Effective Teaching: A Workshop

Richard M. Felder, Ph.D.
Hoechst Celanese Professor Emeritus of Chemical Engineering
North Carolina State University
<http://www.ncsu.edu/effective_teaching>

Rebecca Brent, Ed.D.
President, Education Designs Inc.
Cary, North Carolina
THE TEN WORST TEACHING MISTAKES. I. MISTAKES 5–10

Richard M. Felder, North Carolina State University
Rebecca Brent, Education Designs, Inc.

Like most faculty members, we began our academic careers with zero prior instruction on college teaching and quickly made almost every possible blunder. We’ve also been peer reviewers and mentors to colleagues, and that experience on top of our own early stumbling has given us a good sense of the most common mistakes college teachers make. In this column and one to follow we present our top ten list, in roughly increasing order of badness. Doing some of the things on the list may occasionally be justified, so we’re not telling you to avoid all of them at all costs. We are suggesting that you avoid making a habit of any of them.

Mistake #10. When you ask a question in class, immediately call for volunteers.

You know what happens when you do that. Most of the students avoid eye contact, and either you get a response from one of the two or three who always volunteer or you answer your own question. Few students even bother to think about the question, since they know that eventually someone else will provide the answer. We have a suggestion for a better way to handle questioning, but it’s the same one we’ll have for Mistake #9 so let’s hold off on it for a moment.

Mistake #9. Call on students cold.

You stop in mid-lecture and point your finger abruptly: “Joe, what’s the next step?” Some students are comfortable under that kind of pressure, but many could have trouble thinking of their own name. If you frequently call on students without giving them time to think (cold-calling), the ones who are intimidated by it won’t be following your lecture as much as praying that you don’t land on them. Even worse, as soon as you call on someone, the others breathe a sigh of relief and stop thinking.

A better approach to questioning in class is active learning. Ask the question and give the students a short time to come up with an answer, working either individually or in small groups. Stop them when the time is up and call on a few to report what they came up with. Then, if you haven’t gotten the complete response you’re looking for, call for volunteers. The students will have time to think about the question, and—unlike what happens when you always jump directly to volunteers (Mistake #10)—most will try to come up with a response because they don’t want to look bad if you call on them. With active learning you’ll also avoid the intimidation of cold-calling (Mistake #9) and you’ll get more and better answers to your questions. Most importantly, real learning will take place in class, something that doesn’t happen much in traditional lectures.

Mistake #8. Turn classes into PowerPoint shows.

It has become common for instructors to put their lecture notes into PowerPoint and to spend their class time mainly droning through the slides. Classes like that are generally a waste of time for everyone. If the students don’t have paper copies of the slides, there’s no way they can keep up. If they have the copies, they can read the slides faster than the instructor can lecture through them, the classes are exercises in boredom, the students have little incentive to show up, and many don’t.

Turning classes into extended slide shows is a specific example of:

Mistake #7. Fail to provide variety in instruction.

Nonstop lecturing produces very little learning, but if good instructors never lectured they could not motivate students by occasionally sharing their experience and wisdom. Pure PowerPoint shows are ineffective, but so are lectures with no visual content—schematics, diagrams, animations, photos, video clips, etc.—for which PowerPoint is ideal. Individual student assignments alone would not teach students the critical skills of teamwork, leadership, and conflict management they will need to succeed as professionals, but team assignments alone would not promote the equally
important trait of independent learning. Effective instruction mixes things up: boardwork, multimedia, storytelling, discussion, activities, individual assignments, and group work (being careful to avoid Mistake #6). The more variety you build in, the more effective the class is likely to be.

Mistake #6. Have students work in groups with no individual accountability.

All students and instructors who have ever been involved with group work know the potential downside. One or two students do the work, the others coast along understanding little of what their more responsible teammates did, everyone gets the same grade, resentments and conflicts build, and the students learn nothing about high-performance teamwork and how to achieve it.

The way to make group work work is cooperative learning, an exhaustively researched instructional method that effectively promotes development of both cognitive and interpersonal skills. One of the defining features of this method is individual accountability—holding each team member accountable for the entire project and not just the part that he or she may have focused on. References on cooperative learning offer suggestions for achieving individual accountability, including giving individual exams covering the full range of knowledge and skills required to complete the project and assigning individual grades based in part on how well the students met their responsibilities to their team.4,5

Mistake #5. Fail to establish relevance.

Students learn best when they clearly perceive the relevance of course content to their interests and career goals. The “trust me” approach to education (“You may have no idea now why you need to know this stuff but trust me, in a few years you’ll see how important it is!”) doesn’t inspire students with a burning desire to learn, and those who do learn tend to be motivated only by grades.

To provide better motivation, begin the course by describing how the content relates to important technological and social problems and to whatever you know of the students’ experience, interests, and career goals, and do the same thing when you introduce each new topic. (If there are no such connections, why is the course being taught?) Consider applying inductive methods such as guided inquiry and problem-based learning, which use real-world problems to provide context for all course material.6 You can anticipate some student resistance to those methods, since they force students to take unaccustomed responsibility for their own learning, but there are effective ways to defuse resistance7 and the methods lead to enough additional learning to justify whatever additional effort it may take to implement them.

Stay tuned for the final four exciting mistakes.

References

5. CATME (Comprehensive Assessment of Team Member Effectiveness), <www.catme.org>.
THE TEN WORST TEACHING MISTAKES. II. MISTAKES 1–4*

Richard M. Felder, North Carolina State University
Rebecca Brent, Education Designs, Inc.

In our last column,¹ we presented the bottom six of our top ten list of the worst mistakes college teachers commonly make. Here are the top four, with #4 being particularly applicable to engineering instructors.

**Mistake #4. Give tests that are too long.**

Engineering professors routinely give exams that are too long for most of their students. The exams may include problems that involve a lot of time-consuming mathematical analysis and/or calculations, or problems with unfamiliar twists that may take a long time to figure out, or just too many problems. The few students who work fast enough to finish may make careless mistakes but can still do well thanks to partial credit, while those who never get to some problems or who can’t quickly figure out the tricks fail. After several such experiences, many students switch to other curricula, one factor among several that cause engineering enrollments to decrease by 40% or more in the first two years of the curriculum. When concerns are raised about the impact of this attrition on the engineering pipeline, the instructors argue that the dropouts are all incompetent or lazy and unqualified to be engineers.

The instructors are wrong. Studies that have attempted to correlate grades of graduates with subsequent career success (as measured by promotions, salary increases, and employer evaluations) have found that the correlations are negligible²; students who drop out of engineering have the same academic profile as those who stay³; and no one has ever demonstrated that students who can solve a quantitative problem in 20 minutes will do any better as engineers than students who need 35 minutes. In fact, students who are careful and methodical but slow may be better engineers than students who are quick but careless. Consider which type you would rather have designing the bridges you drive across or the planes you fly in.

