Making a Large Class Small

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1 I'm teaching HOW many next semester?

As budgets shrink and class sizes grow, educators are hard pressed to maintain quality in their classrooms. At Berkeley, the class size of our required undergraduate mechanical engineering courses has ballooned from 40-60 students per professor up to the current level of 130-170. Although less than the 500-600 students that routinely fill introductory chemistry courses, 160-odd students certainly would seem to mandate that what once was (at least potentially) an interactive forum, must perforce become a purely lecture based recital. The question to be addressed is "Can such an alteration be avoided?" Can an indisputably large class be approached in such a way as to preserve the feel of a smaller class without driving the professor insane at the same time? This question is not a new one [1], [2] and it is hoped that the current paper may add a bit to the existing knowledge base.

A widely adopted strategy to large enrollments is to embrace technology as an aid in the educational mission. Electronic learning at a distance (separate classes or individual terminals that receive a video feed) allows a potentially unlimited number of students to "attend" a smaller class. Assuming unlimited bandwidth, the connections can be made fast enough to allow near real-time reception of the class. This sort of solution has its place and is probably a good way to go if one has to reach huge numbers of students. Such a case, however, is not the focus of this paper. Of concern here is a class that's large by historical standards, but for which all the students can still be seated within a single large room.

A key aim is to maintain the centrality of the professor, the actual human being at the front of the room. It seems to the author that the primary differentiator between pre-recorded lectures, which can be viewed at the student's leisure in his or her dorm, and a "normal" class at the university campus, is that in the latter case the students have access to the professor. The professor should be viewed as an invaluable resource, a "fount of knowledge" who is inextricably tied to a particular class at a particular university. There exists a far, far greater value in a professor than simply his ability to transfer material from a book to his students. Here the student has, large as life and in realtime, a person who has spent a lifetime mastering the engineering material that forms to the content of the course. When puzzled, the student can ask a question, thereby enabling learning to continue.

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As class sizes have steadily expanded, the author has developed a group of techniques and presentation approaches that combine to keep the class feeling "small" in spite of the actual large number of students. The result is a quality of education delivery (QED) that is comparable to that found in more modestly enrolled courses. Indeed, in some aspects it is arguable that the QED levels can even increase with greater enrollments.

2 I remember you!

Students are not going to feel that they're an integral part of the class if they feel anonymous, and the only way to avoid anonymity is for the professor to actually know them. Hence, we come to a crucial and at the same time somewhat daunting task - to learn the names of every student in the class. Quickly.

How quickly, you ask? What I'm going to suggest is that you learn most of the names and faces of everyone in your class by the second lecture. As a particular example, I taught 180 students in the Fall, 2004 semester and knew ninety percent of them by the the second class. By the third lecture everyone was memorized.

The most common response of an educator to the suggestion that everyone's name and face be memorized immediately is an expression of shocked disbelief followed by the words "I could never do that!" A common secondary response is "I'm terrible with names." Both are reasonable observations. Interestingly, I used to consider myself terrible with names as well. I still am, when meeting someone new under normal circumstances. The point is that when I'm familiarizing myself with my class it's not a "normal circumstance." I have the time to concentrate on a person's name and face and do this in a very specific way. My approach has evolved over time and benefits from modern technology. Here is the approach.

On the first day of class I block out some time specifically for picture taking. The first day is usually a light one in any class and I sacrifice some of it for this critical activity. In a class of 150-200 students I can get by with three assistants, i.e. with a total of four people working. Two use a digital camera to capture the images and two serve to write down who it is that appears in the picture.

This is a non-trivial task! Without sufficient up-front planning the time to actually take the pictures and write down names is far too high - making it impossible to finish in any reasonable time. A key enabler is give everyone a number. Just for a day, the students are depersonalized by a numerical identifier. At the start of the class I'll take attendance and after the student says they're present I'll tell them what their number is. The numbers start at "1" and go up sequentially (not surprisingly). This step is a crucial one and I stress to the students that they'd better remember their number.

