Random Thoughts . . .

LEARNING BY DOING

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Thanks to some excellent research in recent decades, we know a great deal about how learning happens and how little of it happens in lectures.[1] As fascinated as professors think students should be with an hour of material like

$$dA = - PdV - SdT \rightarrow dA = (\partial A/\partial V)_T dV + (\partial A/\partial T)_V dV \;\&$$
$$dG = VdP - SdT \rightarrow dG = (\partial G/\partial P)_T dP + (\partial G/\partial T)_P dV$$
$$\& \; dH = (\partial H/\partial S)_P dS + (\partial H/\partial P)_S dP \rightarrow V = (\partial H/\partial P)_S = (\partial G/\partial P)_T \rightarrow - S = (\partial A/\partial T)_V = (\partial G/\partial T)_P \; \& \; (\partial P/\partial T)_V = (\partial S/\partial V)_T$$

there's no mistaking the dazed stupor that falls over classrooms after even just a few minutes of it. Numbed minds can't learn. The students who decide that their interests lie in cutting that 8 a.m. class and getting more sleep may be right on target.

You have roughly 40 contact hours in a typical course. If all you do in them is lecture, you might as well just hand out your notes and let the students find something more productive to do with all that time. The only way a skill is developed—skiing, cooking, writing, critical thinking, or solving thermodynamics problems—is *practice*: trying something, seeing how well or poorly it works, reflecting on how to do it differently, then trying it again and seeing if it works better. Why not help students develop some skills during those contact hours by giving them some practice in the tasks they'll later be asked to perform on assignments and tests?

Which is to say, why not use *active learning*? At several points during the class,

1. Give the students something to do (*answer a question, sketch a flow chart or diagram or plot, outline a problem solution, solve all or part of a problem, carry out all or part of a formula derivation, predict a system response, interpret an observation or an experimental result, critique a design, troubleshoot, brainstorm, come up with a question,...*).
2. Tell them to work individually, in pairs, or in groups of three or four; tell them how long they'll have (anywhere from 10 seconds to two minutes); and turn them loose.
3. Stop them after the allotted time, call on a few individuals for responses, ask for additional volunteered responses, provide your own response if necessary, and continue teaching.

You may also occasionally do a *think-pair-share*, in which the students work on something individually and then pair up to compare and improve their responses before you call on them.

As little as five minutes of that sort of thing in a 50-minute class session can produce a major boost in learning. For starters, it wakes students up: we have seen some of them elbowing their sleeping neighbors when an active learning task was assigned. Academically weak students get the benefit of being tutored by stronger classmates, and stronger students get the deep understanding that comes from teaching something to someone else. Students who successfully complete a task own the knowledge in a way they never would from just watching a lecturer do it. Students who are *not* successful are

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put on notice that they don't know something they may need to know, so when the answer is provided shortly afterwards they are likely to pay attention in a way they never do in traditional lectures.

The number of possible active learning tasks is limitless.[2] At a minimum, you can ask the same questions you would normally ask in your lectures, only now you'll get the whole class trying to answer them and not just the same two students who always answer them. You can also use any of the activities suggested in Item 1 of the list several paragraphs back, and you might occasionally run a *TAPPS* ("thinking-aloud pair problem solving") exercise, arguably the most powerful classroom instructional technique for promoting understanding.[3] Have the students work in pairs through a complex derivation or worked-out problem solution in the text or on a handout, with one of them explaining the solution step-by-step and the other questioning anything unclear and giving hints when necessary. Periodically stop them, call on several of them for explanations, provide your own when necessary, and have the students reverse roles in their pairs and proceed from a common starting point. It may take most or all of a class period to work through the entire solution, but the students will end with a depth of understanding they would be unlikely to get any other way.

Here are several techniques to make active learning as effective as possible.

- *At the beginning of the course, announce that you'll be assigning short exercises during class and explain why you're doing it* (*research shows students learn by doing, and the exercises will give them a head start on the homework and tests*). The explanation can help defuse the resistance some students feel toward any teaching approach other than the instructor telling them just what they need to know for the exam.

- *After an active learning exercise, call on a few individuals for responses before opening the floor to volunteers.* The knowledge that you might call on them gets active participation from students who would normally just sit passively and let others do the work.

- *Go for variety.* Vary the type of activity (answering questions, solving problems, brainstorming, etc.), the activity duration (10 seconds–2 minutes), the interval between activities (1–15 minutes), and the size of the groups (1–4 students). Mixing things up keeps active learning from becoming as stale as straight lecturing.

As many as half of the participants in our recent teaching workshops report using active learning in their classes, but nonusers often have concerns about the approach. (1) If I use active learning, will I still be able to cover my syllabus? (2) Can I do it in a really large class? (3) What should I do if some of my students refuse to participate?

We have offered detailed answers to the first two questions in another column[4] and so will just give the short versions here. (1) Yes. (See Reference 4 for details on how.) (2) Yes, and in fact, the larger the class, the more important it is to use active learning. Try finding another way to get students actively engaged when there are 150 of them in the room.

What about students who refuse to participate? There may indeed be several who just sit staring straight ahead when groupwork is assigned, even after the awkwardness of the first few times has passed. We never see more than two or three of them in our classes, but for the sake of discussion let's say it's as many as 10% in yours. That means that while you're doing an active learning exercise, 90% of the students are actively engaged with the material and getting practice in the skills you're trying to teach them, and 10% are out to lunch. On the other hand, at any given moment in a traditional lecture, if as many as 10% of your students are actively involved with the lecture material you're doing very well. No instructional technique works for all students at all times: the best you can do is reach as many as possible, and 90% is more than 10%. If some students opt out, don't let it bother you—it's their loss, not yours.

In short, if you start using active learning in your classes, you can expect to see some initial hesitation among the students followed by a rapidly increasing comfort level, much higher levels of energy and participation, and above all, greater learning. Check it out.

References

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2. **(a)** Johnson, D.W., R.T. Johnson, and K.A. Smith, *Active Learning: Cooperation in the College Classroom*, 2nd edn., Interaction Book Company, Edina, MN, (1998); **(b)** Felder, R.M., and R. Brent, "Cooperative Learning in Technical Courses: Procedures, Pitfalls, and Payoffs," ERIC Document Reproduction Service, ED 377038 (1994), <*www.ncsu.edu/felder-public/Papers/Coopreport.html*>
3. Lochhead, J., and A. Whimbey, "Teaching Analytical Reasoning through Thinking Aloud Pair Problem Solving," in J.E. Stice (Ed.), *Developing Critical Thinking and Problem-Solving Abilities*, New Directions for Teaching and Learning, No. 30, Jossey-Bass, San Francisco, CA (1987)
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