If you want to evaluate your students’ potential to be successful professionals, test their mastery of the knowledge and skills you are teaching, not their problem-solving speed. After you make up a test and think it’s perfect, take it and time yourself, and make sure you give the students at least three times longer to take it than you needed (since you made it up, you don’t have to stop and think about it)—and if a test is particularly challenging or involves a lot of derivations or calculations, the ratio should be four or five to one for the test to be fair.⁴

**Mistake #3: Get stuck in a rut**

Some instructors teach a course two or three times, feel satisfied with their lecture notes and PowerPoint slides and assignments, and don’t change a thing for the rest of their careers except maybe to update a couple of references. Such courses often become mechanical for the instructors, boring for the students, and after a while, hopelessly antiquated. Things are always happening that provide incentives and opportunities for improving courses. New developments in course subject areas are presented in research journals; changes in the global economy call on programs to equip their graduates with new skills; improved teaching techniques are described in conference presentations and papers; and new instructional resources are made available in digital libraries such as SMETE (www.smete.org), Merlot (www.merlot.org/merlot/index.htm), and the MIT Open Courseware site (http://ocw.mit.edu).

This is not to say that you have to make major revisions in your course every time you give it—you probably don’t have time to do that, and there’s no reason to. Rather, just keep your eyes open for possible improvements you might make in the time you have. Go to some education sessions at conferences; read articles in educational journals in your discipline; visit one or two digital libraries to see what tutorials, demonstrations, and simulations they’ve got for your course; and commit to making one or two changes in the course whenever you teach it. If you do that, the course won’t get stale, and neither will you.

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¹ Chemical Engineering Education, 43(1), 15–16 (2009).
Mistake #2. Teach without clear learning objectives

The traditional approach to teaching is to design lectures and assignments that cover topics listed in the syllabus, give exams on those topics, and move on. The first time most instructors think seriously about what they want students to do with the course material is when they write the exams, by which time it may be too late to provide sufficient practice in the skills required to solve the exam problems. It is pointless—and arguably unethical—to test students on skills you haven’t really taught.

A key to making courses coherent and tests fair is to write learning objectives—explicit statements of what students should be able to do if they have learned what the instructor wants them to learn—and to use the objectives as the basis for designing lessons, assignments, and exams. The objectives should all specify observable actions (e.g., define, explain, calculate, solve, model, critique, and design), avoiding vague and unobservable terms like know, learn, understand, and appreciate. Besides using the objectives to design your instruction, consider sharing them with the students as study guides for exams. The clearer you are about your expectations (especially high-level ones that involve deep analysis and conceptual understanding, critical thinking, and creative thinking), the more likely the students will be to meet them, and nothing clarifies expectations like good learning objectives.

Mistake #1. Disrespect students.

How much students learn in a course depends to a great extent on the instructor’s attitude. Two different instructors could teach the same material to the same group of students using the same methods, give identical exams, and get dramatically different results. Under one teacher, the students might get good grades and give high ratings to the course and instructor; under the other teacher, the grades could be low, the ratings could be abysmal, and if the course is a gateway to the curriculum, many of the students might not be there next semester. The difference between the students’ performance in the two classes could easily stem from the instructors’ attitudes. If Instructor A conveys respect for the students and a sense that he/she cares about their learning and Instructor B appears indifferent and/or disrespectful, the differences in exam grades and ratings should come as no surprise.

Even if you genuinely respect and care about your students, you can unintentionally give them the opposite sense. Here are several ways to do it: (1) Make sarcastic remarks in class about their skills, intelligence, and work ethics; (2) disparage their questions or their responses to your questions; (3) give the impression that you are in front of them because it’s your job, not because you like the subject and enjoy teaching it; (4) frequently come to class unprepared, run overtime, and cancel classes; (5) don’t show up for office hours, or show up but act annoyed when students come in with questions. If you’ve slipped into any of those practices, try to drop them. If you give students a sense that you don’t respect them, the class will probably be a bad experience for everyone no matter what else you do, while if you clearly convey respect and caring, it will cover a multitude of pedagogical sins you might commit.

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Three Guiding Principles of Effective Teaching

1. **Constructive alignment.** Lessons, activities, assignments, and assessments all address the same learning objectives.

2. **Practice and feedback.** The more students get, the more they acquire and retain the knowledge and the greater their skill development.

3. **Balance.** Balance the emphasis on basics and high-level skills, lecturing and active learning, individual and group work,....
Workshop Learning Objectives

At the conclusion of the workshop, the participants will be able to

- define learning objectives, write and classify them in terms of Bloom’s Taxonomy levels, and list pedagogical and curricular benefits of writing them for courses.

- generate a set of handouts for the first day of a course (course syllabus, learning objectives, statement of policies and procedures) that provide the students with a full understanding of the course structure and ground rules.

- devise preliminary course activities that capture interest and motivate learning.

- identify characteristics of effective lectures and techniques for obtaining active participation from most or all students in a class, regardless of the class size.

- deal effectively with a variety of common classroom management and other student-related problems.

- identify mistakes made by 95% of new faculty members that limit their research productivity and teaching effectiveness, and outline strategies for avoiding those mistakes.
Print Resources on Learning and Teaching


- Wankat, P.C. (2002). *The effective, efficient professor*. Boston: Allyn and Bacon. Wankat is an engineer at Purdue who has written an excellent resource on teaching and all aspects of an academic career.

Electronic Resources
on Learning and Teaching

Resources in Science and Engineering Education is Richard Felder’s homepage. From the page, you can browse or download:

- A bibliography of Richard Felder’s and Rebecca Brent’s publications with links to online versions of some of them
- Index of Learning Styles (an instrument students can take and self-score to give them information about their learning style on Professor Felder’s learning style model)
- Reprints of all of the Random Thoughts columns from Chemical Engineering Education on specific topics relating to education and some additional articles
- Student handouts on a variety of topics
- Links to other web sites on engineering education

http://www.ncsu.edu/effective_teaching

Articles and Handouts with Teaching Tips

- For Your Consideration is part of the University of North Carolina Center for Teaching and Learning site and contains a series of short monographs designed for faculty and teaching assistants. Topics include among others the first day of class, writing to learn, teaching large lecture classes, evaluating student projects, problem-based learning, peer observation of teaching, and student evaluation of teaching.

http://www.unc.edu/depts/ctl/fyc.html

- How Stuff Works is a comprehensive site with sections on engines and motors, electronics, around the house, things you see in public, basic technologies, computers and the Internet, digital technology, automotive, in the news, food, and your body.

http://www.howstuffworks.com/

- Khan Academy. An incredible library of several thousand generally well-constructed lectures on many topics at all levels in math, science, and other subjects.

http://www.khanacademy.org/

- National Institute for Science Education houses three web sites: Collaborative Learning, Field-Tested Learning Assessment Guide, and Learning through Technology. These sites are specifically designed for college-level science, mathematics, engineering and technology.

http://www.wcer.wisc.edu/nise/cl1

- Ted Panitz’s Web Site is a comprehensive resource for articles and links related to cooperative learning, writing across the curriculum, and problem-based learning.