When I begin the picture taking I have my helper positioned at my side, ready with a piece of paper and a pencil. I then call for people to come to the front in groups of ten. Grouping is very important because without it the students will take too long to come forward and

will have problems getting into a sequential ordering. They're told that I'll want them in sequential order and I rely on them to figure out their internal ordering - something that's easily done. As they approach me, I'll ask if they're number "X" in order to ensure they're in the correct place on the list and, upon hearing a "yes" to my question will take their picture. I make sure to have the digital camera set on a low-resolution setting, both to speed the picture acquisition/storage process and to have an easier time in post-processing. The student then proceeds to my assistant who will write down their number.

A possible snag can occur at this point. The students won't ask me anything as they're still likely in a "the professor is god" mode and I'm clearly busy. But my teaching assistant is another matter and they'll often stop to ask some question. If this is allowed, it will cause a huge bottleneck because I'm taking pictures as fast as I can (having to process 80 students) and if the teaching assistant has to pause to answer a question it will precipitate a huge queue in front of him or her with an attendant misordering of students almost assured. Hence the students (and most especially the teaching assistant) should be pre-advised that no discussion *at all* will occur during the picture taking process. This is the only phase of the course in which a nice, human-based, understanding and respectful atmosphere will not exist. The picture-taking should be as mechanistic as possible - fast and efficient. The reason is obvious. Even with only 80 students per picture-taker, it will take almost 15 minutes with merely 10 seconds allocated per picture. The time pressure is such that only a fast and directed sequence of "number 13?," '<click>, "number 14?, <click>, etc, can work.

The students have to be told that after having their pictures taken they cannot hang around in the front of the room. If they're allowed to accumulate there, they'll quickly form a noisy group, making it difficult for the rest of the class to hear instructions or to even make their way to the front for their own picture. The best solution is for the assistant to be near the door and to have instructed the students that, once their picture has been taken, their class is done and that they must leave the room.

Once all the pictures have been taken, it's time to move to step two. The teaching assistant can be assigned to do this step, as it's easily explained and a bit tedious. The pictures have to be uploaded onto a computer. Once there, each picture's identifier has to be replaced with the corresponding student's name. Both the name/number list that was used for the initial attendance is used along with the number list created during the picture acquisition. I like to enter the name as I'd say it - namely first name followed by last name - rather than in the last/first ordering that appears in grade sheets. This makes it marginally more awkward to find a particular student but is helpful when learning their names.

If the camera's resolution was chosen appropriately it won't be absolutely necessary to resize the pictures but I generally like to compress them anyway. If resizing or compression turns out to be needed/desired, it's helpful to use something like Adobe Photoshop to speed the resizing process and to use a script to automate the process. Once the pictures have all been renamed and sized correctly, they should be placed in a folder with an appropriate name, such as "ME104F03pics."

The next step is to create "flash cards." If desired, the pictures can be printed on a color

printer and this can be used as a traditional flash card. I prefer, however, to remain completely electronic and I do this in two ways. The first, and easiest, is already done. Most computers will display the content of the picture folder with both name and picture. On my Mac, what will display is shown in Figure 1. (Please excuse the appearance of the student in the picture - he wasn't very photogenic.)

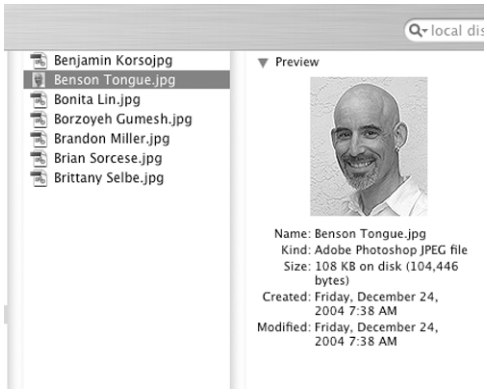

Figure 1: Screen-shot of picture file

By pressing the down (or up) key the computer will highlight and display the students on the list. When beginning the memorization phase, I'll look at the picture, look at the name, and repeat the name out loud. Then I'll move down to the next picture and do the same. After twenty or so people I'll reverse the order.

