Int. J. Engng Ed. Vol. 21, No. 5, pp. 925–930, 2005
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Teaching Prospective Engineering Faculty How to Teach*

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With institutional programs in engineering education in their infancy, there is as yet little scientific proof that teaching prospective engineering faculty how to teach impacts their careers positively, but there is abundant anecdotal evidence. A survey of graduates of a Purdue course 'Educational Methods in Engineering' was conducted. Graduates who chose academic careers reported a very significant impact on their careers, while graduates who chose industrial careers reported a positive but less significant impact. A survey of 17 courses at other institutions showed that the educational topics in how-to-teach courses are similar to the topics in the Purdue course; thus, the results should generalize to other institutions for graduates who choose academic careers.

INTRODUCTION

AMONG THE MANY suggestions for improving engineering education, two steps are critical. The first is the more difficult—and less likely to be implemented: change the reward structure for faculty. More doable is the second step: teach engineering faculty how to teach. In this paper we explore the impact that a graduate course on Educational Methods in Engineering has had on the careers of graduates.

Although most faculty learn how to teach on the job, and over time most do a commendable job, learning on the job is inefficient and time consuming. More important, it also potentially sacrifices many students who are the guinea pigs for the 'apprentice' teacher. Also, since this apprenticeship takes place during the period new faculty are trying to start research, they do not have time for a systematic study and the time spent learning to teach may negatively impact the development of their research programs. Lacking systematic pedagogical training, they imitate the way they were taught, gaining only practical know-how, not theoretical knowledge, and they are unlikely to be aware of, let alone use, scientific advances in learning.

An integrated approach to teaching would ideally include a number of steps that start when one is a graduate student [1]. Since most graduate students serve as a teaching assistant (TA) while in graduate school, a logical place to start is with a short (perhaps one or two days) TA training session [2], before they serve as a TA. After this experience, volunteers could take a graduate course in teaching methods for engineering students [3–9] or a summer workshop for potential and new faculty [10]. Ideally, the teaching course or workshop would be followed with a supervised internship in teaching. Three models for supervised teaching internships are commonly used in other disciplines. First, internships can be modeled after formal programs in education and psychology. In this model the students sign up for a supervision 'course' with a faculty member who supervises 4 to 6 students. The new Department of Engineering Education at Purdue University will use this model. Second, interns can serve at another institution (e.g., a community college) working with a faculty member at that institution. This model, which is used in Preparing Future Faculty (PFF) programs [11], has the advantage of exposing the students to an environment that is very different from a research university. Third, faculty can formally, with course credit [8, 12] or pay [13] or informally [14], share a course with selected graduate students. The faculty member attends class when the graduate student teaches and provides feedback. This model could be employed at any university, and since it is less structured, would be more adaptable to unique circumstances.

Ideally, education in how-to-teach would continue on the job with mentored teaching experiences. New faculty members should have a teaching mentor who helps them go through a practice/feedback/reflection/practice cycle to improve their teaching. Teaching workshops are helpful for those who were not trained while in graduate school [15–17]. Workshops are also helpful for trained faculty to provide motivation and an introduction to new teaching approaches.

GRADUATE COURSE IN EDUCATIONAL METHODS IN ENGINEERING

A three-credit graduate course, ChE 685, 'Educational Methods in Engineering', has been

* Accepted 4 March 2005.

taught by the authors at Purdue University approximately every other year since 1983. It is open to Ph.D. students and post-docs, who audit the course, in all areas of engineering. From 3 to 30 students have taken it each time it has been offered. The textbook *Teaching Engineering* [4] was written for the course. In 2004 this book was supplemented [1]. Some of the students have taken this course without the knowledge of their research advisor and it did not count in their plan of study. They took the course in secret because their research advisor did not want them to spend time away from their research.

