ChE classroom

EFFICIENT, EFFECTIVE TEACHING

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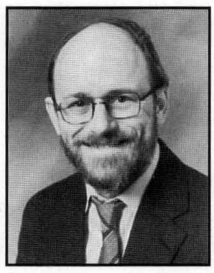
Good teaching requires that students must learn the right content, have a good attitude, and learn how-to-learn. Teaching is efficient for students when there is a high ratio of (student learning)/(student time on the course). Because they are so busy, professors also benefit from courses that are reasonably efficient. A course is efficient for professors when there is a high ratio of (student learning)/(professor's time on the course). Although there are times when effective teaching and efficient teaching conflict, most of the time effective teaching can also be efficient.

As a professor, you can apply the techniques of time management and efficiency by becoming familiar with concepts such as missions, goals, priorities, to-do lists, calendars, and prime time.[1,2] These methods should be applied,[3] paying special attention to efficient teaching.[3-6]

EFFICIENT TEACHING OF LECTURE COURSES[3]

Course Development

Designing a course is basically an engineering design problem. What is the purpose of the course? The purpose of a required undergraduate course is obviously very different than the purpose of an elective. You should obtain several old outlines and syllabi. Talk both to professors who have taught the course and to those who teach prerequisite courses to see what you can expect the students to know. Talk to professors who teach follow-up courses to determine what students must learn in your course.



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The syllabus is a contract with the students. Find a good one and adapt it with appropriate modifications for your course. Be explicit about rules and regulations. The students will not know what you expect of them until you tell them (even then some students will claim ignorance). Start with firm, and perhaps even tough, rules—then relax later on. As part of the syllabus, you should develop a tentative course outline. Plan to spend one or two periods at the beginning of the semester reviewing material the students are supposed to know, and plan one period before every major test for catch-up and review. Cover less, but cover it in more depth than was previously done. Many students only work when there are assignments or tests, so there should be something for the students to do outside of class at least every other week, preferably more often.

Shortly after the first test, ask for feedback from the students, using a "one-minute quiz." Pass out index cards and ask students what you (and the TAs) can do to help them learn more. Using the responses you receive, make appropriate changes to improve the course. Midcourse corrections based on this feedback can rescue a course headed for disaster. Allowing students to have input into test dates and due dates of projects also indicates your willingness to listen—and will be greatly appreciated by your students.

Finally, arrange to teach the same course three or four times in succession. This allows you to reuse much of your preparation and results in a better course in less time. At the end of the semester reflectively analyze what worked and what didn't, then plan changes for the next offering while the details of the course are still fresh in your mind.

Lectures

Lecturing is the most efficient teaching method the first time a course is taught. Since lectures can be prepared immediately before class, it is easy to adjust the course as you proceed through the semester. Lectures must actively engage the students in order to be effective. In subsequent offerings of the course, try modifying the lecture approach or try other teaching approaches such as cooperative group techniques.

When you know the material, you can prepare a new fifty-minute lecture in two hours or less. Repeat lectures can be prepared in one-half hour. Trying to prepare a lecture in less time is obviously dangerous. Unfortunately, many new faculty spend significantly more time than this without becoming good teachers.[5,6] Spend the two hours of preparation time in several short bursts, starting at least a day before the lecture will be delivered. The first fifteen minutes of preparation should be used to develop a title and a brief conceptual outline. Fill in some of the details later, but do not write out your notes word-for-word.

Since a student's maximum attention span is 15 to 20 minutes, the standard fifty-minute lecture hour should have one or two lecture breaks to make it effective. For example, a good scheduling might be

- *Introduction and short review*
- *Mini-lecture*
- *Lecture break*
- *Mini-lecture*
- *Summary and transition to homework for next class*

Good lecture breaks include active learning exercises such as small-group discussion, small-group problem solving, brainstorming, and student reflection. Since the audience's limited attention span forces you to use breaks, you will naturally cover less material; but the breaks serve to refresh the students so they pay more attention to the mini-lectures, and the in-depth processing that occurs during breaks increases student learning.

With a little practice it is possible to be comfortable lecturing and to actually enjoy it. If you are uncomfortable the students will be uncomfortable, regardless of how well-prepared you are. Quickly prepared, brief lecture notes are effective since they control content tyranny. By focusing on the most important points and leaving details to examples, you don't have to race through every second of the lecture. Remember that from the students' viewpoint, it is more important to end on time than to cover everything.

The second time you teach the course, try making partial lecture transparencies. Include most of the material needed for the transparency, but skip some of the key points. Give copies of these notes to the students. This procedure will eliminate many of the errors inherent in note taking and will give the students time to think—but it will still require them to pay attention so they can fill in the key missing items. You can thus cover more material without sacrificing student understanding.

Tests

Write new tests every term. As you teach, create a file of possible test problems. They can be variants of homework problems, or problems sparked by student misunderstandings, and so forth. The purpose of the file is to provide potential problems that can be considered when you write the test. Avoid disasters by solving the test completely before using it, and record how long it takes you to solve the test. Freshmen and sophomores will need about five times as long, juniors about four times as long, and seniors about three times as long.

