These are articles written by an engineering professor:

In-class group problem-solving

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 subsequent embarrassing and time-wasting silences, occasionally **assign a task and give the class one or two minutes to work on it in groups of three to five at their seats**. For example:

- *Sketch and label a flow chart (schematic, force diagram, differential control volume) for this system.*
- *Sketch a plot of what the problem solution should look like.*
- *Give several reasons why you might need or want to know the solution.*
- *What's the next step?*
- *What's wrong with what I just wrote?*
- *How could I check this solution?*
- *What question do you have about what we just did?*
- *Suppose I run some measurements in the laboratory or plant and the results don't agree with the formula I just derived. Think of as many reasons as you can for the discrepancy.*
- *What variations of this problem might I put on the next test?* (This and the last one are particularly instructive.)

You don't have to spend a great deal of time on such exercises; 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!
Warning, however. The first time you assign group work, the introverts in the class will hang back and try to avoid participating. Don't be surprised or discouraged---it's a natural response. Just get their attention---walk over to them if necessary---and remind them good-naturedly that they're supposed to be working together. When they find out that you can see them(1) they'll do it, and by the time you've done three or four such exercises most of the class will need no extra prodding. Granted, there may be a few who continue to hold out, but look at it this way: **in the usual lecture approach, 5% of the students (if that many) are actively involved and 95% are not.** If you can do something that reverses those percentages or comes close to it, you've got a winner. **Key is ENGAGEMENT activities!**

In-class reflection and question generation
The *one-minute paper* is an in-class assignment in which students nominate the most important and/or the most confusing points in the lecture just concluded [3,4]. Variations of this device can be used to powerful effect. **About two minutes from the end of a class, ask the students---working individually or in small groups---to write down and turn in anonymous responses to one or two of the following questions**:

- *What are the two most important points brought out in class today (this week, in the chapter we just finished covering)?* Examination of the responses will let you know immediately whether the students are getting the essential points. Also, when the students know beforehand that this question is coming they will tend to watch for the main points as the class unfolds, with obvious pedagogical benefits.

- *What were the two muddiest points in today's class (this week's classes, this section of the course)?* Rank the responses in order of their frequency of occurrence and in the next class go over the ones that came up most often.

  The responses to this question will surprise you. What you would have guessed to be the most difficult concepts may not show up on many papers, if they show up at all; **what *will* appear are concepts you take for granted, which you skimmed over in your lecture but which are unfamiliar and baffling to the students.**

- *What would make this material clearer to you?* You also never know what you'll get in response to this one---perhaps requests for worked-out examples of solution procedures or concrete applications of abstract material, or pleas for you to write more clearly on the board, speak more slowly, or stop some annoying mannerism that you weren't aware you were doing. **Responses to this question can provide valuable clues about what you could do to make your teaching more effective.**
- *Make up a question about an everyday phenomenon that could be answered using material presented in class today (this week).* (Optional:) *One or two of your questions will show up on the next test.*

I used the last exercise---including the zinger about the next test---at the end of a course segment on convective heat transfer and got back a wonderful series of questions about such things as why you feel much colder in water at 20 degrees celcius than in air at the same temperature; why you feel a draft when you stand in front of a closed window on a cold day; why a fan cools you on a hot day and why a higher fan speed cools you even more; why a car windshield fogs up during the winter and how a defogger works; and why you don't get burned when you (a) move your hand right next to (but not quite touching) a pot of boiling water; (b) touch a very hot object very quickly; (c) walk across hot coals. I typed up the questions (sneaking a few additional ones onto the list) and posted them outside my office---and in the days preceding the test I had a great time watching the students thinking through all the questions and speculating on which one I would put on the test. (I used the one about the fan.) There are other short, easy, and effective instructional methods, but these should do for starters. Check them out and let me know how they work for you. If I collect some good testimonials (positive or negative) I'll report them in a future column.

Coming up with good questions is only half the battle; the other half is asking them in a way that has the greatest positive impact on the students. I have not had much luck with the usual approaches. If I ask the whole class a question and wait for someone to volunteer an answer, the students remain silent and nervously avoid eye contact with me until one of them (usually the same one) pipes up with an answer. On the other hand, if I call on individual students with questions, I am likely to provoke more fear than thought. No matter how kindly my manner and how many eloquent speeches I make about the value of wrong answers, most students consider being questioned in class as a setup for them to look ignorant in public---and if the questions require real thought, their fear may be justified.

