THE FUTURE OF ENGINEERING EDUCATION
IV. LEARNING HOW TO TEACH[*]

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In the next few years a large number of college teachers will retire to enjoy their golden years far from the sound of class bells, the demands of lectures, exams, grades, research, and committee work, and all the other joys and vexations of their busy lives as educators. Hired in the expansionist 1950's and 1960's, they have fought the good fight and have found satisfaction in their work, their colleagues, and their students. Their departure is watched with interest by the young Ph.D.'s who would like to have their jobs. It will be the biggest turnover in faculty since the University of Bologna was founded a thousand years ago!

And what of the qualifications of these hordes of would-be teachers? Do they know anything about course design, learning psychology, classroom dynamics, student learning styles, testing, grading, analysis, synthesis, cooperative learning, problem-based learning, leading discussions...? Do they know anything about teaching? You can bet they probably know very little, but know not that they know not. Teaching? "Why, I'll just teach the way I was taught. By the way, can I borrow your lecture notes?"

Then there are the in-betweeners, who have been teaching for three to fifteen years. Obtaining funding for their research is the biggest roadblock on their path to tenure.[1] They spend inordinate amounts of time writing grant proposals and keeping their research programs together in the face of ever-shrinking funding pools. "It's ridiculous—the two-inch thick proposal has to be so detailed that I almost have to do the research before I can write it," one grumbles in frustration. When they aren't writing proposals and cultivating funding agencies, they visit companies to forge connections that may lead to industrial support. If they venture into the education literature to try to see what they might do more effectively in the classroom, they soon encounter a language that's foreign to them, with terms like *epistemology, Bloom's taxonomy, Jungian typologies*, and *Perry levels*. Deciding that they don't have time to decipher all that gibberish, they give up and just go on lecturing.

Still other faculty members may have given up on the chase for research funds to focus on teaching, concentrating on writing clear sets of notes and designing and preparing good overhead transparencies. They may try some experiments in the classroom like putting students in teams to work on problems but find that their ratings drop, and decide "Forget that!" They

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subsequently focus on playing it safe—avoiding rocking the educational boat—because student ratings are their bread and butter.

Many of the problems faced by these diverse souls—the wannabe faculty members in Ph.D. or postdoctoral programs, the new or well-established professors who suspect there are more effective ways to do things but don't exactly know how, and those who have little time to spare from their never-ending quest for research dollars—stem from a single cause. With rare exceptions, no one teaches college teachers to teach! They receive training as researchers, join faculties, and enter their classrooms without so much as five seconds of instruction on what to do there. A few of them seem to have an innate ability to motivate students and facilitate learning and high-level skill development and some acquire this ability through years of experience. Many never acquire it, however, and in the absence of any pedagogical training, they teach the way their teachers (who also never received any training) taught them. This is a questionable way to run a profession, but it's been done this way for centuries.

The first paper in this series[2] established the need to change the traditional way of delivering engineering education in order to respond to rapidly changing conditions in technology and society, and the second two papers[3,4] explained some of the education jargon and offered ideas for improving teaching effectiveness and personal satisfaction with teaching. We now come to the question of how engineering faculty members can best learn their craft and continue to keep up with emerging developments in educational methods. In this paper, we describe a variety of faculty preparation programs and offer suggestions for self-study.

GRADUATE COURSES ON TEACHING

Every skilled craft provides formal instruction and/or mentorship for its new practitioners...except college teaching, which expects its newcomers to learn everything themselves by trial-and-error. While there is something to be said for trial-and-error learning, requiring it for a craft as complex as teaching is absurd. If the learning occurs at all, it normally takes years, and the ones who pay the penalty for the errors are not the ones who make them.

Much of the knowledge and many of the skills college teachers need to be effective can be taught. Good courses on college teaching are offered on a few—perhaps several dozen—campuses, but our applause at their existence should be somewhat restrained. Why don't we see such courses at every college that offers the doctoral degree? What happened to good old academic entrepreneurship? A change is long overdue.