http://home.capecod.net/~tpanitz/
Digital Resource Libraries

- **Global Campus** is a collaborative multimedia database containing materials for business, fine arts, engineering, liberal arts, library, and science.
  
  http://www.csulb.edu/~gcampus/

- **MERLOT**, Multimedia Educational Resource for Learning and Online Teaching, is an open resource designed primarily for faculty and students of higher education. Links to online learning materials are collected along with annotations such as peer reviews and assignments.

  http://www.merlot.org/merlot/index.htm

- **MIT OpenCourseWare** is an educational resource containing MIT course materials. There is no registration requirement or fee for use. Courses from almost every conceivable discipline are included. You can access lecture notes and in some cases tests, online textbooks, visuals and simulations.

  http://ocw.mit.edu

- **National Engineering Education Delivery System (NEEDS)** is a digital library for engineering education. By searching the learning resources, you can locate and download many courseware tools and multimedia packages for all branches of engineering and the sciences.

  http://www.needs.org

- **National Science Digital Library (NSDL)** is a repository of resources and tools that support innovations in teaching and learning of science, technology, engineering, and mathematics education.

  http://nsdl.org/resources_for/university_faculty/

- **SMETE Digital Library** is an online community of digital collections for science, mathematics, engineering, and technology education.

  http://www.smete.org

- **World Lecture Hall** contains course materials in disciplines including engineering, sciences, mathematics, humanities, social sciences, business, and other professional schools.

  http://www.utexas.edu/world/lecture/index.html
Workshop Facilitator Biographies

Richard M. Felder, Hoechst Celanese Professor Emeritus
Department of Chemical and Biomolecular Engineering
North Carolina State University
Raleigh, NC 27695-7905
Phone/Fax: (919) 851-5374  email: rmfelder@mindspring.com

B.Ch.E., City College of New York
M.A. in Chemical Engineering, Princeton University
Ph.D. in Chemical Engineering, Princeton University

Dr. Felder joined the N.C. State University faculty in 1969. He is a co-author of the book *Elementary Principles of Chemical Processes*, which has been used as the introductory chemical engineering text by over 100 universities in the United States and abroad, and he has authored or co-authored over 200 papers on chemical process engineering and engineering education. He has won the R.J. Reynolds Award for Excellence in Teaching, Research, and Extension, the Chemical Manufacturers Association National Catalyst Award, the University of North Carolina Board of Governors Award for Excellence in Teaching, the American Society for Engineering Education Chester F. Carlson Award for Innovation in Engineering Education, the American Institute of Chemical Engineers Warren K. Lewis Award for Contributions to Chemical Engineering Education, the ASEE Chemical Engineering Division Lifetime Achievement Award for Pedagogical Scholarship, the International Federation of Engineering Education Societies Global Award for Excellence in Engineering Education (first recipient), and a number of national and regional awards for his publications on engineering education. For a bibliography of Professor Felder’s papers and reprints of his columns and some articles, access his World Wide Web page at <http://www.ncsu.edu/effective_teaching>.
Workshop Facilitator Biographies

Rebecca Brent, President
Education Designs, Inc.
101 Lochside Drive
Cary, North Carolina 27511

Phone/Fax: (919) 851-5374 email: rbrent@mindspring.com

B.A. Millsaps College
M.Ed. Mississippi State University
Ed.D. Auburn University

Dr. Brent is President of Education Designs, Inc., a consulting firm in Cary, North Carolina. She has 30 years of experience in education and specializes in staff development in engineering and the sciences, teacher preparation, evaluation of educational programs at both precollege and college levels, and classroom uses of instructional technology. She holds a Certificate in Evaluation Practice from the Evaluators’ Institute at George Washington University. From 1997-2003, she directed the NSF-sponsored SUCCEED Coalition faculty development program, and she currently coordinates faculty development activities for the North Carolina State University College of Engineering. She has authored or coauthored roughly 65 papers on effective teaching and faculty and teaching staff development. Prior to entering private consulting, she was an Associate Professor of Education at East Carolina University. She received the 1994 East Carolina University Outstanding Teacher Award.

Separately and together, Drs. Felder and Brent have presented over 300 workshops on effective teaching, course design, mentoring and supporting new faculty members, and faculty development on campuses throughout the United States and abroad. They co-direct the American Society for Engineering Education National Effective Teaching Institute.
A. How do I plan a course?
Learning Objectives

**Learning objective (or instructional objective):** A statement of something *specific* and *observable* students should be able to do after receiving instruction, plus (optional) conditions under which they would do it and/or what would constitute acceptable performance.

*By the end of this [course, section of the course, week, lecture], the student will be able to *** where *** begins with an action word (explain, calculate, design,...).*

Examples grouped according to their levels on Bloom’s Taxonomy (p. A4):

**Remembering**
- *list* [the steps in Polya’s problem-solving model]
- *identify* [five key provisions of the Clean Air Act]
- *outline* [the procedure for calibrating a gas chromatograph]

**Understanding**
- *explain* [in your own words the role of each step in Polya’s model]
- *describe* [each of the organelles found in animal cell cytoplasm]
- *interpret* [the output from a SAS ANOVA calculation]
- *distinguish* [between cognitive and social constructivism]

**Applying**
- *apply* [Polya’s model to the solution of a given problem]
- *calculate* [the probability that two sample means will differ by more than 5%]
- *solve* [the compressibility factor equation state for P, T, or V from the other two]

**Analyzing**
- *classify* [a complex problem solution in terms of the steps of Polya’s model]
- *predict* [the conflicts likely to arise when students with specified learning styles work on a cooperative learning team]
- *explain* [why we feel warm in 70°F air and cold in 70°F water]

**Evaluating**
- *determine* [whether Polya’s model or an alternative model is better suited to a specified application and explain your reasoning]
- *critique* [an article in the popular press related to the content of this course]
- *select* [one of several options for increasing production and justify your selection]

**Creating**
- *formulate* [an alternative to Polya’s problem-solving model]
- *design* [an experiment to determine the effect of temperature on information retention]
- *create* [a problem involving material we covered in class this week]

**Non-learning objectives:** … the student will
- *know*
- *learn*
- *appreciate*
- *understand…*

*Critically important goals, but not directly observable and therefore not learning objectives.*
Possible Scopes of Learning Objectives

- **Complete course.** Few, general—suitable to include on course syllabus. (See p. A9).
- **Section of course.** 1–2 pages, specific—suitable as study guide for an exam. (See p. A6).
- **Individual lesson.** 1–3 (maximum), very specific—put on board at the beginning of a lecture.

