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**BEATING THE NUMBERS GAME:
EFFECTIVE TEACHING IN LARGE CLASSES**

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Phil Wankat wrote somewhere--and I agree--that anything you can do in a large class you can do better in a small one. When we find ourselves teaching a mob, it's easy to throw up our hands, conclude that there's no chance of getting any responsiveness out of 150 or 300 students in an auditorium, and spend 45 hours showing transparencies to the listless 60% who bother to show up from day to day. We can generate some interest by bringing demonstrations to class, but there are only so many hydrogen balloons we can explode and even they lose their impact after a while.

Fortunately, there are ways to make large classes almost as effective as their smaller counterparts. Without turning yourself inside out, you can get students actively involved, help them develop a sense of community, and give frequent homework assignments without killing yourself (or your teaching assistants) with impossible grading loads. Following are some ideas for doing all that.

In-Class Exercises

Lectures as a rule have little educational value. People learn by doing, not by watching and listening. If you're teaching a small class and you're good, you may be able to prod many of your students into activity--get them asking and answering questions, discussing issues, challenging conclusions, laughing at your jokes, whatever. No matter how good you are, though, you probably won't be able to persuade most students to open their mouths in front of 120 classmates--it feels too risky for them. If you hope to move away from the wax museum-like aspect of most large lectures, you'll have to try a different approach.

A technique you can count on is the in-class exercise. As you lecture on a body of material or go through a problem solution, instead of just posing questions to the class as a whole and enduring the ensuing time-wasting silences, occasionally assign a task and give the students anywhere from 30 seconds to five minutes to come up with a response. Anything can serve as a basis for these exercises, including the same questions you normally ask in lectures and perhaps some others that might not be part of your current repertoire.¹ For example,

- Using terms a bright high school senior (a chemical engineering sophomore, your grandmother) could understand, briefly explain the concept of vapor pressure.
- Why does it take much longer to prepare a hard-boiled egg at a ski resort than at the beach?
- Estimate the rate of heat input to a kettle on a stove.²
- On the last homework, one student reported a required tank volume of $3.657924 \times 10^6 \text{ m}^3$. Name at least two things wrong with this result

You might pose a problem or describe a system and ask the students, individually or in groups, to

- draw and label a flow chart (schematic, free-body diagram, differential control volume).
- sketch a plot of what the problem solution should look like before they do any calculations.
- give several reasons why the solution might be useful.
- write the next step in a derivation.
- find one or two ways to check a solution.
- brainstorm a list of reasons that a calculated result might be wrong or might not be how a real system would behave.
- list possible safety (environmental, quality control) problems with the process unit just designed—double credit for an answer nobody else thinks of.

In these exercises you might sometimes ask the students to write responses individually, sometimes to work in pairs or groups of three, and sometimes to work alone and then to form pairs and combine and improve their individual responses ("think-pair-share"). The more you vary your methods, the more interesting the class tends to be.

Whichever approach you use for the exercises (individual, pairs, groups, or think-pair-share), at least some of the time you should call on groups or individuals to present what they came up with, perhaps landing disproportionately on students near the back of the room so they know they can't hide from you there. If you never do this, students will have little incentive to work on the exercises when you assign them and many won't, but if they think they may be called on, they won't want to be embarrassed and so you'll get 90+ percent of them actively involved in what you're teaching. Even if you're an award-winning traditional lecturer, that's probably better than your usual percentage for active student involvement during class.

The principal benefit of these exercises is that they get students acting and reflecting, the only two ways by which human beings learn. The students who succeed in a task will own the knowledge in a way they never could if you simply handed it to them, and those who try and fail will be receptive to discovering what they didn't know. Group exercises have the added benefit of giving students an opportunity to meet and work with one another, a good first step toward building a sense of community. (You can augment this benefit by periodically asking the students to sit in different locations and work with students they haven't been with before.)

You can also use in-class exercises to wrap up a lecture period. Ask the students to write down and hand in a brief statement of the main point of the lecture, or come up with two good questions or test problems related to what you just presented, or tell you how they think you could improve the class. You can scan their responses and quickly see if they got the main idea you were trying to present, identify their main points of confusion, or discover things you could do that would make the class better for them, like giving more examples or leaving material on the board longer or speaking more slowly or not cracking your knuckles every five seconds.

You don't have to spend a great deal of time on active learning exercises in class: one or two lasting no more than five minutes in a 50-minute session can provide enough stimulation to keep the class with you for the entire period. The syllabus is safe!

Out-of-class Group Assignments

When you're teaching a class of 160 students and you give individual homework weekly, that's 160 papers to grade every week. If the students complete the assignments in teams of four and only one solution is handed in by each team, that's 40 papers to grade every week. The difference has a major impact on the feasibility of collecting homework at all. Unless you have a squadron of teaching assistants, there is no good way to deal with 160 papers every week, and most instructors in this situation either give up on collecting homework (which is a pedagogical disaster), confine themselves to multiple-choice problems that require either memorization or rote substitution, or grade superficially enough for the homework to lose most of its educational value. Even if there are enough teaching assistants to do the job, maintaining quality control on the grading of hundreds of assignments is next to impossible.

Getting students to work on assignments in fixed teams relieves the grading problem but introduces another set of problems, most of which have to do with the fact that the students in a group may have widely varying levels of ability, work ethics, and senses of responsibility. *If an instructor simply tells students to get into groups and do the work, more harm than good may result.* In some groups, one or two students will actually do the work and the others will simply go along for the ride. In other groups, the students will parcel out the work and staple the individual products together, with each student understanding only one-fourth of the assignment.