Studies of language acquisition have indicated that for retention to occur, a new word should to be used soon after being learned. Forgetting will occur at a steady rate if there is no reinforcement. But, if the word *is* reinforced, it will be retained longer - the "forgetting rate" will be reduced. Additional reinforcement will further extend the time that the word is remembered. I base my memorization strategy on this same approach. By breaking the names into small groups, I make it easier to get a handle on the people. At first I don't even worry about remembering them at all. I just look at the picture and say the name. After doing this for the first group, I'll move to the second. After I've gone through sixty or so, I'll again go to the start and repeat.

What's interesting is that after doing this a few times, names will start to gel. The first to do so will be name and face combinations that are in some way distinctive. Perhaps someone has the same name as my brother or another has the first name of a television host. Bit by bit, the familiarity will increase. At this point I'll start to pointedly *not* look at the person's name but just the face and try to recall the name. If I can't do it within a few seconds I'll look over at the name, repeat it and then move on. By continually backtracking and repeating I'll see that person again within a couple of minutes and perhaps this time remember them.

The second avenue I use to memorize the students' names is to download all the pictures onto my PDA, in my particular case a Palm T3. I doubt that the designers had this application in mind, but the T3 is ideally used as a flash card device. It can be switched to picture mode

and sequentially display all the pictures, one at a time, without any identifying information. If I need to refresh my memory, I can press a central button which toggles between a written list and the picture mode. The name associated with the current picture is highlighted, making it easy to identify. In addition, the PDA can be used in a reverse fashion by focusing on the written listing and trying to bring up a mental image of the student. If I can't, then a quick toggle brings up the picture.

The computer-based flash card sequencing works well but requires the user to be seated in front of the computer. The PDA approach shines in that it is accessible at any time. Walking to the car, waiting for lunch, whenever a spare couple of minutes opens up - all can be put to effective use. The only difficulty is that the images are often difficult to see in direct sunlight. This difficulty can be minimized by photo-processing, (increasing the contrast of the image) but until substantially brighter displays are developed will remain as a minor problem area.

If learning everyone's name immediately is too daunting, the instructor should start more slowly. Memorize as many names as possible and then make sure to address these students by their name in the next class. More and more people can be added to the list until all of them are known. The important thing is to begin the interactions early so everyone in the class is aware the instructor is going to be dealing with them as individuals and that they're not simply warm bodies decorating a chair.

This professor/student interaction is of primary importance and is the reason for learning their names in the first place. Students are universally stunned when they realize that I know who they are by the second class. I'll subtly tip them off by greeting them by name as they enter the class. The effort of memorizing is almost worth it just for the look of bewilderment when a professor they've never interacted with in any way suddenly knows them. During the class, I'll continue to speak with the students, always addressing them by name. Very soon most begin to realize that I know all of them. Some, however, continue to doubt until they come to office hours and are greeted by name or until I happen to call on them during class.

3 You all know this, right?

One hidden difficulty in relating to a large class is the fact that the students often come into the class with a significantly different set of ideas and preconceptions than the professor realizes. Recent research has indicated that this problem is not at all uncommon but, except in rare cases, is never explicitly addressed. A telling example comes from a Harvard study [4]. In this study investigators asked graduating seniors two questions which can be briefly paraphrased as:

Why is the earth hot in summer and cold in winter?

Why does the moon exhibit phases?

The presumption of a freshman physics instructor, for example would be that the all the students already know from high school physics that the seasons occur due to the axial tilt of the earth. They'd also know that the moon's phases are a consequence of the relative positions of the earth, sun and moon such that only a portion of the moon's illuminated half is visible at any particular time. They would presuppose this to be a well established piece of knowledge, known to essentially all of the students.