The course focuses on academic careers, not on improving the teaching of teaching assistants, although it also does that. Topics covered in the course include objectives and Bloom's taxonomy; teaching methods, including lecture, co-op groups, active learning, guided design, PBL (problem-based learning), and techno-teaching; testing and grading; written and oral communication skills; student evaluation of teaching; efficient teaching approaches; and information on students such as learning styles, how people learn, Perry's model, and the Myers–Briggs Type Indicator. The course outline and assignments used in Spring 2004 are listed in Table 1. Previous course outlines are available [3, 4, 6]. Most graduate students who take the course are not initially familiar with techniques other than lecture, design and laboratory courses. The course is taught with active learning techniques. In addition to studying co-operative groups, PBL, and guided design the students participate in these methods.

Course assignments (Table 1) include writing a test and solution for this course, and then taking a test formed from questions on the students' tests; presenting a mini-lecture suitable for a beginning engineering course in their discipline; and developing a statement of their teaching philosophy suitable for inclusion with their vita when they look for an academic position. They also visit and critique the pedagogy in an engineering class taught by one of the award winning engineering faculty at Purdue. All of the students take the Myers-Briggs Type Indicator and learn about their personal preferences and how these will impact their teaching. Students also develop a teaching module for an engineering course for the group course project.

There is a modest amount of research on the effectiveness of workshops on improving teaching. All of it has been focused on teaching workshops, not regular classes for credit. For example, Kennedy [18] cites research that found significant improvement in evaluations of clinical teachers after a series of workshops. The organizers of teaching workshops at West Point [16] found that former students believed that they had improved because of an intensive one-week

Table 1. Course outline and assignments for ChE 685 for spring 2004. Classes last one hour and 15 minutes. *For the student mini-lectures one half of the class came on Tuesday and the other half on Thursday. The class lasted from 4:30 until about 8:00 with a pizza break in the middle. Since extra time was required of the students, university regulations require canceling a class to make up the time.

1	Introduction & First Course
2	Models of teaching/Objectives and Taxonomy
3	Syllabus, outlines & course prep. & texts—*Objectives/taxonomy HW due*
4	Lecturing
5	ABET, Communication Skills: Writing/Oral—*Quiz on ABET*
6	Piaget/Perry—*Critique of classroom visit due.*
7	Myers Briggs Type Indicator
8	MBTI—*First draft of Teaching Statement due*
9	How People Learn & Learning styles
10	Testing—*Theory paper due*
11	*Student Mini-lectures**
12	*Student Mini-lectures**
13	No class*
14	Testing & Grading
15	Efficiency & Effectiveness—*Student written tests due*
16	Test
17	Discuss exam. Evaluation of teaching
18	Discipline/Cheating
	Spring Break
19	Cooperative groups/ PBL
20	Individual group meetings with instructors—*Project topics due*
21	Optional group meetings with instructors
22	Group meetings with instructors
23	Optional group meetings with instructors
24	Group meetings with instructor
25	Panel on Obtaining an Academic Position—*Rough draft of project due*
26	Continuing Engineering Education/Technology in Teaching—*Critique due*
27	Group meetings with instructor
28	Advising Graduate Students—*Final written project report due*
29	Panel on Experiences of New Faculty
30	Professional Issues/Course Projects – *Second draft of teaching statement due*
Finals	*Group Oral Reports on Course Projects—Introspective report on experience due*

summer workshop. When asked, 'Has your teaching improved as a result of attending this course?' 90% answered unequivocally yes. A survey by the Succeed coalition [17] found a self-reported increase in use of active learning methods by attendees of teaching workshops. Since there is abundant evidence that the use of active learning methods increases student learning [19], the workshops will result in more learning if the attendees' self-evaluations are correct. All of these studies look at teaching within a year of taking the workshop and do not look at the long-term effect on teaching. Our former students have presented us with abundant anecdotal evidence that taking this course had major impacts on their careers, but there are no scientific studies that look at the long-term impact of a formal course on teaching methods on the careers of graduates. Because the course at Purdue has been offered since 1983, our survey is longitudinal and allows us to study the long-term impact on graduates.

SURVEY OF GRADUATES OF PURDUE COURSE

In planning our survey, the research question we wanted to answer was, 'Does a course on educational methods in engineering impact the careers of the graduates who take it?' Our specific hypotheses were:

1. The course on educational methods would have a significant impact on graduates who followed academic careers.
2. The course on educational methods would have a positive but less significant impact on graduates who followed industrial careers.