Courses on teaching for graduate students offer several benefits:

- Teaching Assistants (TAs) support their graduate studies by providing formal or informal instruction to undergraduates in lecture and lab courses. The students whom the TAs are assisting deserve good teaching, which is what they (and their parents and, for public universities, the state legislature) think they are paying tuition to get. If we can improve the skills of the TAs by as little as five percent in a teaching course, the cost of the course would be a bargain. There is no way a teaching course could fail to lead to at least that much improvement.
- A well-designed teaching course gives students considering academic careers a much better picture of the profession than they could ever get in the normal course of a graduate program. Their career decisions are much better informed after they take the course, and if they

eventually take teaching positions their professional learning curves could be shortened by years. Moreover, if the course is taught well, some students leaning toward industrial careers might be motivated to go into teaching, helping to meet the challenge of filling all the faculty vacancies predicted to occur in the coming decade.

- Students who take teaching courses receive training in effective presentation, teamwork, assessment of learning, time management, dealing with student-related problems, and other important topics that are not part of normal graduate training outside schools of education. The resulting knowledge and skills are useful and marketable, whether the graduate joins a faculty or goes into an industrial or government career.

There are several reasons why such courses are not commonplace, their benefits notwithstanding. First, most faculty do not see a need for courses on teaching, believing that the knowledge and skills required to teach effectively can just as well be picked up on the job. (If they think about some of their colleagues or their own teachers, they will quickly see the fallacy of this reasoning. We never see our own shortcomings in our mental telescope, of course.) In addition, many dissertation advisors actively discourage their graduate students from taking courses that are not required to pass the qualifying exams and take time away from research. Finally, most engineering faculty do not feel prepared by their own education or experience to teach courses on teaching. This fact in itself is a criticism of our system, which allows us to practice in a profession whose skills we are not equipped to pass on to others.

The time has come to change the way we think about preparation for college teaching. In the first three papers in this series, we proposed viewing undergraduate education less as an amassing of information and more as learning how to think, how to create, and how to develop the motivation and skill to be a lifelong learner and problem solver. In this paper, we argue that a graduate education should be viewed in a similar way. Learning how to do research is an important component of a Ph.D. program, but it should be exactly that—a component. All engineering Ph.Ds do not go into research as soon as they graduate, and very few of those who do spend their entire careers there. They may become design engineers, middle and upper-level corporate managers, consulting engineers, faculty members, department heads, deans, provosts, and chancellors, and a wide variety of other things that do not involve research. Part of our responsibility to our graduate students is to equip them with some of the communication and interpersonal skills they will need to succeed in those positions. Providing training in teaching is a good step in this direction. The question now becomes, what options are available for doing so?

Since 1972, Jim Stice has offered a course at the University of Texas at Austin on improving teaching skills.[5] The following topics are covered in a typical one-semester offering.

1. Introduction and overview (1 period)
2. The Kolb Learning Style Inventory (2 periods)
3. The Myers-Briggs Type Indicator (2 periods)
4. Instructional design (1 period)
5. Writing instructional objectives (2 periods)
6. Production of overhead transparencies (1 period)
7. Microteaching-short videotaped presentations by class members (4 to 5 periods for a class of about 15)
8. Testing and grading (3 periods)

9. Student characteristics (1 period)
10. Teaching by lecture (1 period)
11. Teaching by discussion (1 period)
12. Learning theory (2 periods)
13. Microteaching II (4 to 5 periods)
14. Theories of Jean Piaget (1 period)
15. Individualized instruction (2 periods)
16. Teaching problem solving: analytical thinking (3 periods)
17. Teaching problem solving: creativity (1 period)
18. Where the teaching jobs are (1 period)
19. Summary of the course; evaluation (1 period)

Stice suggests that anyone who has the interest and several years of teaching experience can teach such a course. Those who feel apprehensive about the first few offerings can team up with someone from the College of Education—which is what Stice did—or the Instructional Development Center. Teaching the course will provide a real learning experience for the instructors (as teaching courses always does). After a few semesters the engineering professor should be able to go it on his/her own, although if the course is going well there is a lot to be said for continuing to present as a team. The prime recommendation is to keep the class small—say, below 15—primarily because the microteaching exercises (topics 7 and 13) take too long when the class size increases.