I find that a better way to get the students thinking actively in class is to ask a question, have the students work in groups of 2-4 to generate answers, and then call on several of the groups to share their results. I vary the procedure occasionally by having the students formulate answers individually, then work in pairs to reach consensus. For more complex problems, I might then have pairs get together to synthesize team-of-four solutions.

Chemical Engineering Education, 31(3), 178-179 (1997).

OBJECTIVELY SPEAKING

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Student A: "*Buffo's first test is coming up in a week. I haven't had him before--can you just plug into formulas on his exams or does he make you do derivations and stuff?"*

Student B: "*It's tough to predict--last fall most of his questions were straight substitution but a couple of times he threw in things I never saw in the lectures."*

Student C: *"Yeah, and if you ask him what you're responsible for on the test he just gets mad and gives you a sermon on how bad your attitude is--we had a 600-page textbook and according to Buffo we were supposed to know everything in it."*

Student A:"*Forget that-no time. I'll just go through the homework problems and hope it's enough*."

You can often hear conversations like that in the student lounge, and if you step across the hall to the faculty lounge you'll hear their counterparts.

Professor X: "*All these students can do is memorize--give them a problem that makes them think a little and they're helpless*."

Professor Y: "*I don't know how most of them got past their first year. The average on my last test was 47 and some of them went to the department head to complain that I was testing them on things I never taught them, even though the chapter we just covered gives them everything they needed to know.*"

Professor Z: "*It's this whole spoiled generation--they want the grades but don't want to work for them!"*

Things are clearly not going quite the way either group would like. Many students believe that their primary task in a course is to guess what their professors want them to know, and if they guess wrong they resent the professors for being unreasonably demanding, tricky, or obscure. Professors then inaccurately conclude that the students are unmotivated, lazy, or just plain dumb…when in reality, the <u>lack of clear instructional objectives</u> hinders student learning before the lectures ever even start. Students should not be required to 'guess' at what is expected, it should be clearly stated in the instructional objectives. This is the FIRST and most basic requirement of the instructional process (see below for more detail).

There is another way things can go. Suppose you give your students a detailed outline of the kinds of problems you would be calling on them to solve, including some that require real understanding, and then ask them to solve such problems on homework assignments and tests. **Since you told them what you expected them to do and gave them practice in doing it,**

many or most of them will end up being able to do it--which is to say, they will have learned what you wanted them to know. Some professors might regard this process as "spoon-feeding" or "coddling." It is neither. It is **successful teaching**.

Instructional Objectives

An effective way to prepare students for the imminent possibility of having to think is by giving them *instructional objectives,* statements of specific observable actions that the students should be able to perform if they have mastered the course material. An instructional objective has one of the following stems:

- *At the end of this [course, chapter, week, lecture], you should be able to ****
- *To do well on the next exam, you should be able to ****

where *** is a phrase that begins with an action verb (e.g., *list, calculate, estimate, describe, explain, predict, model, optimize,...*). **The more specific the task, the more likely it is that the students will learn to complete it.**
Here are some examples of phrases that might follow the stem of an instructional objective, grouped in six categories according to the levels of thinking they require.

1. **Knowledge** (repeating from memory): *list* [the first ten alkanes]; *identify* [five key provisions of the Clean Air Act]; *summarize* [the procedure for calibrating a gas chromatograph].

2. **Comprehension** (demonstrating understanding of terms and concepts): *explain* [in your own words the concept of vapor pressure]; *describe* [how a flash evaporator separates components of a liquid mixture]; *interpret* [the output from an ASPEN flowsheet simulation].

3. **Application** (applying learned information to solve a problem): *apply* [the mechanical energy balance equation to estimate the pressure drop in a process line]; *calculate* [the probability that two sample means will differ by more than 5%]; *solve* [the compressibility factor equation of state for P, T, or v from given values of the other two].

4. **Analysis** (breaking things down into their elements, formulating theoretical explanations or mathematical or logical models for observed phenomena): *derive* [Poiseuille's law for laminar Newtonian flow from a force balance]; *explain* [why we feel warm in 70^{o}F air and cold in 70^{o}F water]; *classify* [a problem solution in terms of the steps of Polya's problem-solving model].

5. **Synthesis** (creating something, combining elements in novel ways)**:** *formulate* [a model-based alternative to the PID controller design presented in Wednesday's lecture]; *design* [an experiment to determine the effect of agitator speed on mixing efficiency in a stirred tank]; *create* [a homework problem involving material we covered in class this week].