The shocking result of this quiz was that essentially every student queried answered the questions incorrectly. Their first response was that, due to the earth being much farther away from the sun in winter than in summer, due to its elliptical orbit, it is therefore colder in winter. They suggested that the phases of the moon occurred because of the earth's shadow falling on the moon. Further investigation indicated that most students never really learned this material in high school (in spite of it appearing in their physics courses) and filled in their knowledge gaps with their own speculations. Both of the incorrect answers aren't physically absurd - it certainly would be colder during the winter if the earth moved in a strongly elliptical orbit and the moon is periodically obscured by earth's shadow (during lunar eclipses).

Learning theory suggests that people will cling long and hard to their "knowledge" once it has been acquired and will try to interpret new knowledge in term of the old rather than discarding the old ideas and replacing them with the new. The attendant difficulty is clear. A professor, under the impression that he is building upon a solid foundation, is actually presenting material that, rather than being assimilated as presented, is often warped to allow the original misconceptions to remain.

The reader shouldn't think - "Well they were probably liberal arts majors." That may be a comforting thought, but one that's not founded in reality. In order to validate the results for myself, I gave 165 students, mostly juniors in mechanical and civil engineeing, a pop quiz that contained these same two questions. The results were illuminating. Luckily for Berkeley's honor, these students did better than their Harvard compatriots. But better isn't necessarily great. Fully one third of the students were incorrect in their explanation of why we have seasons (opting for the popular elliptical orbit explanation) and sixty percent failed to understand why the phases of the moon occur. One particular student said it was due to the earth's shadow but, to his credit, also wrote that this explanation seemed highly dubious given the low frequency with which such a phenomenon would occur and concluded that he just didn't know why.

A key aspect in shrinking the classroom is establishing an easy communication between the students and the professor and this process is undoubtedly hindered when students bring by incorrect mental baggage to the educational table. Hence we come to my next suggestion, which is to offer a low-stress, short but pointed quiz. The instructor should sit down and decide what, in his mind, are the key nuggets of understanding that someone entering the course should have. For instance - can the student construct a free-body diagram? If they're starting a dynamics course then this is a very basic, needed skill. Do all the students possess it? There's only one way to find out and knowing the answer sooner rather than later gives the instructor time to schedule a discussion section to address problem areas.

This realization isn't a new one and efforts to construct more formal "Concept Inventories" have helped delineate key information that should pre-exist when entering particular courses [5], [6], [7]. This continuing work will hopefully help support a more unified and coherent educational strategy throughout the student's undergraduate program.

4 Why bother?

The reason for my emphasis on learning the names and faces of everyone isn't just to appear impressive to them. It's hard to overemphasize the effect on students when they realize that their professor cares enough about them to learn *who they are*. It's the most superficial kind of "knowing," of course, but a deeper acquaintance can and often does occur over the semester. However, just knowing that their professor has gone to the effort of learning who they are makes them want to reciprocate with equivalent effort. In effect, I've put them a bit into my debt, having spent that most precious commodity, time, on them, and they'll want, unconsciously to be sure, to reciprocate. The notion of *reciprocity* [3] has been examined by several researchers and it's used extensively in marketing. By giving the potential client something small, perhaps a free pen in a mailing, the recipient feels a very strong need to discharge this debt. The marketer hopes that the avenue will be to buy the product being sold, of course. In my case I'm hoping that the student will "pay me back" with an increased level of involvement in the class.