By 'impact' we mean more than just becoming a better teacher and receiving higher ratings from students. Impact also includes any effects on finding an academic position, on start-up time as a new faculty member, on promotion and tenure decisions, and on their careers in general.

In spring 2004 we sent a survey (see Table 2) to all former students and auditors of ChE 685 for whom we could find an address or e-mail address. From these 105 surveys we received 42 useful responses (40%) plus one response that it had been a long time and the graduate did not remember the course! A 5-point Likert scale was used for questions 1 to 10. Each question had room for comments, and 39 surveys included comments. The total number of comments was 157. Since the comments are an integral part of the results, we will present the questions, the score based on the Likert scale, and representative comments for that question.

The number of responses is modest for Questions 3 and 5, and only nine responses were received for Question 4. Thus, the numerical scale result for Question 4 is probably not significant even though it is in the direction suggested by the hypothesis. The 4.90 score for Question 3 (effect of course as an assistant professor), the 4.80 score for Question 5 (impact on academic career), and the 4.90 score for Question 8 (recommend similar course for Ph.D. students planning on academic careers) are very high for a 5-point Likert scale. Clearly, the respondents thought that this course had significant impact for graduates who followed academic careers. The comments agree with this conclusion. The scores and comments for the industrial career-oriented Questions 6 and 7, 3.78 and 4.34, are also quite positive, particularly since they are from graduates who chose a different career path than the focus of the course.

Based on the numerical survey results and the comments, we conclude that *this course on educational methods in engineering had a very significant impact on the careers of students who selected this elective if they followed an academic career. The impact was clearly positive but not as significant for graduates who followed industrial careers. Thus, the hypotheses appear to be valid for this particular course.*

GENERALIZATION OF RESULTS

Shavelson and Towne [20] state, 'Since all studies rely on a limited set of observations, a key question is how individual findings generalize to broader populations and settings.' In other words, do the results obtained from this survey of the Purdue course generalize to courses on educational methods at other universities?

To explore this question a survey of other how-to-teach courses and workshops was sent to 32 people we thought were currently involved or had been involved in the past with these courses or workshops. The names were obtained from authors of papers on courses or workshops on how-to-teach, personal contacts, and requests to reprint *Teaching Engineering*. We received 17 (53%) useful responses and two responses notifying us that the person had retired. Of the 17 courses/workshops, 11 were for engineering students and faculty while the other six were for graduate students from the entire university.

Our main interest in this survey was coverage of topics. A four point Likert scale of coverage was used with the following categories: None = 1; Slight = 2, which was defined as approximately 5 to 15 minutes in one class session plus maybe some reading; Modest = 3, which was defined as approximately 30 to 60 minutes in class plus reading plus perhaps homework; and Extensive = 4, which was defined as more than one hour in class plus reading plus an assignment plus test and/or quiz questions. The ratings of the topics are given in Table 3.

The average and Purdue rankings of topics in Table 3 overlap considerably. Because most educational topics are similar, results from the Purdue

Table 2. Survey results from Purdue graduates of ChE 685, 'Educational Methods in Engineering.'