Taxonomies of Educational Objectives

**Cognitive Domain**¹ (intellectual outcomes including knowledge, understanding, thinking skills)

- **Remembering**—Retrieving, recognizing, and recalling relevant knowledge from long-term memory
- **Understanding**—Constructing meaning from oral, written and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing and explaining
- **Applying**—Carrying out or using a procedure through executing or implementing
- **Analyzing**—Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure or purpose through differentiating, organizing and attributing
- **Evaluating**—Making judgments based on criteria and standards through checking and critiquing
- **Creating**—Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning or producing

**Affective Domain**² (emotional outcomes including interests, attitudes, appreciation)

- **Receiving**—attend to a stimulus [read a handout, listen attentively to a lecture]
- **Responding**—react to a stimulus [carry out an assignment, participate in a discussion, show interest in a subject]
- **Valuing**—attach value to an object, phenomenon, or behavior [demonstrate a positive attitude, appreciation, belief, or commitment through expression or action]
- **Organization**—organize (compare, relate, and synthesize) different values into the beginning of an internally consistent value system [recognize a need to balance freedom and responsibility, formulate a career plan, adopt a systematic approach to problem solving]
- **Characterization by a value or value complex**—internalize a value system and behave accordingly in a pervasive, consistent, and predictable manner [work independently and diligently, practice cooperation in group activities, act ethically]

**Psychomotor Domain**³ (motor skill outcomes including operating equipment, sports)

- **Perception**—use sense organs to obtain cues about motor activity [relate labels to need for special handling of dangerous materials]
- **Set**—readiness to take a particular action [explain steps required to operate a piece of lab equipment]
- **Guided response**—early stage of learning a performance skill including imitation and trial and error [consciously follow a prescribed instrument calibration procedure]
- **Mechanism**—later stage of learning a performance skill when it can be performed with proficiency [follow the same procedure smoothly and effortlessly]
- **Complex overt response**—skillful performance of a complex movement pattern [repair electronic equipment quickly and accurately]
- **Adaptation**—skills that are so well-developed that the individual can modify them to fit the situation [alter a routine procedure to adapt to a novel situation]
- **Origination**—creating new movement patterns based on highly developed skills [develop a procedure for building an experimental prototype]

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Bloom’s Taxonomy of Educational Objectives: Cognitive Domain*

- Each skill involves the skills below it.
- Usually, undergraduate education deals almost exclusively with Remembering, Understanding and Applying.
- Ideally, all Bloom levels should be addressed in every course (need not be sequential).

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Illustrative Detailed Objectives

**Example 1.** By the end of Chapter 4 of the course text, you (or “the student”) will...

*Unacceptable:* …learn how to design and conduct experiments.

*Weak:* …be able to design an experiment to measure *** and analyze the results

*Good:* …be able to

(a) **design** an experiment to measure *** as a function of *** (*Creating*) and **perform** an error analysis (*Applying or analyzing*)

(b) **explain** in terms a bright high school senior could understand the meaning of the results (*Understanding*).

(c) **rate** the applicability of different empirical correlations for *** vs. ***. (*Evaluating*)

**Example 2.** By the end of this course, you (or “the student”) will...

*Unacceptable:* …understand the requirements of multidisciplinary teamwork.

*Weak:* …be able to function effectively on a multidisciplinary project team.

*Good:* …be able to

(a) **function** effectively as a team member on a multidisciplinary project team, with effectiveness being determined by peer ratings and self-assessment (*Applying & affective*)

(b) **judge** the relative importance of the different disciplines in the project (*Evaluating*)

**Reasons for Writing Objectives**

- **Identify & classify course material.** Use objectives as a basis to
  — construct syllabus
  — plan lessons
  — identify and delete obsolete or extraneous course material
  — make sure all Bloom levels are being addressed
  — minimize time spent in class on low-level material. *Suggestion: If Level 1 material is important, put it on a study guide for exams but don’t spend any time on it in class.* Reserve class time for things the students need a teacher for, not writing definitions to be copied and memorized.

- **Get constructive alignment** (Biggs) among lectures, activities, assignments, and exams. Avoid common disaster of teaching one thing and testing on something else; help assure that adequate practice and feedback is provided on high-level skills before the skills are assessed; make multiple sections of a course consistent.

- **Provide a study guide for students** (see next two pages). If you don’t give your objectives to the students, the course becomes an exercise in guessing what you think is important for them to know. If you give all of your objectives to the students on Day 1, they will never look at them again. Giving them as study guides for tests helps assure that the students will pay attention to them, and maximizes the likelihood that the students capable of meeting the objectives will end up doing so.

- **Tell faculty colleagues what they can expect students who pass this course to be able to do.**
  — teachers of follow-on courses, new instructors, adjunct instructors
  — curriculum planning committees
  — accreditation coordinators
Illustrative Study Guide*

In order to do well on the next test, you should be able to do the following:

1. Explain in your own words the terms separation process, distillation, absorption, scrubbing, extraction, crystallization, adsorption, and leaching. (What are they and how do they work?)

2. Sketch a phase diagram ($P$ vs. $T$) for a single species and label the regions (solid, liquid, vapor, gas). Explain the difference between a vapor and a gas. Use the phase diagram to define (a) the vapor pressure at a specified temperature, (b) the boiling point at a specified pressure, (c) the normal boiling point, (d) the melting point at a specified pressure, (e) the sublimation point at a specified pressure, (f) the triple point, (h) the critical temperature and pressure. Explain how the melting and boiling point temperatures vary with pressure and how $P$ and $T$ vary with time (increase, decrease, or remain constant) as a specified path on the diagram is followed.

3. Estimate the vapor pressure of a pure substance at a specified temperature or the boiling point at a specified pressure using (a) the Antoine equation, (b) the Cox chart, (c) the Clausius-Clapeyron equation and vapor pressures at two specified temperatures, (d) Table B.3 for water.

4. Use data in the text to speculate on whether distillation and/or crystallization might be a reasonable separation process for a mixture of two given species. **List the additional information you would need to confirm your speculation.**

5. Distinguish between intensive and extensive variables, giving examples of each. Use the Gibbs phase rule to determine the number of degrees of freedom for a multicomponent multiphase system at equilibrium, and state the meaning of the value you calculate in terms of the system's intensive variables. Identify a feasible set of intensive variables to specify that will enable the remaining intensive variables to be calculated.

6. In the context of a system containing a single condensable species and other noncondensable gases, explain in your own words the terms saturated vapor, superheated vapor, dew point, degrees of superheat, and relative saturation. Explain the following statement from a weather report in terms a first-year engineering student could understand: "The temperature is 75°F, barometric pressure is 29.87 inches of mercury and falling, the relative humidity is 50%, and the dew point is 54°F."

7. Given an equilibrium gas-liquid system with a single condensable component (A) and liquid A present, a correlation for $p_A^*(T)$, and any two of the variables $y_A$ (mole fraction of A(v) in the gas phase), temperature, and total pressure, calculate the third variable using Raoult's law.

8. Given a mixture of a single condensable vapor, A, and one or more noncondensable gases, a correlation for $p_A^*(T)$, and any two of the variables $y_A$ (mole fraction of A), temperature, total pressure, dew point, degrees of superheat, and relative, molal, absolute, and percentage saturation (or humidity), use Raoult's law for a single condensable species to calculate the remaining variables.