Although interacting with the students is good, it is important to realize that some students are inherently passive learners and will feel uncomfortable if they're put on the spot by a question they can't answer. One way to deal with this is to request that anyone not comfortable with the concept of direct interaction should email you. There's no reason to completely cut these students off from discussion but simply remember not to pose technical questions. They can still be included in the process by asking them innocuous questions that *anyone* can answer as a means of a lead-in to the topic of the day. For instance, a professor could ask such a person which application would be more interesting to them - a car or a plane. This is a purely subjective decision and presumably is non-threatening. Whichever is chosen could then be the example for, say, a lecture dealing with yawing motions. The main point is to, as far as possible, get the students comfortable with asking questions.

The instructor needs to really push on this aspect of the class because the sheer size of the room and the number of the students within it invariably has a stifling affect on all but the most self-confident and outgoing students. The fear of appearing stupid is quite overpowering in such circumstances. Hence the instructor needs to not just say "please let me know if you have any questions" (which is one of the more futile requests one can make) but actively bring the students into a questioning mode. The instructor should be sure to inform the students on the first day that the class is going to be interactive and everyone will be expected to be an active participant. In some disciplines, foreign language instruction for instance, this is considered absolutely normal and expected behavior. A fluid mastery of a foreign tongue can't occur without continuous practice in realtime. In engineering, however,

such an approach is certainly not the norm. By alerting the students to the change, they'll be less likely to panic when suddenly chosen out of the entire class to speak.

Of course, I can keep myself as the primary speaker in the class but what I also want is to help acquaint them with the ideas of being responsible for their own learning. A very nice technique that works far better than one would imagine is to force the students to start interacting with each other in a fun and non-competitive way by challenging them with a non-trivial question. In this approach the professor would first come up with a question that doesn't have an obvious answer. Luckily, the field of engineering is littered with such problems. A concrete example that has already been alluded to is to ask why it's cold in the winter and hot in the summer. Knowing that there exist two common thoughts on the matter, he could actually tell them the two competing answers. Then he could ask for a show of hands of who believes it's due to axial tilt. This would be followed by asking who thinks it was due to an elliptical orbit. The rough percentages could be marked on the board.

The key part of the entire procedure comes next. The professor should ask the students to discuss it with the person(s) in the immediate vicinity and try to determine "the truth" through discussion. They'll stare blankly at first but once the instructor says "No, I'm serious - discuss it with each other," they'll get the message. One might suppose that the result of such a request would be some desultory and quiet discussions which would quickly die down. How wrong such a presumption would be. Every time I've initiated such a process the noise level ratchets up at an amazing rate. Students truly get into it - arguing forcibly for one view or another. The energy level generated is simply astounding.

After a couple of minutes the instructor should call time and again ask for a show of hands. Depending on the point that the instructor wants to make and the question originally chosen, the response can vary from essentially everyone getting the answer correct, to an equal mix of correct and incorrect to essentially everyone being incorrect. Especially in dynamics, some phenomena are quite counter-intuitive and most anyone who isn't familiar with the field will quite easily be convinced of an answer that is, in fact, wrong. Other times the problem can be one in which the correct answer is "obvious" once pointed out and therefore most of the incorrect guessers will change their vote once they hear a correct explanation. Finally, some problems simply aren't obvious and the same random distribution of opinions will remain after the discussions have been ended.

Another fun, low-stress quiz that really helps to buoy the students up at the end of the semester (assuming they've been following along) is one that presents them on the 2nd day of class with a series of problems similar to the ones they'd get on the final examination. It needs to be stressed to them that it doesn't count, won't be graded, and is simply given as a point of interest. Of course, they won't be able to get very far at all with it and the questions will appear almost insurmountably difficult. The instructor can then inform them that, the the end of the course, they'll be able to handle such questions, hard as they may appear initially. They can then be shown the questions again at the end of the semester, at which point most presumably fully comprehend what's being asked and can, in fact, solve them. This provides them with a very graphic demonstration of what they've actually learned over the semester. It's always difficult to assess how far one has come because the knowledge

builds slowly - this is a way to graphically demonstrate just how far they've come.