Since the early 1980s, Phil Wankat and Frank Oreovicz have offered a 2- to 3-credit course on college teaching in the School of Engineering at Purdue University.[6] Their general outline follows:

Part I. Methods and procedures

1. What works
2. Efficiency and effectiveness
3. Taxonomy and objectives
4. ABET and accreditation
5. Problem solving and creativity
6. Obtaining an academic position
7. Teaching methods: lecture, cooperative groups, discussion, teaching with technology, mastery and Personalized System of Instruction (PSI), laboratories, design
8. Graduate mentoring
9. Testing and grading, cheating and discipline
10. Evaluation of teaching

Part II. The student

1. Piaget, Jung, and Perry
2. How people learn
3. Motivation

Part III. Redesign of engineering education

1. Web page project
2. Case study: ideal graduate program
3. Project: Ideal undergraduate program

At McMaster University, North Carolina State University, and other campuses, the campus Instructional Development Center offers courses to graduate students interested in academia and to interested faculty. Attendance by engineering graduate students in these courses is generally low unless someone in the school of engineering vigorously champions the courses and encourages graduate students to attend them.

WORKSHOPS AND SEMINARS

Workshops and seminars lasting anywhere from an hour to a week are far more common than academic courses as vehicles for teaching about teaching. These programs may be external to any campus (e.g., at a professional society conference), campus-wide, engineering-specific, or departmental.

The National Science Foundation sponsors the *Engineering Education Scholars Programs*,[7] week-long summer workshops at Carnegie Mellon University, Stanford University, and the University of Wisconsin that examine all facets of academic careers. The EESPs are for engineering graduate students and relatively new faculty members, with 30-40 applicants accepted for each offering. Nationally known engineering educators give presentations, and the program at Carnegie Mellon University uses the excellent book by Davidson and Ambrose[8] as a required text. Table 1 summarizes the topical outlines of recent offerings. In the summer of 1999, the University of Wisconsin presented the *Science and Engineering Education Scholars Program* to new faculty members and graduate students in science.

The National Effective Teaching Institute [NETI] is a three-day workshop given to faculty members in engineering and engineering technology under the auspices of the American Society for Engineering Education (ASEE), with some funding from industry.[9,10] Beginning in 1991, the NETI has been given every year immediately preceding the annual ASEE Meeting in June. The topics include learning styles and teaching styles, planning a course (including writing instructional objectives) and getting it off to a good start, effective lecturing, active and cooperative learning, testing and grading, helping students develop problem-solving and critical and creative thinking skills, dealing with student problems and problem students, and managing the stresses associated with academic careers. Deans of engineering and engineering technology are invited every January to nominate up to two of their faculty members to attend the NETI. Nominations are accepted on a first-come-first-served basis, and the enrollment is closed at 50. Since 1991, 472 faculty members from 157 different institutions have participated.

One-day and half-day workshops on education-related topics are generally offered before, during, or after the annual ASEE meeting in June[11] and the Frontiers in Education (FIE) Conference in October or November.[12] Educational workshops are also offered by the American Institute of Chemical Engineers, the Mexican Institute of Chemical Engineers, and other professional societies. Every five years the Chemical Engineering Division of the ASEE sponsors a week-long "summer school" for chemical engineering faculty that offers a rich set of workshops on effective teaching in general and on teaching specific topics.

The Educational Research and Methods Division of the ASEE has compiled a list of its members who present workshops on campuses around the country.[13] The list includes workshop topics and fees.

Many universities offer workshops and seminars on different aspects of academic careers or specifically on teaching. Some are open to all faculty members and some are designed

specifically for new faculty members and/or graduate students. The paragraphs that follow describe several illustrative programs of this type.

At the University of Texas, a unique approach for new faculty is the three-day Summer Seminar, initiated in August 1980 by Jim Stice and his colleagues in the campus-wide Center for Teaching Effectiveness.[14,15] All new hires are invited to attend by their department chairs and the Provost. The presenters—all UT faculty members and administrators (including the president)—discuss a variety of topics, including learning and teaching styles, instructional objectives, writing a syllabus, testing and grading, student characteristics, important university rules and regulations, research activities and resources, and what to do on the first day/week of class. Attendance ranges from 60 to 90 each year. Participants have reported that when they arrived at the seminar they felt like strangers, and by the end they felt they were members of the academic community. The seminar wasn't really planned with this result in mind—it was a real bonus! The unsolicited remarks of one participant are worthy of etching in marble: "After 30 years I am changing my career. I never expected to be a college teacher, and I've been worried about what in the world to do with my students. I didn't know what to expect from them, I didn't know what they expected from me, and I had no idea how to conduct a class. Lately I've had stomach problems, and I haven't had a good night's sleep in three weeks. Then I came to your Seminar, and now I know what I'm going to do, and I have some ideas about how to do it—and I'm sleeping like a baby again. I am very much in your debt."

