An Education Course for Engineering Graduate Students

Phillip C. Wankat, Frank S. Oreovicz
Chemical Engineering, Purdue University

I. Introduction

What educational experiences do PhD students in engineering need ?

In class: We want all of our graduates - both BS and advanced - to meet the spirit of ABET Criteria 2000.[1] Since approximately half of the PhD students have not graduated from an ABET accredited undergraduate program, the graduate courses should supply the same educational experiences as undergraduate courses, but studying advanced topics.[2] Thus graduate students need to practice the following: oral and written communication, being a member of a technical team, design and open ended-problems, and learning how-to-learn. The course content provides the needed technical breadth to the graduate education.

In research: They need to become complete researchers who can study an area, define problems, write proposals, design and conduct experiments - both real and virtual - interpret results, and communicate the results. To do this they need practice and feedback (i. e., mentoring) in all these steps. Research provides the needed technical depth.

In teaching: To begin a teaching career effectively, a new assistant professor should be able to plan a course--with confidence, choose appropriate teaching methods, present the material, develop rapport with the students, encourage the students to study the material and practice, test the students and assign final grades. Some understanding of the psychological principles of how people learn will enhance their future teaching as well as their own efforts to stay abreast of technology.[3]

Once schools have learned how to satisfy ABET Criteria 2000 for the B.S. curriculum, it should not be too difficult to extend this reform to the graduate courses. Graduate students are generally well mentored in research. It is in the third category, learning to teach, that the current system of graduate engineering education is lacking.

Why is learning how to teach important? For future professors the reasons are self-evident. New professors who know how to teach when they start will do a better job during the first few years, will have a good base to build on to further improve their teaching, will be better able to write the teaching part of NSF proposals, and will have more time to devote to starting their research programs since they won't be engaged in on-the-job training in how to teach. Learning how to teach will also be valuable for those who go into industry or government. Teaching involves communication and understanding others--skills that all engineers need. And many Ph.D.'s in industry report that they teach, although it is more informal than in academe.

Teaching is a very complex human activity. There are a variety of ways Ph.D. students can learn how to teach. Most have the opportunity to be a teaching assistant (TA). The TA experience can be made much more rewarding by having training programs before becoming a TA and a support seminar during the period one is a TA.[4-7] More advanced TAs can be made instructors with considerably more responsibility for the course. This experience can be enhanced if the instructor is mentored by an experienced teacher throughout the semester.[8.,9] Formal courses on teaching based in either the College of Education[10] or in the College of Engineering[3, 11-14] are also effective methods. Engineering students are more likely to take these courses if they are offered in Engineering.[15] If Ph.D. students miss the opportunity to learn how to teach as graduate students, workshops for new faculty are helpful.[16-18] The focus of the remainder of this paper will be on the course taught at Purdue University since 1983.

II. The Course: Educational Methods in Engineering

CHE 685, "Educational Methods in Engineering," is open to all Ph.D. candidates in engineering. Students who plan on earning a terminal master's degree are not allowed to enroll. This course is an elective which can be used in the plan of study in the School of Chemical Engineering and some of the other schools, although Electrical and Computer Engineering will not accept it. The course has been offered seven times since 1983, which is nominally every other year. Enrollment was 14 students taking the class for credit plus four auditors in 1998. In other years credit enrollment has varied from two to fifteen students. The higher enrollments occur when we send fliers to every graduate student in engineering at Purdue.

The goals of the course are to:

- Help prepare the students to teach.
- Help prepare the students to become college professors.
- Expand the students' horizons about teaching.
- Make the students think about teaching.
- Provide a small amount of practice.

The course is team-taught by a professor of chemical engineering who also has an MS in education and a communications specialist who has a BS in Physics in addition to his PhD in English and certification in administering the Myers-Briggs Type Indicator. This combination is very useful since the course content is very broad. Since engineers are extremely chauvinistic, it is probably necessary to have one member of the team be an engineering professor.[15]

The textbook used is Wankat and Oreovicz, *Teaching Engineering*, McGraw-Hill, New York, 1993. Unfortunately, this book is out-of-print. To provide a resource on teaching engineering, ASEE has decided to develop a website on engineering education. The entire textbook will be available free on this website.

