Course and curriculum organization
- *Traditional*: Theory (basic science and mathematics) followed by applications (applied science and engineering design).
- *Alternative*: Integrated theory and applications. Theory taught on a need-to-know basis ('just-in-time'), introduced in the context of real engineering problems.

Course structure
- *Traditional*
  - Subjects compartmentalized, with minimal connections made to other subjects in the same field and to other disciplines.
  - Students segregated by discipline and chronology: for example, third-year chemical engineering students take classes only with other third-year chemical engineering students.
  - Courses taught by individual instructors.
- *Alternative*
  - Some courses integrated across disciplines and chronologically. Students from different fields and at different levels work together on common projects.
  - Courses taught by teams of instructors, exposing the students to a broad range of faculty expertise and a variety of instructional styles.

Course content dictated by
- *Traditional*: The syllabus ('I will cover the following topics . . .').
- *Alternative*: Instructional objectives ('The student will be able to do the following things . . .').

Emphasis in courses placed on
- *Traditional*: Presentation of content (facts, theoretical concepts, computational procedures).
- *Alternative*: Presentation of content (facts, concepts, procedures and aspects of professional practice) and, more importantly, development of skills—problem-solving and problem definition skills, critical and creative thinking skills, and interpersonal and communication skills.

HOW SHOULD ENGINEERING FACULTIES BE CONSTITUTED?

- *Traditional*: All professors should be active in basic research throughout their careers.
  - No one can join a faculty without a Ph.D. Industrial experience is not highly regarded in a potential faculty member, and may be viewed negatively if it did not involve research and publication.
  - Research performance is the pivotal criterion for promotion, tenure and rewards. Outstanding researchers whose teaching is only fair enjoy the full benefits of the academic system, including advancement to full professor. Outstanding teachers whose research is only fair generally fail to earn tenure, and those with tenure who choose to emphasize teaching are regarded as second-class citizens within the academic community.
- *Alternative*: Professors may pursue different academic pathways, each with its own area of specialization [3, 4].
  - *Basic research*. Ph.D. always required.
  - *Applied and multidisciplinary research*. Ph.D. usually required.
  - *Engineering practice*. Professional experience required, Ph.D. not required. Functions would include teaching engineering design, economics, and operations, providing career counseling, and serving as role models of professionalism.
  - *Education*. Outstanding teaching ability, background in educational theories and methodologies required. Activities would include developing, implementing, and writing about innovative teaching materials and methods, writing textbooks and instructional software, and seeking external funding to support education-related efforts.

Professors would not begin their careers on the education pathway, but could switch to it from one of the first three pathways after several years. All pathways would be equally regarded within the academic community, with equally rigorous criteria for advancement and equal rewards and status for those succeeding.

HOW SHOULD ENGINEERING COURSES BE TAUGHT AND EVALUATED?

Teaching style

- *Traditional*: Instructional approach (lecturing) compatible with a single learning style—intuitive, verbal, deductive, reflective and sequential [5].
- *Alternative*: Instructional approach (lectures, in-class group exercises, multimedia demonstrations, interactive computer tutorials) compatible with a full spectrum of learning styles—sensing and intuitive, visual and verbal, inductive and deductive, active and reflective, sequential and global.

Student role in the classroom

- *Traditional*: Passive observation. The professor talks, writes and occasionally asks questions; the students watch, listen and take notes.
- *Alternative*: Active learning. Much of each class period taken up by students discussing, explaining, solving problems, brainstorming, troubleshooting, generating questions, and/or working at computer terminals.

Problems addressed in classroom and homework assignments

- *Traditional*: Almost exclusively closed-ended problems (having only one correct answer, which the student's task is to find).
- *Alternatives*: A mixture of closed- and open-ended problems. Student tasks include generating and evaluating alternative solutions to given problems, explaining observed or described phenomena, constructing derivations and formulating problems.

Mode of student interaction on assignments

- *Traditional*: Individual. Students work alone and turn in individual solution sets or project reports.
- *Alternative*: Sometimes individual, sometimes in teams that generate a single solution set or project report ('cooperative learning'). Team assignments structured to assure both positive interdependence and individual accountability [6].

Design projects

- *Traditional*: Confined to the final ('capstone') design course, done individually or by teams of seniors within a single discipline.
- *Alternative*: Spread throughout the curriculum, done by teams integrated horizontally (across departments and disciplines) and/or vertically (across years of the curriculum).

Course grading

- *Traditional*: Norm-referenced (curving). Leads to a competitive environment, since students who help other students could be hurting themselves.
- *Alternative*: Criterion-referenced (no curving). Leads to a cooperative environment, since all students can in principle get high course grades.