It is worth noting that the new faculty members who attended the Summer Seminar from 1980 through 1984 received an extra week's salary. This stipend was a powerful incentive to participate. Many said something like, "I came for the money—and I'm glad I did!" In 1985 the prices of oil and beef went down the drain, and the economy of the State of Texas suffered to an extent that the University was no longer able to provide the extra salary money. Attendance at later Summer Seminars suffered, but by this time the administrators had heard a lot of positive things from those of their faculty who had attended and so the Seminar's good reputation was established. It is still held each summer, and department chairs and deans still recommend that their new people attend.

Several years after the inception of the Summer Seminar, members of the regular faculty began to ask if they could attend it. This was not felt to be a good idea, so instead a second program called the Seminar for Experienced Faculty was initiated at a more sophisticated level.[16] It was held in January during the week before registration for the spring semester, and also lasted three days. The first year the number of participants was modest, but those attending were very enthusiastic. In the third year, 170 experienced faculty members attended.

At North Carolina State University, three-day faculty workshops have been offered annually in the College of Engineering since 1986 by Richard Felder and faculty colleagues. The workshop content is similar to that described previously for the National Effective Teaching Institute. Felder *et al.*[17] describe the workshop and offer tips for getting engineering faculty to attend such workshops and making them effective. The suggestions include having both engineering expertise and pedagogical expertise on the presenting staff (sometimes the same individuals can fill both roles but this situation is rare), emphasizing practical applications and putting learning theory and research in a supporting role, and drawing examples primarily from engineering courses.

At the Universidad Iberoamericana in Puebla, Mexico, an eight-hour teaching workshop is presented to all beginning professors, the School of Engineering offers workshops on teaching development in a yearly summer program, and the Department of Teaching Development offers courses and workshops for Mexican and Latin American institutions. A series of seven seminars on academic careers given to chemical engineering students at Carnegie Mellon University is described by Ko.[18]

MENTORSHIPS

In most skilled professions, novices are mentored by experienced practitioners who provide guidance and constructive feedback on the novices' initial efforts. This process can cut years off the learning curve normally required for unmentored novices to reach an acceptable level of effectiveness at a skilled profession. Doctors, psychologists, lawyers, pre-college teachers, and practitioners of every type of craft are routinely inducted into their professions with the aid of such guidance. As noted previously, the only skilled profession that does not routinely provide mentoring is college teaching.

Felder[19] describes a mentoring program in the Chemical Engineering Department at North Carolina State University. Each new faculty member is assigned a research mentor and a teaching mentor. The teaching mentor—who should be an excellent teacher with a desire to serve in that capacity—and the new professor co-teach a course in the latter's first semester. The mentor initially takes most of the responsibility for planning lectures, class activities, assignments, tests, and conducting classes; the mentee observes and takes notes; and the two discuss the class at a weekly debriefing meeting. As the semester progresses, the mentee gradually takes more responsibility for the instruction and the mentor becomes more of an observer, refraining from intervening in class if the mentee gets into difficulty and troubleshooting the problem at the next debriefing. Next semester, the mentee teaches a course and the mentor functions only as an occasional observer in class and consultant at periodic (but not necessarily weekly) debriefings. The mentor also makes an effort to introduce the mentee to faculty colleagues with related interests, both locally and at professional conferences. After the first year, the formal mentorship terminates and the mentee joins the normal teaching rotation.

A similar mentoring approach called *peer counseling* was pioneered by Roger Beck of the University of Alberta and has spread to campuses throughout Canada. Still another approach to teaching improvement involves partnerships in which two faculty colleagues visit each other's classrooms and offer feedback and suggestions.[20,21]

Some institutions have programs wherein faculty members provide mentoring in teaching to graduate students contemplating academic careers. The University of Colorado has an advanced TA requirement for all PhD students that is typically fulfilled in the third year of graduate study.[22] Typically, the student prepares and presents several videotaped lectures, prepares and grades homework and test questions, holds office hours, and teaches a recitation section if one is offered for the course, and the instructor provides feedback and guidance at weekly meetings. In the "Preparing the Professoriate" program at North Carolina State University, a faculty mentor and graduate student mentee may work together on a course (as at Colorado) or on a classroom research study.[23,24]

An important requirement for a mentorship program is for department heads and deans to recognize that effective mentoring takes a certain amount of skill and a great deal of time.