The course content can be loosely divided into three parts: 1. Methods and procedures: includes objectives, ABET requirements, problem solving, a number of teaching methods, testing and grading, and evaluation of teaching. Each teaching method is used when that topic is covered. For example, the PSI/mastery section is done in that format with no lecture and a mastery quiz. 2. The student: explores psychological theories such as those of Myers and

Briggs, Piaget, and Perry in addition to theories of motivation and how people learn. 3. Design of engineering education involves projects and assignments which are interspersed throughout the semester. The course outline continues to evolve. The latest version is shown in Table 1. One topic which does not appear in Table 1 but was discussed frequently is attitude. It is important for new faculty to want to teach well and to realize that being smart is a gift, not a virtue.

It is interesting to compare the current outline with earlier versions.[13,14] Between 1991 and 1993 the order of presentation was switched to make it more inductive. Now the practical aspects are taught first followed by the theory. This appears to work better for many students since they can see the reasons for studying the theory (this reasoning works in technical engineering courses also). Between 1993 and the current outline more emphasis has been paid to student projects and group interactions in class. We feel this has resulted in more student learning. It certainly has resulted in some friendships across disciplinary lines. The students complained that the 1998 version of the course was too demanding. [We don't dismiss this complaint since the previous offering students thought there was not quite enough work. We appear to have over-reacted when we increased the workload.] The next time we offer the course we plan to drop the undergraduate redesign project, reduce the scope of the paper on psychological theories, and make the web project due earlier.

Although not originally designed with this in mind, the course has become an A/B course. Students who receive B's do so either because they choose to put insufficient time into the course, or because their English communication skills are poor. The grading percentages were: Test 25%, Mini-lecture 10%, class participation 10%, Web page project 20 %, and 35% for all other assignments (5% each). The nominal A-B break point is 90%.

The student assignments are designed to promote active involvement of the students. During the first half of the semester the students keep journals to encourage them to reflect on teaching. The journals are turned in and comments are made on their entries. As long as the journals are done, the student automatically receives full credit (5%). As part of the session on obtaining an academic position the students individually interview either their department head or an assistant professor in their department. They report on these interviews in a one-page paper which also serves to provide us with a writing sample. The students then share their experiences in a discussion. In the past we have used a panel discussion for the same purpose. Both methods appear to work well. Another writing assignment is a 5 to 6 page paper on "The implications and use of the Myers-Briggs Type Indicator *or* Piaget's Theory *or* Perry's Theory in engineering education." This assignment involves the students in these theories.

Another assignment involved making arrangements with three awarding winning professors in engineering and technology to have our students visit their classes. Students choose which class to visit and then write a two page critique of their visits. The professors have the opportunity to see these critiques anonymously. These visits allow the students to see that very different teaching styles can be effective.

The assignment that was a highlight for many of the students was the presentation of a 15 minute mini-lecture on a technical topic. The audience (their classmates) consisted of intelligent

professionals who were not experts in their topic. Everyone was encouraged to use visuals, do demonstrations, bring in artifacts, and engage the audience. All of the students were videotaped, with arrangements made to watch their videotapes. The students in the audience did a peer review of each presentation and gave their comments directly to the presenters. Grades were not affected by the student ratings. To do 14 presentations without spending too much class time, we divided the class in half. One half came to class on Monday at the regular time and they came Monday evening. The instructors supplied refreshments in the evening. The other half did their presentations on Wednesday. Class was canceled on Friday to make the time requirements for the week reasonable.

Perhaps the most practically useful assignment required each student to write a mid-term test and a solution key for CHE 685. The students also had to classify each of their problems by using Bloom's taxonomy. The quality of the tests was graded. Students were surprised at how difficult it was to construct a good test. The tests that the students took was constructed from the set of test questions developed by them. The students were told they could share all their questions with each other.