Discussing procedures in class thoroughly before the first test will help reduce the students' anxiety. A good practice is to use old tests as ungraded practice tests that the students can do on their own, posting the solution on a bulletin board or on the web. This access to old tests helps greatly in reducing student test anxiety. Be present for the test since you are the best one to fix any last-minute errors or problems. There is also less cheating when the professor is present. If at least half the class is unable to finish the test on time, the test is too long.

Try to make grading as fair as possible, keeping in mind that students consider unfair grading to be unethical. For reasons of consistency, prepare a solution key to allocate partial credit when appropriate. Fair grading requires a regrade procedure. Reduce the hassle of regrades by requiring written regrade requests.

Attention to Students

Students want and deserve individual attention. They are very tolerant of fumbling in the lecture if they believe you care about them. Although the average engineering undergraduate may not be as smart as your peers in graduate school were, remember that he or she counts among the best undergraduates at your school. And sheer technical competence is less important for success in industry than motivation, hard work, timing (or luck), communication skills, and the ability to work well with a diverse assortment of people. Look for the best in your students, and you will probably find it—professors with a good attitude usually end up with students with good attitudes.

If you don't learn the students' names, they will feel like just numbers on a list and will be much more likely to skip class, be disruptive, not do the work, and/or cheat. Admittedly, learning a lot of new names each semester is difficult, but the effort is repaid by smoother course operation. Any-

thing you know beyond their names, such as hometowns or career goals, will greatly help you gain rapport with them.

Since personal attention to the students' needs requires a significant expenditure of time, efficiency and effectiveness can get lost in the competition for their share of time. A reasonable compromise is to hold scheduled group help sessions (particularly before tests) and a modest number of scheduled office hours during the week. Be available to the students during your office hours. Also, asking your teaching assistants to hold office hours provides another opportunity for the students to learn.

Come to class five minutes early and stay five minutes after class. In addition to giving you a chance to prepare the classroom, coming early sends the message to the students that you are looking forward to this class. Staying late offers a good time to answer questions. The combination of coming early and staying late provides an opportunity for individual attention, particularly for those students who will not use office hours.

When students ask for special arrangements to take tests or to turn in homework, be flexible, but require them to be responsible and to inform you in advance if possible. Occasionally students will abuse your generosity. It will usually be clear when this has happened, however, and you should make sure it does not happen a second time. If you treat students as adults, most of them will act accordingly.

A NEW TEACHING-LEARNING PARADIGM

Standard courses use a teacher-centered paradigm. Even when such courses are well taught, using advanced strategies such as cooperative groups, they suffer from some deficiencies that appear to be inherent to the basic paradigm. Students seldom learn how-to-learn on their own and there is a clear limit to the professor's efficiency in teaching the course. Relatively mature students can take more responsibility for their learning and be taught with a problem- or project-centered paradigm.

Engineering students will focus on learning when there is a task that must be completed. Problem-based learning[7] (PBL) is a method for using problems or short projects to focus student attention on learning. While PBL does help students learn how-to-learn, it does not increase the professor's efficiency since preparation and grading of the projects is very time-consuming. PBL is usually reported as increasing, not decreasing, the time the professor spends on the course. For students to learn how-to-learn and to drastically increase the professor's efficiency while retaining course effectiveness, a different paradigm is needed.

Fortunately, the efficiency literature gives us a clue as to what this paradigm should include—delegation.[1,2] Instead of the professor planning the material, picking topics, preparing material, lecturing, etc., ask the students do this work. With appropriate feedback from the professor, delegation of these responsibilities to the students can result in significant growth in their ability to learn. Delegation can be used for the entire course[8] or for a portion of the course.

Course projects are an effective way to focus students' attention, and they lend themselves to delegation of responsibilities. Projects lead to more learning if significant class time is devoted to them. For example, finish the lecture portion of the class before the end of the term and spend the remaining class time on project work. If class time is not devoted to the project, students consider it add-on work. Although projects can be done by individuals or groups, group projects result in much more significant efforts. I assign the groups to ensure that they are diverse in ability, learning styles, and work styles. Use the principles of good cooperative group instruction.[4]

The professor sets the tone for the project work. Expect graduate students and seniors to deliver professional quality work. Provide examples of papers or reports that surpass the minimal quality standards. Give guidelines for topics and some examples, but expect the students to devise their own topics and titles. Work with the students to narrow the scope of their projects so that they can be finished in the time available. For example, one group that started with the topic of supercritical extraction had 19,000 hits in a computerized search. Two iterations later, the topic supercritical extraction of coffee resulted in 65 hits, which is a much more manageable number. The topic must be something new for the students. Do not allow recycling of projects from other courses and note in writing that recycling projects will be considered a form of cheating. Although allowing students to do a project on their master's or PhD research might seem efficient, it is unfair to students who are not doing research in an area related to the course.