Several hours of mentor training should be provided by campus instructional development staff or experienced mentors, and all mentors should be compensated in some manner for their efforts.

NETWORKING

The most common—and arguably the most effective—way for new members of a professional organization to learn the ropes and adapt to the local culture is informal networking with experienced colleagues. Unfortunately, many new faculty members are introverted and wait in their offices for their more experienced colleagues to come to them. It does not always happen, and it is least likely to happen to women and minority faculty in engineering, who may have the greatest need for such support.

In *The New Faculty Member*,[25] Robert Boice reports on studies he has conducted of the early careers of many professors. Boice found that about 13% of his subjects were "quick starters" who reached high levels of research productivity and teaching effectiveness in their first 1-2 years on faculties, as opposed to the 4-5 years required by most new faculty members. Prominent among the factors that differentiated quick starters from their more numerous counterparts was that the quick starters spent between two and four hours per week networking with faculty colleagues—going to lunch or for a cup of coffee with them or visiting them in their offices—and talking about research and teaching. Boice strongly recommends that new faculty members force themselves to engage in such activities and that department administrators and senior faculty members proactively and frequently initiate conversations with new colleagues in their first year.

Other vehicles for teaching-related networking are campus *learning communities,*[26,27] in which groups of faculty members meet periodically to talk about teaching-related topics or to read and discuss selected references on teaching, and meetings of professional societies like the American Society for Engineering Education. Other organizations that sponsor conferences on teaching and learning include the American Educational Research Association, International Society for Exploring Teaching Alternatives, National Science Teacher's Association, and the Canadian organization called Society for Teaching and Learning in Higher Education. Woods and Ormerod[28] offer additional ideas about networking and its importance.

CONSULTATIONS WITH CAMPUS TEACHING EXPERTS

Analyzing a videotape of a lecture with the help of a teaching consultant is an effective (albeit sometimes humbling) first step toward teaching improvement. The Clinic to Improve University Teaching of the University of Massachusetts developed the following structured approach to classroom videotaping that can be implemented either with a consultant or alone.[29] Before the class, make a list of six questions you have about your lecturing and write down your guesses at the answers. Have the class videotaped and ask the class members to complete a traditional student evaluation form. Complete the same form yourself twice, once based on how you felt the class went and once based on how you guess the students rated the experience. Then watch a replay of the videotape and analyze it in the context of your six questions. Compare the student evaluations with your two sets of responses and identify five strengths and two areas to work on. This process works best if you go through the process with a consultant, but it is still useful if you do it alone. Much can be learned even without the videotaping.

RESOURCES FOR SELF-STUDY

Books

McKeachie's *Teaching Tips*[30] is probably the best known general reference on college teaching. Now in its 10th edition, it offers suggestions on every aspect of teaching and cites research supporting the suggestions. An excellent reference that applies specifically to technical disciplines is Wankat and Oreovicz's *Teaching Engineering,*[31] which recently became available on the World Wide Web, and other books discuss the attributes of effective college teaching and teachers irrespective of discipline.[32-39] Some references survey the theory and practice of the instructional models discussed in References 3 and 4 that have repeatedly been shown to promote learning and skill development. Johnson *et al.*[40] do this for cooperative learning, and Woods[41] does so for problem-based learning. For Mexican and Latin American educators, Rugarcia's book, *La Formación de Ingenieros*,[42] is recommended.

Several references are written specifically for faculty members new to the profession, including books by Davidson and Ambrose,[8] Schoenfeld and Magnan,[43] Whicker et al.,[44] Gmelch,[45] and the previously mentioned work of Boice[25] on the characteristics of "quick starters." The last reference may be particularly useful to department heads and senior faculty members serving as mentors to their junior colleagues.

Assessment of learning is becoming an increasingly important topic in engineering education as the day approaches when the outcomes-based Engineering Criteria 2000 becomes the accreditation standard for all U.S. engineering departments.[46] Besides the usual midterm and final examinations, classroom assessment techniques (CATs) can be used to monitor what students are learning and what confuses them. Angelo and Cross[47] describe a variety of CATs that can be used to assess learning and student attitudes, and Boud[48] offers ideas for helping students to self-assess their own learning.

Journals and Newsletters

ASEE Prism is the news journal and *The Journal of Engineering Education* (JEE) the research journal of the American Society for Engineering Education. *Prism* contains Washington updates, feature articles on current issues and recent developments in engineering education, and a column on teaching methods written by Wankat and Oreovicz, the authors of *Teaching Engineering*.[31] JEE contains articles on instructional methods and programs as well as reviews of recent books of interest to engineering professors. Both journals come with membership in the ASEE.