Student groups did a guided design project in class to design a graduate program in their area of engineering for Utopia University. After this experience, the same groups designed undergraduate programs at Utopia University. Most of this work was done outside of class. Short oral and written reports were required for the undergraduate curriculum design.

The semester-long course project was to develop a web page on an engineering education topic. A variety of acceptable topics were given to the students, and they were allowed to select others. The students were assigned to groups that spread out the students with web experience. Each group had a "web master," a person with modest html experience, and a neophyte. Based on the students' Myers Briggs Type Indicator results, each group had at least one intuitive (N) and one extrovert (E). Finally, we mixed the engineering disciplines in each group. Groups were assigned early in the semester (the fifth class period).

The student groups selected the topic and designed their web pages. The four topics chosen were: ChE 685 home page, Applications of the Myers-Briggs Type Indicator in engineering education, Obtaining an engineering academic position, and A guide for new graduate students at Purdue. Groups had to present informal progress reports the 20th class period, written and oral progress reports the 24th and 35th periods, and the web pages were to be functioning by the 43rd class period. Each student reviewed and critiqued the other web pages. During the last class period (during finals) we met in a computer lab and the groups discussed the process they went through while designing their web pages. We then adjourned to the classroom for pizza.

The ChE 685 home page, which includes links to the other sites, is at <http://unitops.ecn.purdue.edu/~che685g1//>. We feel that all the home pages are excellent. Though proud of their finished home pages, all felt that the workload was somewhat excessive. One group reported saving significant amounts of time by using Claris Home Page instead of writing html. In the future, students will be encouraged to use one of the commercial products.

This project required the students to obtain, digest and organize a large amount of material.

They had to develop effective presentation formats for the web. The eight students who were not already web masters also learned to develop web pages. The four web masters sharpened their skills by teaching their group members--and had an opportunity to do some mentoring. We strongly urge use of web projects in other graduate courses. Since this is an extensive undertaking, this project should be a group assignment, and there should be intermediate check points to prevent excessive procrastination.

III. Course Results

There are a number of ways to assess courses. The most important question is: "Did the students learn?" Based on the quality of their mini-lectures, written assignments, curriculum designs, tests, and web sites, the unequivocal answer is yes. Readers may visit the web sites to judge that part of the course for themselves. In addition to learning about pedagogy, the students also showed distinct improvement in oral and written communication during the course. Significant improvements in student resumes/CV's were noted. Several students have later informally reported that this course helped them write their theses.

A related question, particularly for a course like this, is: "Did the students grow?" Based on our informal observations it is clear that approximately one quarter of the students incurred major, observable growth which was sometimes similar to an "Aha!" experience. Other students may also have grown, but chose to conceal it. To a large extent the growth occurred due to exposure to the psychological theories. Every time the course is offered some students find the Myers-Briggs Type Indicator to be emotionally freeing. They suddenly realize that it is OK to be the way they are. A smaller number of students have found that Perry's model helps them understand their own developmental issues. From the point of view of other engineering professors this growth is not entirely positive. Two students have dropped out of the PhD program after taking CHE 685. In these cases the course was probably a catalyst which hastened an inevitable result.

A popular but somewhat controversial way to assess courses is with student evaluations. The Purdue Cafeteria course evaluation instrument was administered to the students each time the course was offered. The Cafeteria system allows the instructor to choose up to 40 items from over 200 questions. In addition five core questions are added automatically. The response is on a machine-readable form using a five point Likert type scale (1 is strongly disagree and 5 is strongly agree). Since the purpose of this course is to teach the students about all aspects of teaching, we asked student groups to select the optional questions. Thus, they varied from offering to offering. The five core questions were always the same. These core questions and the resulting scores are shown in Table 2. The fluctuations are probably from a combination of the students in the course, the time available to the instructors and the presence or absence of major mistakes made by the instructors. It is interesting that the students consistently rated the instructor slightly higher than the course.