Question 1. 'Impact of your 697W/685 experience on you as a Grad Student (e.g., effect as a TA or changes in career goals).'
Score 4.58 **42 responses**
Scale for questions 1, 2, and 4 to 7: Negative = 1, Slightly Negative = 2, Neutral or No effect = 3, Slightly positive = 4, and Positive = 5.
Comments:
'Made me more effective; able to try out various teaching techniques as a TA.'
'Helped me find my true interest in becoming a professor.'
Question 2. 'Impact of the Educational Methods course during job search for academic position (*skip to Question 6 if you have NOT tried to obtain an academic position*).'
Score: 4.55 25 responses
Comments:
'Writing the teaching statement and knowing what to expect as a professor has helped tremendously.'
'It never came up in my interview. I assumed everyone had a course like this. Little did I know, that I was ahead of the curve on this.'
Question 3. 'Effect of 'Educational Methods' course on your first 2 years or less as an assistant professor?'
Scale: Harmful = 1; Slightly harmful = 2; Neutral = 3; Slightly helpful = 4; Helpful = 5.
Score 4.90 17 responses
Comments:
'Helpful.'
'It was immensely helpful. I feel that I was very well prepared for what I would face.'
'Made teaching a relatively easy task, which freed my time for research.'
Question 4. 'Impact of course on promotion/tenure decision? (*if no decision yet, go to Q 5).'*
Score 4.11 9 responses
Comments:
'Very positive in my case since my school had a balanced approach between teaching and research.'
'Promotion or tenure decision does not heavily rely on teaching, but on research outcomes.'
Question 5. 'Impact of course on your academic career?'
Score 4.80 17 responses
Comments:
'Improved my delivery skills on university lectures and training offerings to industry personnel.'
'Gave me a foundation on which to build a research program and continue to develop as a teacher.'
'*For industrial work, please answer Q 6-7 (If no industrial work, skip to Q8).*
Question 6. 'Impact of course during job search for industrial position.'
Score 3.78 24 responses
Comments:
'Understanding my strengths and weaknesses had some impact on the types of jobs I was looking for.'
'The learning styles and interpersonal effectiveness aspects of the course are of most use here.'
Helped me recognize different personality types.'
Question 7. 'What impact have parts of the course (e.g., communication skills or Myers-Briggs Type Indicator) had on your industrial career?'
Score 4.34 24 responses
Comments:
'These sections are highly relevant.'
'I had to learn how to communicate & interact with people of other MBTI types.'
'I've exercised Myers-Briggs on coworkers and have found it useful for industry teamwork.'
Question 8. 'Would you recommend a similar course to engineering PhD students planning on academic careers?'
Scale: Strongly not recommend = 1; Not Recommend = 2; Neutral = 3; Recommend = 4; Strongly recommend = 5. (Same scale for Q. 9)
Score 4.90 42 responses
Comments:
'Should be a required course.'
'The belief that the possession of a PhD gives you some innate ability to teach is ridiculous.'
'Strongly recommended for those seeking positions at a teaching institution.'
Question 9. 'Would you recommend a similar course to all engineering PhD students?'
Score 3.91 42 responses
Comments:
'Not sure of value for those not interested in academia.'
'Depends on the individuals' goals.'
'Would be valuable to anyone in a leadership position.'
Question 10. 'The impact on you of the 'Educational Methods in Engineering' course compared to all 600 level electives that you took at Purdue.'
Scale: Very low = 1; Below average = 2; About average = 3; Above average = 4; Very high = 5.
Score 4.16 42 responses
Comments:
'As I am in an academic career path. . .this is the most valuable course.'
'I don't think the course is as 'hard' or 'advanced' as most.'
'Very high impact because it effectively identified and filled a void in my educational experience.'
Question 11. 'What parts of the Educational Methods course have proven to be most useful to you? (There was no scale for this question.)
Comments on 38 questionnaires (90.5%) named 28 different items. The top item was learning styles, which received 15 responses. The second item was the Myers-Briggs Type Indicator, which received 13 responses. There were several items with 5 responses each.
Question 12. 'Any additional Comments?'
Twenty-three surveys (54.8%) had Comments. Example Comments:
'A candid discussion about departmental politics would be useful.'
'This was an excellent course. A necessity for all aspiring teachers, and highly relevant for industrial engineers.'
My spouse is an academic (humanities). 'She and several of her younger colleagues have been very appreciative of the information your class taught me.'

Table 3. Ratings of topics in survey of teachers of How-to-Teach courses

Topic (Purdue rating)	Average Ranking
1. Objectives (3)	3.5
2. (tie) Coop groups (3) and learning cycles (4)	3.3
4. Grading (4)	3.2
5. (tie) Perry's theory (4) and testing (4)	3.1
7. (tie) PBL (4) and taxonomy (3) and assessments (2)	3.0
10. (tie) Discussion (2) and learning theories (4)	2.9
12. Student evaluations of teaching (4)	2.8
13. Syllabus/course outlines (3)	2.7
14. (tie) Lecture (4) & MBTI (4) & Discipline/cheating (3) & Motivation (3) & Formative student evaluation (2)	2.6
19. Peer review of teaching (2)	2.3
20. Faculty portfolios (1)	2.2
21. (tie) Efficient teaching (4) & Academic job search (4)	2.1
23. Laboratory (1)	2.0
24. Case studies (3)	1.9
25. (tie) Accreditation (4) & PowerPoint (2) & Design (1)	1.8
28. Computer course management tools (2)	1.7
29. (tie) Computer tutorials (2) & Student response systems (2)	1.6
31. (tie) TV/streaming video (3) & Internet courses (2) & Service learning (1)	1.4