Other journals containing useful articles for college teachers include *The Journal of College Science Teaching*, *College Teaching*, *Change*, *Journal on Excellence in College Teaching*, the *AAHE Bulletin* (published by the American Association for Higher Education), and *Studies in Higher Education.* Several education journals such as *Chemical Engineering Education* and, in Spanish, *Educación Química* and *Revista del IMIQ,* focus on issues related to specific branches of engineering.

Newsletters that offer teaching tips and summaries of recent books include *The Teaching Professor,*[49] *The National Teaching and Learning Forum,*[50] and *Cooperative Learning and College Teaching*.[51]

Electronic and Videotape Resources

A substantial and rapidly growing collection of resources for instructors can be found on the World Wide Web. Table 2 lists sites particularly relevant to engineering education. The sites contain class materials (including multimedia resources), teaching and assessment guides, handouts for students, and links to still more sites.

A growing number of listservers provide rich opportunities for interaction with colleagues seeking to improve their teaching. Table 3 lists several of them.

The National Technological University regularly offers seminars on education-related topics over satellite links to campuses around the country, and also makes available videotapes of past programs.[52] Some topics that have been presented include cooperative learning (Karl Smith and Richard Felder), programs for minorities (Ray Landis), learning styles (Felder), and women in engineering (Eleanor Baum).

The University of Technology at Sydney makes available excellent videotapes on four topics—"Lectures," "Tutorials," "Practicals," and "Assessment"—and a support text called *Survival Guide for New Teachers*.[53] The University of Victoria offers a series of "Critical Incident Videotapes," brief scenarios of typical class problems that provide focal points for discussion.[54] For example, the ten critical incidents on Tape 1 include one that deals with a student at one level of intellectual development trying to write an essay that calls for thinking at a higher level, and another that involves students complaining to the instructor that the class lacks structure. Woods has produced a videotape on self-directed learning that can be obtained by request.[55] Margarita Sanchez of the Instituto Tecnológico y Estúdios Superiores de Monterrey (ITESM) offers satellite-linked courses on problem solving.

A MODEL ENGINEERING FACULTY DEVELOPMENT PROGRAM

Beginning in 2001, engineering departments seeking accreditation will have to show that they are equipping their graduates with a specified array of skills and that they have established a program to assess the levels of these skills and remedy any deficiencies revealed by the assessment.[46] Qualitative changes in the content and delivery of engineering courses along the lines outlined in the first and second papers of this series will be required to attain the desired learning outcomes. To implement these changes, most engineering professors will have to be educated in the new instructional methods, as opposed to the relative few who have been motivated to learn about them in the past.

A model engineering faculty development program is being developed by the Southeastern University and College Coalition for Engineering Education (SUCCEED) and implemented at the eight Coalition campuses.[26] The core of the program is a broad variety of learning opportunities and resources for faculty members and graduate students. Opportunities may include courses on teaching, workshops and seminars, mentorships and partnerships, learning communities, and individual consulting with instructional development personnel. Some of these programs are open to all faculty members and others are designed specifically for faculty members in their first two years of teaching. Programs for graduate students include courses on teaching, workshops and seminars, and mentorships. Some of the graduate student programs are designed for teaching assistants and others for students contemplating academic careers. Resources for self-study are also provided as part of the program, including books,

journals, videotapes, and guides to useful Web sites. Program facilitators should collectively have expertise in both pedagogy and engineering.

An essential component of a successful faculty development program is strong institutional support. An adequate budget is of course a necessary condition. Beyond that, academic administrators should convey a clear expectation that the faculty will be good teachers, good teaching will be rewarded in tangible ways, and inadequate teaching will be penalized. We will return to this point in the last paper in this series.

SUMMARY

Few engineering schools explicitly prepare their graduate students to teach, and new professors consequently join faculties equipped with a Ph.D. in their discipline but no background in pedagogy. Also, most colleges and universities have few criteria to screen prospective candidates for their teaching ability; much of the emphasis in hiring is on perceived potential as a researcher. Candidates often give seminars on their research, and if they can give a passable performance and can answer a few questions without complete intellectual collapse, then their teaching skills are judged "good enough." As time passes, some of those hired become good teachers by instinct and others learn their craft by years of trial-and-error effort, but some never rise above mediocrity or worse.