5 What's needed?

Downsizing a large class can't occur without some minimal amount of support. This is an absolutely key aspect as a lack of sufficient support will doom the class from the start. Perhaps the most important piece of equipment is a cordless lapel microphone and a good loudspeaker setup in the room. A room big enough to fit 160 students is, by necessity, a large room and no matter how good the acoustics are, a professor will need amplification. Without it the instructor will be reduced to shouting and will therefore be unable to generate the varied intonation that is so crucial to a good presentation. A fixed podium mike is not really an option as it ties the professor to a single spot, effectively killing the energy level. A good quality mike is essential, along with a good speaker system. If the students have to strain to understand the words then they'll have that much less intellectual energy left to actually think about what's being discussed.

Helpful but not necessary is a good projection system. PowerPoint usage should in general be used only sparingly but occasionally it's invaluable. Additionally, it's often advantageous to hook up a computer to display an animation that illustrates some point of the lecture. This entails a real cost to the school and should be appreciated when available but not expected.

The instructor should definitely strive to arrange for proper seating and proper blackboards. The room's floor should be sloped, as do theatre floors, so that all students can see the blackboards. Just as important is that with this arrangement the instructor can see the students. It isn't helpful to know everyone by face if one is unable to actually see those faces. If a student feels that he can hide in the back, he may try to do so and as a consequence become disengaged from the discussion. By being able to see everyone in the room the instructor can ensure that this doesn't occur.

Good blackboards are even more critical than proper seating. Because the room is large, the instructor's writing must perforce be large as well. Writing large doesn't come naturally to most instructors but is necessary if students are going to be able to see and comprehend what's being written. Remember that those at the back of the room are quite far away. The difficulty with writing large is that a blackboard will fill that much more quickly. Hence several blackboards must be available so that the instructor can fill one and move on to another, leaving the first for further perusal by those who wish to do so. Best of all is a set of three triple blackboards - the type in which two vertically movable boards lie in front of a fixed rear board. Material can be written on the first movable board, that board can be moved up and then writing can continue on the next. When full, the instructor can move to the board to the right and finally to the one to the right of that.

This covers the required inanimate resources. Quite crucial, in addition, are the animate resources - the instructor's teaching assistants. Without a sufficient number of well super-

vised TA's, the workload will become unreasonably large. 165 students will generate a lot of questions, a lot of homework and a lot of exams. To operate efficiently, the instructor needs to spend some time in allocating time for discussion sections and making sure that the TA's understand what to present and how to present it. Unless they're already experienced the instructor should seriously consider sitting in on the discussions and critiquing their performance afterwards in the quiet of his office. Quite helpful is to divide the class into smaller sections and assign each section to a particular TA. This creates a nice hierarchy. Students who feel hesitant to contact the instructor will usually find it easy to interact with the TA whereas other students prefer contact with the instructor. Either way, there's a good avenue available for the student.

6 Conclusion

Hopefully the foregoing has presented some techniques that may prove useful for instructors venturing into the realm of large classes and for those already doing so who desire a better teaching experience. I can certainly say that, at least from the objective measures available at the current time, they've proven very successful in my classes. In spite of the large increase in class size, my class ratings have stayed steady. Judging from both written and numerical student feedback I can confidently assert that the student's perception of the class and the satisfaction they've derived from it, hasn't diminished with the increasing student/faculty ratio. Certainly there are limits on the techniques - trying to handle a single room with 500 people would likely be less successful. But for up to 200 there seems to be no particular problem.

It should be made clear that what has been discussed here are the author's experiences in how to give a similar feel to the class as would exist in one with a lower enrollment and in so doing give the current students an equivalent QED to that enjoyed by students in prior years. An objective assessment of how the actual learning has altered as a consequence of a larger class size, with or without these approaches, has not been undertaken. This would be a valuable piece of information and is certainly worthy of future work. The obstacles, though, are formidable, as assessment would have to be done across different instructors and with regard to students whose general level of preparation has altered over time just as has class size.

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