6. **Evaluation** (choosing from among alternatives and justifying the choice using specified criteria): *determine* [which of the given heat exchanger configurations is better, and explain your reasoning]; *optimize* [the given methanol production process design]; *select* [from among available options for expanding production capacity, and justify your choice].

- The six given categories are the levels of Bloom's *Taxonomy of Educational Objectives* [1]. The last three categories--**synthesis, analysis, and evaluation**--are often referred to as Bloom's ***higher level thinking skills.***

Why Bother?
Well formulated instructional objectives are more than just an advance warning system for your students. **They can help you to prepare your lecture and assignment schedules and to identify and possibly delete course material that the students can do little with but memorize and repeat.** They also facilitate construction of in-class activities, out-of-class assignments, and tests: **you simply ask the students to do what your objectives say they should be able to do. A set of objectives prepared by an experienced instructor can be invaluable to someone about to teach the course for the first time, and can help instructors of subsequent courses know what they should expect their students to have learned previously. If objectives are assembled for every course in a curriculum, a departmental review committee can easily identify both unwanted duplication and gaps in topical coverage, and the collected set makes a very impressive display for accreditation visitors.**

Tips on Writing Objectives

- ***Try to write instructional objectives for every topic in every course you teach***. Consider taking a gradual approach: formulating good objectives for a course may take some time, and there is no need to write them all in a single course offering.

- ***Include some objectives at the three highest levels of Bloom's Taxonomy*. Analysis, synthesis, and evaluation questions can and should be included in every course, but they rarely show up in undergraduate courses.** They are not that hard to write, but if you don't consciously set out to write some, you probably won't. Examples of higher-level questions are given by Felder [2] and by Brent and Felder [3].

- **Avoid beginning an instructional objective with any of four forbidden works: *know, learn, appreciate*, and *understand*.** These may be the ultimate goals of instruction but they are not valid instructional objectives, since you cannot directly observe whether they have been achieved. Think of what you will ask the students to *do* to demonstrate their knowledge or understanding, and make those activities the instructional objectives for that topic.

Formulating detailed instructional objectives for a course or even for a single topic in a course is not nearly as easy as simply listing the course topics in a syllabus. The effort is worthwhile, though. When we have asked alumni of our teaching workshops which of the instructional methods we discussed they found most useful, instructional objectives ranked second only to cooperative learning. Many professors testified that once they formulated objectives for a course--sometimes one they had taught for years--they changed the course dramatically to one that was both more interesting and more challenging to the students and more enjoyable for them to teach.

References

1. B.S. Bloom, *Taxonomy of educational objectives. 1. Cognitive domain*. New York, Longman, 1984.
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4. N.E. Gronlund, *How to write and use instructional objectives* (4th ed.) New York, Macmillan, 1991.
5. J.E. Stice, "A first step toward improved teaching," *Engineering Education*, *66*(5), 394 (1976).

LEARNING YOUR STUDENTS' NAMES!!!...one of the most underestimated (and easiest to implement) of all the motivational techniques! Use them, and use them frequently!!

Our special efforts to get to know students' names can enhance their self-esteem and promote class participation. Most of us are overwhelmed by a large number of new faces and new names. However, memory of names and faces often can be triggered by associating them with some activity or event, such as a discussion after class about an assignment or the outcome of an examination. One way to create such memory jogging events for names and faces is to ask students to write a half-page self-description or to introduce themselves to the class with a statement of their interests or goals. In return, we should offer our own statements of interests, reasons for teaching the course, and goals and expectations. If your class enrolls fewer than 40 students, call roll for several class meetings at the beginning of the term to help you learn names. During the term, call students by name when you return homework or quizzes, and use names frequently in class. Ask students who are not called upon by name to identify themselves.

Tips for Learning Students' Names

- **Arrive for class as early as you can and use this time to sit and talk to the students that are waiting for you to begin.**
- **Use name cards. For seminar classes, place name cards in front of each student. For lab courses, post students' names above their work stations.**
- **Use a seating chart. Ask students to sit in the same general area for the first few weeks and block out on a piece of paper general locations within the room and write the names of students inside the appropriate blocks. During the first class meeting, ask students to write on index cards answers to some simple questions about their background, interests, and motivation. Collect the cards and use them as memory aids as roll is called or papers and quizzes are returned.**
- **Early in the course, write personalized comments on assignments returned; invite students to come by to discuss their progress.**
- **Require students to pick up their exams in person to discuss the outcome briefly.**