course should generalize to other courses for engineering students who follow academic careers; however, the Purdue course may have more impact on academic job searches since more time was spent on this aspect. The lower emphasis on MBTI and efficiency than in the Purdue course may mean less generalization for graduates in industrial careers. Unfortunately, since we did not list communication as a topic in the survey, we cannot compare the coverage of communication in the courses.

Note that none of these courses are heavily concerned with techno-teaching. Our course at Purdue spends a modest amount of time on technology, and some of the student groups choose projects that employ technology. This lack of emphasis on technical methods probably occurs because it is widely believed that it is the use of good learning principles, not a particular technology, which makes a course effective. After the basics have been covered there is little time left in the courses to cover technology.

We also asked, 'Do you have any evidence that how-to-teach courses or workshops help attendees become better teachers?' Five respondents noted they had anecdotal evidence from former attendees and three respondents cited local studies based on instructor evaluations.

DISCUSSION AND CONCLUSIONS

One reason for doing this research was to encourage the development of similar courses at the top research universities, which are the universities producing the majority of new engineering faculty. Based on the results of the surveys and our over twenty years of experience, we will briefly suggest how to structure such a course. The attendance numbers for the courses in the survey showed that since the pool of potential students is much larger, more students take a university-wide course than an engineering-only course; however, the attendance of engineers is significantly higher in courses designed specifically for engineers. This agrees with our experience at Purdue. Secondly, engineering students and, particularly, engineering faculty listen to engineering faculty more than to other presenters [5, 17]. Since few engineering faculty have an extensive knowledge of research in learning and pedagogy, we suggest that a team be formed to teach the course [5, 17]. This team should include an engineering faculty member who is a good teacher and is interested in pedagogy plus a person with a background in education, psychology or communication. It is also necessary to sell the course to important faculty. Ideally, a course on teaching methods will count in the students' plans of study. As a minimum, we would wish that all students felt free to take the course without hiding it from their adviser. Finally, it helps to advertise the course to graduate students. We noticed a significant increase in enrollment the years we did extensive advertising.

One of the reviewer's of this paper asked, 'Are the conclusions drawn in this paper the same for scientific disciplines such as physics?' Since no data were collected on this question, we can only speculate; however, we expect that the conclusions would hold for new faculty in any discipline.

Based on the survey of graduates of the Purdue course, 'Educational Methods in Engineering', we conclude that this course had a very significant impact on the careers of engineering graduates who followed academic careers. The course also had a positive impact on the careers of engineering graduates who chose industrial careers especially with respect to communication and understanding interpersonal relationships. Since the educational topics covered in how-to-teach courses at other

universities are quite similar to those covered at Purdue, the results should generalize to other universities for engineering graduates who choose academic careers. The results may not generalize for engineering graduates who choose industrial careers because most courses at other universities have significantly less emphasis on efficiency and the Myers-Briggs Type Indicator than the Purdue course.

Acknowledgments—We thank Dr. Walter L. Robb for his support of the Walter L. Robb Engineering Education Senior Fellow of the National Academy of Engineering. Although supported by NAE, the direction, conduct and conclusions of this research are solely the responsibility of the authors. The assistance of Dr. Winnie Cook at the University of Florida and Dr. Marne Helgeson at Purdue University in beta-testing the survey of teaching courses is greatly appreciated. The assistance of Ms. Lee Meadows and Ms. Jenni Layne in distributing and analyzing the surveys was critical for the success of this research. We also thank all our former students and the teachers at other institutions who responded to surveys. Presented as Plenary Lecture: 'Teaching Professors How to Teach' at International Conference on Engineering Education 2004 (ICEE04), University of Florida, Gainesville, FL, October 19, 2004.

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