Assessment/evaluation of course and instructors

- *Traditional*: Post-course student evaluations, or no evaluation at all. Little or no followup to remediate perceived problems.
- *Alternative*:
  - Evaluate courses by examining student products (completed assignments and examinations, project reports) and determining extent to which stated instructional objectives were met ('Outcomes assessment'). Supplement with student evaluations.
  - Evaluate instructors on basis of *teaching portfolio* containing course outcome assessments and post-course student evaluations over a 2–3 year period, retrospective graduating senior and alumni evaluations, notes from classroom observations by colleagues, and representative class materials and student products.
  - Maintain a continual dialog among administrators, faculty and students to reflect on evaluations and work toward remediation of perceived problems ('continuous quality improvement', 'total quality management').

HOW SHOULD PROFESSORS BE TRAINED TO TEACH?

- *Traditional*: No training provided. Professors first teach in imitation of their own teachers (who also had no training). Some later improve their instructional methods through trial-and-error or with information from teaching workshops or references like McKeachie [7] or Wankat and Oreovicz [8].
- *Alternative*: Training routinely provided in courses and workshops on college teaching for graduate students, teaching workshops for faculty, and mentorship programs for new professors [9].

SUMMARY

Undergraduate engineering education is currently experiencing a resurgence of interest on American campuses. This movement, which arose partly as a reaction to the decreasing status accorded to teaching in the past four decades and partly as a response to recent major educational funding initiatives, is encountering resistance from supporters of the current research-dominated system. The following issues are being debated:

1. *Curriculum structure*. Should theory precede applications, or should theory and applications be integrated? Should subject areas be compartmentalized along traditional disciplinary lines, or should they be integrated along disci-

plines? Should instructional emphasis be placed exclusively on presentation of content (facts and procedures), or on a combination of content—including aspects of professional practice—and skill development in problem-solving, problem-formulation, critical and creative thinking, teamwork and communication?

2. *Faculty composition*. Should all professors be Ph.D.s specializing in basic research, or should there be alternative pathways to academic advancement, allowing for some specialists in basic research, some in applied and multidisciplinary research, some in engineering design and practice, and some in undergraduate education and educational scholarship?
3. *Teaching methodology*. Should instruction be designed to address a single learning style or the multiplicity of styles that characterizes most college classrooms? Should lecturing be the sole vehicle for classroom instruction, or should active (student-centered) learning play a more dominant role? Should all problems addressed be of the closed-ended (single correct answer) type, or should there be a mixture of closed-and open-ended problems? Should students work individually, competing for grades, or should they work cooperatively, helping one another to learn?
4. *Teacher training*. Should engineering professors continue to enter their profession with no training in educational theories and instructional methods, or should some training be provided to graduate students and faculty members?

Two additional questions remain. First, can we find the resources needed to cover the costs of the proposed changes? Second, can we afford *not* to make the changes? The coming decade will provide the answers.

Acknowledgements—A version of this paper was presented at the 5th Brazilian Conference on Chemical Engineering Education, Itatiaia, Brazil, September 1993.

REFERENCES

1. R. M. Felder, Does engineering education have anything to do with either? *Engng Ed.*, **75**(2), 95–99 (1984).
2. A. W. Astin, *What Matters in College: Four Critical Years Revisited*. Jossey-Bass, San Francisco (1993).
3. E. L. Boyer, *Scholarship Reconsidered: Priorities of the Professoriate*. Carnegie Foundation for the Advancement of Teaching, Princeton, NJ (1990).
4. R. M. Felder, The myth of the superhuman professor. *J. Engng Ed.*, in press.
5. R. M. Felder and L. K. Silverman, Learning and teaching styles in engineering education. *Engng Ed.*, **78**(7), 674–681 (1988).
6. D. W. Johnson, R. T. Johnson and K. A. Smith, *Cooperative Learning: Increasing College Faculty Productivity*. ASHE-ERIC Higher Education Report no. 4, George Washington University, Washington, DC (1991).
7. W. J. McKeachie, *Teaching Tips*, 8th edn. D. C. Heath, Lexington, MA (1986).
8. P. C. Wankat and F. Oreovicz, *Teaching Engineering*. McGraw-Hill, New York (1993).
9. R. M. Felder, Teaching teachers to teach: the case for mentorship. *Chem. Engng Ed.*, **27**(3), 176–177 (1993).

Dr Richard M. Felder is Hoechst Celanese Professor of Chemical Engineering at North Carolina State University, Raleigh, North Carolina. He is a co-author of the book *Elementary Principles of Chemical Processes* (2nd edn, Wiley, 1986) and of over 100 papers on chemical process engineering and engineering education. He won the Chemical Manufacturers Association National Catalyst Award in 1989, was designated the AIChE Institute Lecturer in 1991, and was selected as one of five Outstanding Engineering Educators of the Century by the Southeastern Section of the American Society for Engineering Education in 1993.