Teaching is a complex craft, but the skills required to do it effectively can be taught. In this paper we have outlined the elements of an effective engineering faculty development program. To recapitulate, we advocate a program that includes a subset of teaching improvement workshops, courses, seminars, mentorships and partnerships, learning communities and consultation with campus teaching experts. Graduate courses in college teaching should be provided for those students who think they might be interested in academic careers. The faculty development coordinator should maintain resources for self-study, including books, journals, multimedia resources and guides to useful Web sites. Such a program should enable a far greater percentage of new faculty hires to become highly effective in 1-2 years—i.e., to become what Robert Boice has termed "quick starters"—instead of the 4–5 years required by most of the new faculty members Boice studied.

Table 4 invites reflections on the options for teaching improvement presented in this paper.

IF YOU GET ONE IDEA FROM THIS PAPER

We have described many options for new instructors to learn the craft of teaching, including courses, workshops and seminars on teaching, professional society conferences, mentorships, and working with teaching consultants. Faculty members should take advantage of as many of these opportunities as possible rather than relying on trial-and-error for mastering the craft of teaching.

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Table 1
Engineering Education Scholars Program Workshops*

	University of Wisconsin-Madison	Carnegie Mellon University	Stanford University
Sunday	Get acquainted	Prior knowledge assessment. Introductions. Challenge of change.	Goals. Problem-based learning activity. Activity: Why am I a professor? Academic roles: teaching, research, administration
Monday	Goals. Retention. Options for teaching. Improving teaching. Collaborative learning. Diversity and equity.	Goals. Retention. Understanding student needs. Diversity. Cognitive processes in learning.	Trends in engineering education. How students learn: Diversity and learning styles. NSF programs.
Tuesday	Academic careers: finding mentors, seeking tenure, writing grant proposal. Climbing the academic ladder. Departmental tours.	Systematic course design. Problem-based learning. Balancing teaching, research, and administration. Assessment of learning. Active learning, accounting for student workloads.	Lecturing. Problem-based learning. Instructional technology.
Wednesday	Course design. Assessing student performance.	Course design. Mentoring and supervising graduate students. Videotape participant presentations with feedback.	Videotape participant presentations with feedback. Course design.
Thursday	Innovative teaching options (overview and parallel workshops). Panel: Young faculty reflect from the trenches.	Getting research funding. NSF programs. The future of engineering education. Instructional technology.	Balance in an academic career. Stress and time management. Getting tenure. Networking and staying current.
Friday	NSF programs. Participant exchange of materials developed. **Activity:** participants share materials developed.	Ethics. Workshop evaluation.	Participant presentations. Workshop evaluation. Celebration.
Saturday	Diversity. Workshop evaluation.		

*This table shows workshop outlines for one recent year: the programs at each institution vary from year to year. All programs also include "open" times, which might be free times, planned social events, concerts, banquets, or sports events.

Table 2
Useful Web Sites for Engineering Educators.