We have not done a longitudinal study to systematically contact the alumni of this course. From scattered anecdotal evidence we know that in some cases it has helped former students obtain their first academic position. Other reports have testified that the former students feel more capable teaching in their first positions.

IV. Summary and Conclusions

All engineering graduate students would benefit from learning how-to-teach. One efficient way to do this is through a graduate-level elective on teaching for engineers. This course should cover a large number of pedagogical topics including such practical aspects as writing objectives, developing the course outline, various teaching methods, writing tests, grading and discipline. They should also provide an introduction to theories of educational development and how students learn. Finally, they should involve the students in a variety of experiential activities including field trips, discussions, test writing, curriculum design and a course project. We have found that developing a website is an excellent group course project which integrates knowledge of the subject with communication of that knowledge using modern technology. The informal and formal assessments indicate that this course is fulfilling its goals. We believe that all institutions graduating substantial numbers of Ph.D. engineers should offer some structured opportunity in learning how to teach.

Bibliography

1. Anon., "Engineering Criteria 2000: Criteria for Accrediting Programs in Engineering in the United States," ASEE PRISM, p. 41 (March 1997).
2. Wankat, P. C. and Oreovicz, F.S., "Re-engineering Graduate Programs," ASEE PRISM (1999, in press).
3. Wankat, P. C., "Educating Engineering Professors in Education," Phillips Petroleum Company Lecture, Oklahoma State University, Stillwater, OK, February 20, 1998. [Available from the School of Chemical Engineering, Oklahoma State University.]
4. Anon., "College of Engineering, University of Colorado at Boulder, Engineering TA Manual," revised 1995.
5. Anon., "Graduate Teacher Program," Graduate School, University of Colorado at Boulder, 1994-1995.
6. Fitzgerald, N., "Showing TAs the Ropes," *ASEE PRISM*, 27, October 1995.
7. Torvi, D.A., "Engineering Graduate Teaching Assistant Instructional Programs: Training Tomorrow's Faculty Members," *J. Engr. Educ., 376*, October 1994.
8. Sherwood, J.L., Petersen, J.N. and Grandzielwski, J.M. , "Faculty Mentoring: A Unique Approach to Training Graduate Students 'How to Teach'," *J. Engr. Educ., 119*, April 1997.
9. Norris, P. M. and Palmer, S.C. , "Effectiveness of the Woodruff School Doctoral Teaching Intern Program," *J.Eng. Educ, 87*, 223, July 1998.
10. Centra, J.A., *Reflective Faculty Evaluation*, San Francisco, Jossey-Bass, 1993.
11. Stice, J.E., "The Need for a 'How to Teach' Course for Graduate Students," Proceedings American Society for Engineering Education Annual Conference, 65-68, Washington, D.C., ASEE, 1991.
12. Wankat, P.C. and Oreovicz, F.S., "Teaching Prospective Faculty Members About Teaching: A Graduate Engineering Course," Engr. Educ., 75, 84-85, 1984.
13. Wankat, P. C. and Oreovicz, F.S., "Engineering Grad Students: Careers in Academia," Proceedings Frontiers in Education Conference, ASEE-IEEE, Washington, D. C., 767, 1991.
14. Wankat, P.C. and Oreovicz, F.S., *Teaching Engineering*, New York, McGraw-Hill, 1993.
15. Wankat, P.C. and Oreovicz, F.S., "Teaching Teachers to Teach Teachers to Teach or Who is Going to Lead the Teaching Workshops?" Proceedings ASEE Annual Conference, 1999-2002, Washington, D.C., ASEE, 1994.
16. Felder, R.M., Leonard, R., and Porter, R.L. , "Oh God, Not Another Teaching Workshop," *Engr. Educ., 79*, 622 (1989).
17. Stice, J. E., "A Model for Teaching New Teachers How to Teach," *Enn.r Educ., **75*** (2) 83 (November 1984).
18. Womack, K.C., Anderson, L.R., Smith, M.W. and Gorder, K.A., "A Teaching Workshop for Engineering Faculty," *J. Engr. Educ., 371*, October 1994.