9. For a process system that involves a gas phase containing a single condensable component and specified or requested values of feed or product stream saturation parameters (temperature, pressure, dew point, relative saturation or humidity, degrees of superheat, etc.), draw and label the flowchart, carry out the degree-of-freedom analysis, and perform the required calculations. **Make up and solve your own problem involving such a system.**

10. After completing your analysis of a vapor-liquid phase change process, identify as many possible reasons as you can for discrepancies between what you calculated and what would be measured in a real process. **Include any assumptions made in the calculation.**

* Higher-level objectives in boldface.
11. Explain the meaning of the term "ideal solution behavior" in the context of a liquid mixture of several volatile species. Write and clearly explain the formulas for Raoult's law and Henry's law, state the conditions for which each correlation is most likely to be accurate, and apply each one to determine any of the variables $T$, $P$, $x_A$, or $y_A$ (temperature, pressure, and mole fractions of A in the liquid and gas phases) from given values of the other three. Make up and solve your own problem involving such a system.

12. Explain in your own words the terms bubble point, boiling point, and dew point of a mixture of condensable species, and the difference between vaporization and boiling. Use Raoult's law to determine (a) the bubble point temperature (or pressure) of a liquid mixture of known composition at a specified pressure (or temperature), and the composition of the first bubble that forms, (b) the dew point temperature (or pressure) of a vapor mixture of known composition at a specified pressure (or temperature), and the composition of the first liquid drop that forms, (c) whether a mixture of known amount (moles) and composition (component mole fractions) at a given temperature and pressure is a liquid, a gas, or a gas-liquid mixture, and if the latter, the amounts and compositions of each phase, (d) the boiling point temperature of liquid mixture of known composition at a specified total pressure.

13. Use a $T_{xy}$ or $P_{xy}$ diagram to determine bubble and dew point temperatures and pressures, compositions and relative amounts of each phase in a two-phase mixture, and the effects of varying temperature and pressure on bubble points, dew points, and phase amounts and compositions. Outline how the diagrams are constructed for mixtures of components that obey Raoult's law. Construct a diagram using a spreadsheet.

14. For a process system that involves liquid and gas streams in equilibrium and vapor-liquid equilibrium relations for distributed components, draw and label the flowchart, carry out the degree-of-freedom analysis, and perform the required calculations. Make up and solve your own problem involving such a system.

15. Explain in your own words the terms solubility of a solid in a liquid, saturated solution, and hydrated salt. Given solubility data, determine the saturation temperature of a feed solution of given composition and the quantity of solid crystals that precipitate if the solution is cooled to a specified temperature below the saturation point. Perform material and energy balance calculations on a crystallizer, and identify sources of error in your calculation.

16. Given a liquid solution of a nonvolatile solute, estimate the solvent vapor pressure lowering, the boiling point elevation, and the freezing point depression, and list the assumptions required for your estimate to be accurate. Give several practical applications of these phenomena. Identify sources of error in your calculation.

17. Given the description of a familiar phenomenon involving more than one phase, explain it in terms of concepts discussed in this chapter. Given an explanation of such a phenomenon, evaluate its scientific soundness.
Choosing a Text (Paper or On-Line)

General
- How well does the text match your course syllabus?
- Pick a couple of topics you don’t know cold, and read the text on them. Is it clear to you? Would it be clear to the students? The average ones?
- Are there lots of visuals—pictures, schematics, charts, plots?
- Are “real-life” examples or applications included?
- Are there self-tests or chapter-end questions to help students with studying?
- What support materials are available to you and/or the students? Instructor’s manual? Masters for transparencies? A test bank? Software? CD-ROM? What is the quality of the support material?
- How much would the text cost the students? If the cost is out of line, can quantity discounts be obtained?

Technical
- Are all major points, methods, etc., illustrated by clear worked-out examples?
- How are the text problems—mostly simple drills, long and difficult skullcrackers, or a graded blend?
- Are there enough problems for you to vary the assignments from term to term?
- Does the text deal with real processes and systems or purely hypothetical ones?

Course Syllabus

What should be included?
- Course number, course name, semester
- Instructor’s name, office number, office hours
- Teaching assistants’ names, offices, office hours
- Prerequisites, departmental restrictions
- Required text (e.g., statements about students with disabilities and academic misconduct)
- Policies and procedures for assignments and grading
- Note: Be sure to check for university syllabus requirements.

What may be included?
- Course description
- Topical outline or concept map
- Course-level learning objectives (recommended!)
- Dates for tests (recommended!), drop date
- Assignment schedule
- Supplementary references
Sample Syllabus

NCSU Department of Chemical Engineering
CHE 205: Chemical Process Principles

Instructor (Section 1): Dr. Lisa G. Bullard (lisa_bullard@ncsu.edu), 2012 EB1, (919)515-7455
Office Hours: M 1:30 – 3PM, T 10 – 11:30AM

Instructor (Section 2): Dr. Richard Felder (rmfelder@mindspring.com), 2088D EB1, (919)515-2327
Office Hours: T H, 2:30 – 4PM

Teaching Assistants: ...
Graders: ...


Course prerequisites: C– or better in MA 241, PY 205, and CH 201 or the transfer equivalent. This requirement is strictly enforced. If you have questions, see one of your instructors.

Course purpose: CHE 205 prepares you to formulate and solve material and energy balances on chemical process systems and lays the foundation for subsequent courses in thermodynamics, unit operations, kinetics, and process dynamics and control. More fundamentally, it introduces the engineering approach to problem solving: breaking a process down into its components, establishing the relations between known and unknown process variables, assembling the information needed to solve for the unknowns, and finally obtaining the solution using appropriate computational methods.

Course Objectives: By the end of the course, you should be able to do the following things:

- **Basic engineering calculations.** Convert quantities from one set of units to another quickly and accurately; define, calculate, and estimate properties of process materials including fluid density, flow rate, chemical composition variables (mass and mole fractions, concentrations), fluid pressure, and temperature.
- **Material and energy balance calculations.** Draw and label process flowcharts from verbal process descriptions; carry out degree-of-freedom analyses; write and solve material and energy balance equations for single-unit and multiple-unit processes, processes with recycle and bypass, and reactive processes.
- **Applied physical chemistry.** Perform pressure-volume-temperature calculations for ideal and non-ideal gases. Perform vapor-liquid equilibrium calculations for systems containing one condensable component and for ideal multi-component solutions. Calculate internal energy and enthalpy changes for process fluids undergoing specified changes in temperature, pressure, phase, and chemical composition. Incorporate the results of these calculations into process material and energy calculations.
- **Computation.** Use spreadsheets (EXCEL) and an equation-solving program (EZ-Solve) to solve material and energy balance problems.
- **Teamwork.** Work effectively in problem-solving teams and carry out meaningful performance assessments of individual team members.
CHE 205: Chemical Process Principles
POLICIES AND PROCEDURES

- **Academic integrity.** Students should refer to the University policy on academic integrity found in the Code of Student Conduct (found in Appendix L of the Handbook for Advising and Teaching). It is the instructor’s understanding and expectation that the student's signature on any test or assignment means that the student contributed to the assignment in question (if a group assignment) and that they neither gave nor received unauthorized aid (if an individual assignment). Authorized aid on an individual assignment includes discussing the interpretation of the problem statement, sharing ideas or approaches for solving the problem, and explaining concepts involved in the problem. Any other aid would be unauthorized and a violation of the academic integrity policy. This includes referring to homework from previous semesters. (Note that the instructors will provide all students with sample exams from previous years.) Any computer work submitted must be completed on your own personal computer or from your own NCSU account to avoid confusion about the origin of the file, and no sharing of files in any way is allowed. All cases of academic misconduct will be submitted to the Office of Student Conduct. If you are found guilty of academic misconduct in the course, you will be on academic integrity probation for the remainder of your years at NCSU and may be required to report your violation on future professional school applications. It’s not worth it!