Regular meetings with groups during scheduled class time and periodic student presentations to the entire class help combat procrastination. Final reports will be significantly better if students first turn in a rough draft. Have another group critique each rough report. These critiques help to improve the final reports and give the students practice in the highest level of Bloom's taxonomy—evaluation. If the critiques are graded, the students will take this exercise seriously. I also critique the drafts with the idea of showing the groups areas for improvement. Allow about one week for groups to finish their reports after the critiques are returned. I also ask the students to fill out forms to critique oral presentations, but these critiques are not graded. A side benefit of requiring critiques is that everyone pays attention and learns from the projects of all groups.

Weekly group meetings instead of lectures help prevent procrastination, keep the professor informed of group progress, and provide an inkling of personal interactions within each group. In addition to commenting on the techni-

cal work, take time to discuss work habits when necessary. For example, most graduate students have not learned how to rapidly sort articles so that only the most important are read thoroughly. The professor can also be a cheerleader when groups feel that they will never be able to finish their projects. When the members of a group are not getting along, part of the meeting time can be used to help the students start processing group interactions. Do not try to solve their interpersonal problems, however. Make the students do this work or at least muddle through it.

The bane of grading group work is freeloaders. Delegate the responsibility of lowering the grades of freeloaders to the students. My grade assigned to each project is the highest grade students in the group can receive for the project. I require the students in each group to assign what percentage of this grade (ranging from 0 to 100%) each group member should receive. I then average these percentages for each group member and calculate their project grades. This procedure reduces freeloading and drastically reduces complaints from other group members when freeloading occurs.

This project-based paradigm is very efficient for professors. During the project work I typically spend a total of four hours per week on the course, with most of that time focused on the students. During project work the students spend much more time working on the course than the professor does!

Grading reports takes time, but since the reports are better than in other classes it is easier. The students learn their topic in depth, they learn how-to-learn, and they actually pay attention to the feedback on their writing.

A note of caution is in order, however. Most professors and students are inexperienced with project-based teaching. Professors need a certain amount of chutzpah to relinquish the normal control of a lecture course. They also need to know the material better than they would for a lecture class since it is impossible to prepare for student questions. Note that this method is not "turning the students loose." Students actually receive increased guidance and support. Despite the support, the freedom and responsibility may overwhelm immature students. Students, particularly those with high grades, may rebel. Other faculty may be skeptical and probably will not be supportive if the course flounders. Because of these risks, a graduate- or senior-level elective course is a good place to experiment.

IMPROVEMENT AND GROWTH

Master teachers may be born, not made; but good, efficient teaching is a learned skill. Sign up for a teaching workshop. Study and try out new teaching methods. After each class, reflect on what worked and what didn't, and tailor your future actions accordingly. Take notes, with the aim of improving the course next time. Find someone in your department with whom you can discuss teaching on a regular basis. Continual experimentation with teaching methods helps to prevent boredom and burnout, which can be major problems. Such experimentation can lead to teaching improvement and eventual recognition as a master teacher.

REFERENCES

1. Covey, S.R., *The Seven Habits of Highly Effective People*, Simon and Schuster, New York, NY (1989)
2. Lakein, A., *How to Get Control of Your Time and Your Life*, Signet Books, New York, NY (1973)
3. Wankat, P. C., "Effective, Efficient Teaching," Proceedings ASEE 1999 Annual Conference, CD ROM pdf file 000167, (1999)
4. Wankat, P.C. and F.S. Oreovicz, *Teaching Engineering*, McGraw-Hill, New York, NY (1993). [Out of print. Available free as pdf files at <http://unitflops.ecn.purdue.edu/ChE/News/Book/>
5. Boice, R., *The New Faculty Member*, Jossey-Bass, San Francisco, CA (1992)
6. Boice, R., *Advice for New Faculty Members: Nihil Nimus*, Allyn and Bacon, Boston, MA (2000)
7. Woods, D.R., *How to Gain the Most from Problem Based Learning*, D.R. Woods, Waterdown, Ontario, Canada, (1994). [Available from McMaster University Bookstore, 905-572-7160]
8. Wankat, P.C., "Learning Through Doing: A Course on Writing a Textbook Chapter," *Chem. Eng. Ed.*, **27**(4), 208 (1993) ❐

ChE book review

Multimedia Fluid Mechanics

by G.M. Homsy, *et al.*

Cambridge University Press (2000) $19.95

Reviewed by

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The CD by Homsy, *et al.*, is a most welcome and timely educational tool for students (and instructors!) of introductory fluid mechanics. Fluid mechanics is a very visual discipline. To date, such visual accompaniment to the mathematical equations describing flow physics has either come from labs or from samplings of the fantastic movies put together in the 1960s. Whereas the material of those movies will never become outdated, the innovative multi-media approach adopted by Homsy, *et al.*, adds dimensions to the presentation that were simply not available forty years ago. This CD ROM is a true multi-media tool that has no paper counterpart. In other words, this is not a book typed on a CD—it is truly all that the box cover promises, and then some.

The approach is based on modules. Currently, there are three technical modules, with more promised. The current modules are dynamics, kinematics, and boundary layers. There is also a module on history, which should be studied by all students.

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