PHILLIP C. WANKAT

Phillip C. Wankat is the Clifton L. Lovell Distinguished Professor of Chemical Engineering at Purdue University. He received a BSChE from Purdue, a Ph.D. from Princeton and a MS in Education from Purdue. He was Head of

Freshman Engineering and Interim Director of Continuing Engineering Education at Purdue. He is the coauthor of the book *Teaching Engineering*.

FRANK S. OREOVICZ
Dr. Frank S. Oreovicz is a communications specialist in the School of Chemical Engineering at Purdue University. He received a BS in Physics as well as an MS in English from the Illinois Institute of Technology and a Ph.D. in English from Penn State University. He is the coauthor of the book *Teaching Engineering.*

Table 1. Course outline for ChE 685, Spring 1998.

Class	Topic	Chapter
1	Introduction and Housekeeping	1
2	What Works & First Course.	
	Handout Myers-Briggs	3
3	Efficiency & Effectiveness for Professors	2
4	Taxonomy & Objectives	4
5	Start Web Page Project	
	Mini-lecture Obtaining Academic Position	App. A
6	ABET and Textbooks	4 + Handouts
7	Field Trip - Agronomy 255.	
	Meet in Soils Study Center, Third Floor, Lilly Hall	8
8	Discuss Field Trip and Problem Solving/Creativity	15
9	Problem Solving/Creativity II	5
10	Student Reports on Interviews -	
	Obtaining an Academic Position Turn in Report	
11	Lecture	I6
12	Lecture II	6
13	TV and Video - Tour Studios in Potter 268	8
14	Questions and Discussion	7
15	Advising Graduate Students [Turn in Critique of Class Visit]	10.1, 10.4
16	Mastery and PSI-Quiz	
	[Arrange for Individual Make-up]	7
17	Communication Skills I	
18	Student Mini-Lectures Gp A. Also Evening	
19	Student Mini-Lectures Gp B. Also Evening	
20	Informal Oral Reports on Web Project	
	Arrange to watch videotape.	
21	Testing	11
22	Testing & Grading	11
23	Disruption and Cheating	12
	SPRING BREAK	
24	Intermediate Project Reports/Writing Exam	
25	Computer Simulations	8 + Handouts
26	Professional Concerns and Ethics	17
	(Student Exams Due)	
27	Exam	
28	Go over test	
	Guided Design and Case Studies	Sect. 9.1.4 and 9.15
29	Case Study: Ideal Graduate Program	Handouts
30	Myers-Briggs	13
31	Myers-Briggs	13
32	Piaget	14
33	Perry	14
34	Perry	14
35	Near Ideal Undergraduate Program-Start Project	
	Intermediate Project Report-Web Page	
36	Communication Skills II	15
37	Learning Theories I	15
38	Learning Theories II [Theory Paper Due]	
39	Evaluation of Teaching	16
40	Evaluation of Teaching - Design Cafeterial form	16
41	Group Presentations-Ideal U.G. Program Written Report Due	
42	Motivation and Efficiency for Students	2 and 15

43	New Faculty Experiences
44	Course Evaluation/Administering Course Projects
Final	**Group Oral Reports on Web Site Project - Feedback** **Web site should be functioning by April 29.** **Written report due at orals.**

Table 2. Average Course Evaluations for ChE 685, 1983-1998.

	High	Low	Median	Average
Core 1	4.3	4.0	4.0/4.1	4.12
Core 2	4.5	3.9	4.1	4.17
Core 3	4.3	3.8	4.2	4.15
Core 4	4.9	3.9	4.6	4.47
Core 5	5.0	4.1	4.7	4.62

Core 1. My instructor motivates me to do my best work.
Core 2. My instructor explains difficult material clearly.
Core 3. Course assignments are interesting and stimulating.
Core 4. Overall, this course is among the best I have ever taken.
Core 5. Overall, this instructor is among the best teachers I have known.