- **Homework.** Students will submit homework individually for the first few assignments. Early in the semester, the instructors will designate teams of 3-4 individuals, and all subsequent assignments should be submitted by those teams unless otherwise specified. The assignment schedule will be posted on the course web site.

- **Homework format.** Use green (Bullard section) or yellow (Felder section) engineering paper (available in the Student Supply Store), one side of each page (clear side, not grid side); begin each problem on a new page; and box all final answers. Each completed assignment should be in one person's handwriting (the recorder's for group assignments). The problems should be submitted in the same order as in the homework assignment. Staple the pages and fold them vertically with the fold on the left hand side when you hand them in. Put your name and problem set number (individual assignments) or the names and roles (coordinator, recorder, checker, and monitor) of the participating team members (team assignment), and the problem set number on the outside. The problem numbers should be written vertically on the opposite side as your name. If a student’s name appears on a solution set, it certifies that he/she has participated in solving the problems. In order to encourage you to follow the instructions given above, standard point deductions will be assigned for not stapling, no name, etc. (refer to the course web site for specifics).

- **Late homework.** Completed assignments should be turned in at the beginning of the class period. You may choose to turn in the homework in early in the CHE 205 homework box in the CHE student lounge. If it's your job to turn in the homework and you're late, so is the homework. Late assignments will receive a point deduction of -20. Late solution sets will be accepted up to 8:15AM on the Monday after the due date, turned in to Dr. Bullard’s mailbox in 2009 EB1, which is inside the main office suite (2001 EB1). However, once an individual or a group hands in two late assignments, they will no longer be accepted.

- **Posted solutions.** Complete problem set solutions will not be posted, but the final numerical solution to each problem will be posted on Dr. Bullard’s bulletin board. It is your responsibility to make sure you find out how to solve the problems by asking about them in class, during office hours, or in the problem session after they have been handed in.

- **Individual effort assessments for team homework.** Teams will periodically be asked to submit individual effort assessments with completed assignments. These assessments will be incorporated into the assignment of homework grades. If repeated efforts to improve team functioning (including faculty intervention) fail, a non-participant may be fired by unanimous consent of the rest of the team, and a team member doing essentially all the work may quit. (Details of the required procedures are given in the handout on team policies and expectations.) Individuals who quit or are fired must find a team unanimously willing to accept them; otherwise they will receive zeros for the remainder of the homework.

- **Exams.** There will be three exams during the semester and a comprehensive final exam. All tests will be open-book, closed-notes. The lowest test grade will count half as much as each of the other two. Tests will be given as a common exam on scheduled Fridays from 3-5PM (see detailed course schedule for dates and locations). Students who are unable to take the test at those times (with a documented excuse—not just that you don’t want to) will schedule an alternate time to take the exam.

- **Test and homework grading.** If you believe that an error was made in grading the homework, you should write a short justification of your claim and attach it to the original homework assignment in question. Put the
justification and homework paper (stapled together) in Dr. Bullard’s mailbox in 2009 EB1 or in the red homework box. Put the name(s) of the TA(s) who graded the problem(s) in question as well as your contact email. The TA or one of the instructors will review your concern and respond to you directly. The “statute of limitations” for submitting such claims is one week after the homework is returned.

- **Missed tests.** If you miss a test without either a certified medical excuse or prior instructor approval, you will take a makeup test at a designated time during the last week of the semester. The makeup exam will be fair but comprehensive (covering all the course material) and challenging. Tests missed with certified medical excuses or prior instructor approval will be dealt with individually. Only one missed test can be made up. **Note:** if you show up to take the test, you must take the grade – you cannot decide mid-way through to walk out and take the makeup exam.

- **Problem session.** All 205 students must be registered for one of the weekly problem sessions (205P). Several computer applications will be taught during the problem sessions. 10% of your grade is based on problem session quizzes and in-class exercises. Attendance is expected and is included as part of your problem session grade. You should not float between problem sessions; stay in the one in which you are registered. However, if it is necessary to miss a problem session, you may attend another session that week to make up the time as long as you notify the TA of the problem session you attend so that your attendance can be recorded.

- **Attendance.** Students who miss class due to an excused absence should work with the instructor or problem session TA to make up any missed work or tests. Documented medical excuses should be presented to the instructor. For a full statement of the university attendance policy see <www.ncsu.edu/provost/academic_regulations/attend/reg.htm>. Examples of anticipated situations where a student would qualify for an excused absence are:
  a. The student is away from campus representing an official university function, e.g., participating in a professional meeting, as part of a judging team, or athletic team. These students would typically be accompanied by a University faculty or staff member.
  b. Required court attendance as certified by the Clerk of Court.
  c. Religious observances as verified by Parents & Constituent Services (515-2441). For more information about a variety of religious observances, visit the Diversity Calendar.
  d. Required military duty as certified by the student’s commanding officer

- **Calculation of course grade.** A weighted average grade will be calculated as follows:
  - Exams (3) = 40%
  - Final examination = 30%
  - Homework = 20%
  - Problem session quizzes and in-class exercises = 10%

The lowest exam grade counts half as much as the other two (lowest exam counts 8%, other two count 16%). The homework grades will only count if the average grade on class exams and the final exam is 60 or above—in other words, if you can’t pass the individual tests, then you can’t pass the course.

The course grades will be determined as follows:

<table>
<thead>
<tr>
<th>Score</th>
<th>97 ≥</th>
<th>92 – 96.9</th>
<th>89 – 91.9</th>
<th>82 – 88.9</th>
<th>77 – 81.9</th>
<th>72 – 76.9</th>
<th>67 – 71.9</th>
<th>62 – 66.9</th>
<th>60 – 61.9</th>
<th>&lt; 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>A+</td>
<td>A– or B+</td>
<td>B</td>
<td>B– or C+</td>
<td>C</td>
<td>C– or D+</td>
<td>D</td>
<td>D–</td>
<td>F</td>
<td></td>
</tr>
</tbody>
</table>

If you fall into one of the “gray areas” (A- or B+, B- or C+, C- or D+), your grade will be determined by whether your performance has improved or remained consistent (higher grade) or gotten worse, especially on the final exam (lower grade).

**Note: We do not curve grades in this course.** It is theoretically possible for everyone in the class to get an A (or an F). Your performance depends only on how you do, not on how everyone else in the class does. It is therefore in your best interests to help your classmates within the limits of the academic integrity policy.