To minimize the likelihood of these situations occurring, the instructor must structure the assignments to assure that the defining conditions of **cooperative learning**³ are met: (1) *positive interdependence* (if one team member fails to meet his or her responsibilities, everyone loses in some way); (2) *individual accountability* (each student is held personally accountable for his or her part and for everyone else's part as well); (3) *face-to-face interaction*, at least part of the time; (4) *development and appropriate use of teamwork skills* (leadership, time management, effective communication, and conflict resolution, to name a few), and (5) *periodic self-assessment of group functioning* (What are we doing well as a group? What do we need to do differently?)

Books, articles, and workshops abound that describe techniques for achieving the requisite conditions of cooperative learning.³⁻⁵ For example, individual accountability is promoted by testing individuals on *all* of the material covered in group assignments and by factoring individual effort assessments into team project grading. Positive interdependence is fostered by assigning rotating roles to team members (coordinator, recorder, checker), and by offering small bonuses on tests to all members of teams with average test grades above (say) 80. References 3-5 offer many other suggestions.

Miscellaneous Ideas

- Put your policies and procedures for grading, attendance, late homework, missed tests, etc., in writing, and hand them out on the first day. Making up the rules as you go along is never a good idea, but it can be disastrous in a large class.
- Learn as many of the students' names as you can. If you have 250 of them to deal with and you're not a mentalist, it may not be worth the effort to try learning them all; however, if the class is small enough to justify the attempt, tell the students to sit anywhere they want to on the first day and remain there in subsequent classes. Then

prepare a seating chart and study it during tests and when the students are working on in-class exercises. Also think about taking and labeling photographs and studying them out of class.

- Prepare handouts far enough ahead of time to make sure that they will be ready for the class in which they will be used. Telling a secretary at 9:30 a.m. that you need 275 copies of a six-page document printed front-and-back in time for your 10:00 class is not a good way to win friends and influence people.
- After you have taught the course enough times to be comfortable with your lecture notes, consider having them duplicated and bound by a commercial photocopier and sold as coursepacks, thereby saving your department hundreds or thousands of dollars in photocopying costs. Leave gaps in the notes to be filled in during class or by the students in or out of class, sprinkle the notes with questions about the contents, promise the students that some of the gaps and questions will show up on the tests, and keep your promise. The students will then actually read the notes. (Some of them will, anyway—at least after the first test.)
- If you hand out notes or provide a coursepack, don't spend the lecture hours simply going over all the derivations, explanations, etc., for the students to follow along. You're guaranteed to put them to sleep like that. Instead, use the time to go over the conceptually difficult points, provide additional examples, fill in some of the gaps and answer some of the questions in the notes, and carry out some of the active learning exercises described earlier.
- If homework sets are handed back in class, get the TA's or secretary to stack them alphabetically and start them in the back row of the classroom at the beginning of the period. The students will be able to find their papers quickly and pass the stack along, and left-over papers will end up in the front where you can easily pick them up at the end of class.
- Announce your office hours and hold to them, making it clear to the students that you are not available as a round-the-clock consultant to help them with homework problems (as opposed to real emergencies). Setting your boundaries is always good practice, but it may be critical to your sanity if you have really large classes and a reputation for accessibility.
- To minimize the number of times you have to answer the same questions, encourage students to come to your office hours in groups and invite students waiting in the hall to come in. Also encourage students to send questions via e-mail, and if you find yourself answering the same questions repeatedly, create an FAQ (frequently asked questions) file with your responses and insert it in subsequent replies. (You could also print it out and post it.)
- Publish your test dates at the beginning of the semester. Consider giving only one comprehensive make-up test near the end of the semester for students who miss any of the tests during the semester, rather than one for each test.
- If a test is not multiple-choice and will be graded by teaching assistants, have a grading party soon after the papers have been collected so that the grading can be completed and

the papers returned to the students reasonably quickly. (Pizza and soft drinks will be greatly appreciated-you can afford it.) Make up a thorough solution key, spelling out in as much detail as possible how partial credit should be assigned. Go over the key with the graders, making sure they understand what you have in mind. (If grading in a large class is sloppy or inconsistent, the subsequent parade of disgruntled students can be endless.)

- Make sure that each part of an assignment or test is graded by only one grader so you don't have to deal with two students getting different grades for the identical response. Encourage the TA's to consult with one another and with you about responses that are difficult to grade.
- Prepare spreadsheets for recording homework and test grades. You'll be very glad you did when the final grades have to be computed, especially when a necessary correction is discovered that requires refiguring averages. If a TA maintains the grade spreadsheet, have him or her get you a copy each time additions or revisions are made. If you change a grade, send word of the change (both the old grade and the new grade) to the responsible TA, get a confirmation, and keep a record of all requests in case of a communication breakdown.

Summary

Teaching a large class effectively is hard work, but it's possible to do it even if you're not a big-league entertainer. If you make the necessary logistical arrangements far enough in advance, provide plenty of active learning experiences in the classroom instead of relying on straight lecturing, and take full advantage of the power of teams in both in-class and out-of-class work, large classes can come close to being as educationally rewarding as small classes. The instructor's satisfaction may be even greater in the large classes: after all, many professors can teach 15 students effectively, but when you do it with 100 or more you know you've *really* accomplished something.

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