Site	Comments
World Lecture Hall <*www.utexas.edu/world/lecture/index.html*>	Lecture notes and multimedia resources for courses in many fields, including engineering.
NEEDS—National Engineering Education Delivery System <*www.needs.org*>	Multimedia resources for a vast collection of topics.
Resources in Engineering and Science Education (Richard Felder's Web site) <*www2.ncsu.edu/effective_teaching/* >	Articles, " Random Thoughts" columns from *Chemical Engineering Education*, student handouts, software tutorials.
Deliberations on Teaching and Learning in Higher Education (London Guildhall University) <*www.lgu.ac.uk/deliberations/* >	Material on collaborative learning, assessment of learning and teaching, and engineering education.
Collaborative Learning Website (National Institute of Science Education) <*www.wcer.wisc.edu/nise/CL1/CL/clhome.asp* >	Practical suggestions, anecdotes, research citations, and an extensive annotated bibliography on cooperative learning.
Field-Tested Learning Assessment Guide (National Institute of Science Education) <*www.wcer.wisc.edu/nise/CL1/flag/flaghome.asp*>	Techniques, resources, and references on assessment of learning in science, mathematics, engineering, and technology.
Computer-Based Teaching and Learning Links (University of Newcastle) <*http://lorien.ncl.ac.uk/ming/Resources/cal/CAL.htm*>	Large collection of links to sites that deal with applied and theoretical aspects of instructional technology.
Taking Your Course On-Line (North Carolina State University) <*www2.ncsu.edu/ncsu/cc/edu/online/*>	Suggestions and resources for course delivery via the World Wide Web and other electronic media.
Problem-Based Learning and the McMaster Problem Solving Program (McMaster University) <*http://chemeng.mcmaster.ca/innov1.htm*>	Techniques and instructional resources for both programs.
For Your Consideration (University of North Carolina) <*www.unc.edu/depts/ctl/fyc.html* >	Short monographs on topics such as active learning, writing to learn, teaching large lecture classes, and assessment of teaching and learning.
Mount Allison University Teaching and Learning Page <*http://aci.mta.ca/MtATeach/*>	Listings of education-related conferences and links to other sites sorted by topic (collaborative learning, learning styles, technology, etc.).
Links to a Better Education <*http://w3.nai.net/~bobsalsa/linkstoa.htm* >	Handouts for students on learning and problem-solving skills, taking tests, critical thinking, technical writing, time management, teamwork, learning styles, creativity, and many other topics.
University of Guelph <*www.tss.uoguelph.ca/trc.html* >	Suggestions, on-line assessment tools, and links to sites that deal with learning styles, teaching portfolios, copyright laws, and course design.
University of Technology, Sydney (Australia**)** <*http://www.clt.uts.edu.au/pb.html*>	Survival guide for new teachers, evaluating teaching and courses, teaching portfolios.

Table 3
Education-Related Listservers

Organization or Theme	Information	E-mail Address
Alternative and collaborative learning		<L-aclrng@psuvm.psu.edu>
Alternative learning approaches		<altlearn@sjuvm.stjohns.edu>
Association for Higher Education		aahesgit@list.cren.net <LISTPROC@list.cren.net>
Adult education network		aednet@pulsar.acast.nova.edu
Association for the Study of Higher Education		<ashe-L@listserv.american.edu>
Problem solving and creativity, learning	The approach of Tony Buzan to learning, memory, and creativity	<listserv@sjuvm.stjohns.edu>
Cooperative Learning		<CL_news@iubm.ucs.indiana.edu>
		CL@jaring.my <LISTSERVER@jaring.my> " Subscribe CL firstname lastname"
Learning Styles		<edstyle@sjuvm.stjohns.edu>
Higher Education Processes		<heproc-L@listserv.american.edu>
Problem-based Learning		<imsacpbl-L@imsa.edu>
	PBL-LIST. Monash University, Australia.	<LISTSERV@eng.monash.edu.au> " SUB PBL-LIST yfname ylname"
Center for Faculty Development	University of Arizona	<lrnasst@listserv.arizona.edu>
Exploring the way we educate		<newedu-L@uhccvm.uhcc.hawaii.edu>
Professional and Organizational Development		<pod@lists.acs.ohio-state.edu>
Society for Teaching and Learning in Higher Education (Canada)		stlhe-L@unb.ca <listserv@unb.ca> " sub STLHE-L yfname ylname"
Continuous Quality Improvement		CQI-L@mr.net <listerv@mr.net>

Table 4
Reflection and Self-Rating

Reflection:

_____

_____

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_____

_____

Rate the ideas

	Already do	Would work	Might work	Not my style
Draw on others				
Take a course on effective teaching	O	O	O	O
Attend workshops on teaching	O	O	O	O
Ask for a mentor	O	O	O	O
Partner with a colleague to improve teaching	O	O	O	O
Work with a teaching consultant	O	O	O	O
Be videotaped in class	O	O	O	O
Other _____	O	O	O	O
Self study:				
Read books about effective teaching	O	O	O	O
Read articles in education journals	O	O	O	O
Watch videotapes about effective teaching	O	O	O	O
Browse education-related Web sites	O	O	O	O
Other _____	O	O	O	O
Keep up to date				
Join the American Society for Engineering Education	O	O	O	O
Read at least one education journal each month	O	O	O	O
Subscribe to an education-related listserver				
Attend an education conference	O	O	O	O
Other _____	O	O	O	O
Pass on your knowledge				
Give a workshop or seminar on effective teaching	O	O	O	O
Serve as a mentor to a new instructor or graduate student	O	O	O	O
Give a conference presentation and/or write a paper about a teaching method you have tried.	O	O	O	O
Teach a course on effective teaching	O	O	O	O