- **Instructors’ commitment.** You can expect your instructors to be courteous, punctual, well-organized, and prepared for lecture and other class activities; to answer questions clearly; to be available during office hours or
to notify you beforehand if they are unable to keep them; to provide a suitable guest lecturer when they are traveling; and to grade uniformly and consistently according to the posted guidelines.

- **Consulting with faculty.** We strongly encourage you to discuss academic or personal questions with either of the CHE 205 course instructors during their office hours or by email.

- **Students with disabilities.** North Carolina State is subject to the Department of Health, Education, and Welfare regulations implementing Section 504 of the Rehabilitation Act of 1973. Section 504 provides that: "No otherwise qualified handicapped individual in the United States... shall, solely by reason of his handicap be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance." This regulation includes students with hearing, visual, motor, or learning disabilities and states that colleges and universities must make "reasonable adjustments" to ensure that academic requirements are not discriminatory. Modifications may require rescheduling classes from inaccessible to accessible buildings, providing access to auxiliary aids such as tape recorders, special lab equipment, or other services such as readers, note takers, or interpreters. It further requires that exams actually evaluate students' progress and achievement rather than reflect their impaired skills. This may require oral or taped tests, readers, scribes, separate testing rooms, or extension of time limits.
INDUCTIVE TEACHING AND LEARNING*

Course topics and entire courses can be taught


- **Inductively** — start with challenges, introduce principles and methods on a need-to-know basis in the context of the challenges. Various forms— inquiry-based learning, problem-based learning, project-based learning, case-based instruction, just-in-time teaching. Effective at promoting conceptual understanding, long-term retention, transfer.

- Deductive presentation does not convey a sense of how science, engineering, and learning in general really happen. Inductive presentation does.

**Features of common inductive instructional methods**

<table>
<thead>
<tr>
<th>Method Feature</th>
<th>Inquiry</th>
<th>Problem-based</th>
<th>Project-based</th>
<th>Case-based</th>
<th>Discovery</th>
<th>JITT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questions or problems provide context for learning</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Complex, ill-structured, open-ended real-world problems provide context for learning</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Major projects provide context for learning</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Case studies provide context for learning</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Students discover course content for themselves</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Students complete conceptual exercises electronically; instructor adjusts lessons according to responses</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Primarily self-directed learning</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
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<tr>
<td>Active learning</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Collaborative/cooperative (team-based) learning</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

1 – by definition, 2 – always, 3 – usually, 4 – possibly

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Inquiry-Based Learning

- Any inductive teaching method that does not fall into any of the categories in Columns 3–7 of the preceding table can be designated inquiry-based learning.

- To teach with an inquiry-based approach
  - introduce each major course topic with a challenge (a question to be answered, a problem to be solved, a set of observations or experimental data to be explained, or a case study or dilemma to be worked through);
  - to the greatest possible extent, get the students to speculate on or predict outcomes before they do any of the required work and to identify the need for information before you provide it;
  - get them to outline solution procedures for complex problems before they undertake the procedures and to identify possible applications of formulas and algorithms before they work through detailed derivations;
  - anticipate that not all students will welcome this approach and some may resist it vigorously, and be prepared with strategies to eliminate or at least minimize the resistance. For some ideas, see “Navigating the Bumpy Road to Student-Centered Instruction” (reference on p. A15).

- Integrated inquiry-based strategy
  - In the first week of class, present an open-ended problem that will require course material to solve. Have students briefly work in groups to itemize what they know and what they need to determine and outline how they would proceed.
  - Use the problem to introduce each new topic and to provide context for the next body of course material.
  - Repeat the opening exercise at the end of the course to give students a sense of what they have learned.

Problem-Based Learning (PBL)

- In PBL, complex real-world problems provide context for learning course material. Student groups
  - define the problem
  - build hypotheses to initiate the solution process
  - identify what is known, what must be determined, and how to proceed
  - generate possible solutions and decide on the best one
  - complete the solution and defend it
  - reflect on lessons learned

Caution: Full-scale problem-based learning is hard—the instructor must deal with sometimes heavy time demands, conflicts among students in teams, and possible intense student resistance to the method. Instructors—especially untenured ones—are advised to ease into this method, perhaps beginning with a less demanding inquiry-based approach and using cooperative learning for several semesters to get accustomed to working effectively with student teams.
Resources on Inductive Teaching and Learning

- Case-based education library of cases, National Center for Case Study Teaching in Science, [http://ublib.buffalo.edu/libraries/projects/cases/case.html](http://ublib.buffalo.edu/libraries/projects/cases/case.html).
- University of Delaware Problem-Based Learning Web Site, <[http://www.udel.edu/pbl/](http://www.udel.edu/pbl/).>
HOW TO PREPARE NEW COURSES WHILE KEEPING YOUR SANITY*

Richard M. Felder
North Carolina State University

Rebecca Brent
Education Designs, Inc.

Think of a two-word phrase for a huge time sink that can effectively keep faculty members from doing the things they want to do.

You can probably come up with several phrases that fit. “Proposal deadline” is an obvious one, as are “curriculum revision,” “safety inspection,” “accreditation visit,” and “No Parking.” (The last one is on the sign posted by the one open space you find on campus minutes before you’re supposed to teach a class, with the small print that says “Reserved for the Deputy Associate Vice Provost for Dry Erase Marker Procurement.”)

But the phrase we have in mind is “new prep”—preparing for and teaching a course you’ve never taught before. This column describes the usual approach, which makes this challenging task almost completely unmanageable, and then proposes a better alternative.

Three steps to disaster, or, how not to approach a new course preparation

1. Go it alone. Colleagues may have taught the course in the past and done it very well, but it would be embarrassing to ask them if you can use their materials (syllabi, learning objectives, lecture notes, demonstrations, assignments, tests, etc.), so instead create everything yourself from scratch.

2. Try to cover everything known about the subject in your lectures and always be prepared to answer any question any student might ever ask. Assemble all the books and research articles you can find and make your lecture notes a self-contained encyclopedia on the subject.

3. Don’t bother making up learning objectives or a detailed syllabus—just work things out as you go. It’s all you can do to stay ahead of the class in your lectures, so just throw together a syllabus that contains only the course name and textbook, your name and office hours, and the catalog description of the course; invent course policies and procedures on a day-by-day basis; and decide what your learning objectives are when you make up the exams.

Here’s what’s likely to happen if you adopt this plan. You’ll spend an outlandish amount of time on the course—ten hours or more of preparation for every lecture hour. You’ll start neglecting your research and your personal life just to keep up with the course preparation, and if you’re unfortunate enough to have two new preps at once, you may no longer have a personal life to neglect. Your lecture notes will be so long and dense that to cover them you’ll have to lecture at a pace no normal human being could possibly follow;

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you’ll have no time for interactivity in class; and you’ll end up skimming some important material or skipping it altogether. Your policies regarding late homework, absences, missed tests, grading, and cheating will be fuzzy and inconsistent. Without learning objectives to guide the preparation, the course will be incoherent, with lectures covering one body of material, assignments another, and tests yet another. The students’ frustration and complaints will mount, and the final course evaluations will look like nothing you’d want to post on your blog.

There’s a better way.

A rational approach to new course preparation.

1. **Start preparing as soon as you know you’ll be teaching a particular course.**

   Dedicate a paper file folder and a folder on your computer to the course and begin to assemble ideas and instructional materials. While you’re teaching the course, continue to file ideas and resources as you come up with them.

2. **Don’t reinvent the wheel.**

   Identify a colleague who is a good teacher and has taught the course you’re preparing to teach, and ask if he/she would be willing to share course materials with you. (Most faculty members would be fine with that request.) In addition, try finding the course on the MIT OpenCourseWare Web site (<http://ocw.mit.edu>) and download materials from there. Open courseware may contain visuals, simulations, class activities, and assignments that can add considerably to the quality of a course and would take you months or years to construct from scratch. The first time you teach the course, borrow liberally from the shared materials and note after each class what you want to change in future offerings. Also consider asking TA’s to come up with good instructional materials and/or inviting students to do it for extra credit.

3. **Write detailed learning objectives, give them to the students as study guides, and let the objectives guide the construction of lesson plans, assignments, and tests.**

   Learning objectives are statements of observable tasks that students should be able to accomplish if they have learned what the instructor wanted them to learn. Felder and Brent recommend giving objectives to students as study guides for tests\(^1\) and show an illustrative study guide for a midterm exam.\(^3\)

   Before you start to prepare a section of a course that will be covered on a test, draft a study guide and use it to design lessons (lectures and in-class activities\(^4\)) and assignments that

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provide instruction and practice in the tasks specified in the objectives. As you get new ideas for things you want to teach, add them to the study guide. One to two weeks before the test, finalize the guide and give it to the students, and then draw on it to design the test. The course will then be coherent, with mutually compatible lessons, assignments, and assessments. Instead of having to guess what you think is important, the students will clearly understand your expectations, and those with the ability to complete the tasks specified in the objectives will be much more likely to do so on the test. In other words, more of your students will have learned what you wanted them to learn. The objectives will also help you avoid trying to cram everything known about the subject into your lecture notes. If you can’t think of anything students might do with content besides memorize and repeat it, consider either dropping that content or cutting down on it in lectures, giving yourself more time to spend on higher-level material.

4. **Get feedback during the course.**

   It’s always a good idea to monitor how things are going in a class so you can make mid-course corrections, particularly when the course is new. Every so often collect “minute papers,” in which the students anonymously hand in brief statements of what they consider to be the main points and muddiest points of the class they just sat through. In addition, have them complete a survey four or five weeks into the semester in which they list the things you’re doing that are helping their learning and the things that are hindering it. Look for patterns in the responses to these assessments and make adjustments you consider appropriate, or make a note to do so next time you teach the course.

5. **Do everything you can to minimize new preps early in your career, and especially try to avoid having to deal with several of them at a time.**

   Some department heads inconsiderately burden their newest faculty members with one new prep after another. If you find yourself in this position, politely ask your head to consider letting you teach the same course several times before you move on to a new one so that you have adequate time to work on your research. Most department heads want their new faculty to start turning out proposals and papers in their first few years and will be sympathetic to such requests. It might not work, but as Rich’s grandmother said when told that chicken soup doesn’t cure cancer, it couldn’t hurt.
Additional Resources on Course Design & Developing High-Level Skills

Course design

- CDIO (Conceive, Design, Implement, Operate), <www.cdio.org>. An outcomes-based conceptual framework for designing engineering curricula and courses that has been adopted by a large number of schools around the world. The CDIO syllabus maps well to the ABET Engineering Criteria and Bloom’s Taxonomy.
- Fink, L.D. (2003). *Creating significant learning experiences*. San Francisco: Jossey-Bass. An integrated approach to developing learning experiences for students. Check out Chapter 2 (pp. 27-59) for an alternative to Bloom’s Taxonomy that includes foundational knowledge, application, integration, the human dimension, caring, and learning how to learn. Chapter 3 (pp. 60-101) has a detailed approach to course design.

Developing higher level thinking skills:

B. How can I be an effective lecturer and get students actively involved in class?
What to Do During the First Week

Note: Select one or more of these activities in each category—don’t attempt to do them all.

Introduce yourself

- Introduce yourself & talk briefly about your background, experience, and interests. The better the students get to know you and vice versa, the better the class will work.

Establish expectations (yours and the students’)

- Summarize your expectations of the students and what they can expect from you.
- Hand out the syllabus. Review critical rules and procedures likely to be unfamiliar to the students (e.g., rules for groupwork).
- Have students in pairs read through the syllabus and raise questions.
- Distribute advice collected from students at the end of the previous offering of the same course.
- Have students write their goals for the semester.
- Have students anonymously hand in rumors they’ve heard about the course or about you. Next class period, address them.

Establish student-instructor and student-student communication mechanisms

- Learn the students’ names. Use a seating chart and quiz yourself during exercises and tests, or take and label digital photos or photocopy their ID’s and study them after class. This may be the single most effective way to motivate them to learn.
- Set up a class e-mail alias or list server or chat room or Web site. Require their use at least once or twice.
- In very large classes, designate student representatives to collect and relay feedback from constituent student groups.

Find out what students know and want to know

- Have students list (1) things they know about the course content, and (2) questions they have about it.
- Schedule a test on course prerequisites sometime in the next 1–2 weeks; hand out a summary of key learning objectives covering the prerequisites to be used as a study guide; hold an optional review session, and give the test. Count it toward the final grade. (This is an alternative to spending weeks re-teaching things they should have learned before taking your course.)

Motivate the students’ interest in the course.

- Show a graphic organizer for the course.
- Do a demonstration. Get the students to predict the outcome first.
- Survey (or get students to brainstorm) real-world applications of the course topics.
- Show photos & videos of real-world connections to course material.
- Inquiry-based strategy: Present an open-ended problem that will require course material to solve. Have students briefly work in groups to itemize what they know and what they need to determine and outline how they would proceed. Subsequently use the problem to introduce each new topic and to provide context for the next body of course material. Repeat the opening exercise at the end of the course to give students a sense of how much they have learned.

Lecturing Tips

Preparing for the lecture

- **Decide on a reasonable amount of time to prepare for a lecture and stick to it.** Often faculty find they are spending all their time preparing for teaching, leaving no time for research and writing. Two hours of preparation for a one hour lecture is a good target—you won’t always make it, but if you find yourself spending six or seven hours you’re going overboard.

- **Organize your lecture around your learning objective(s).** When you identify what you want students to be able to do as the result of the lecture, you can select the important content and activities to lead to that result.

- **Preview lecture content and learning objectives.** Overview what is to come by telling students what they will learn (e.g. “By the end of the period today, you should be able to....”) Some instructors write the objective for the day on the board and refer to it at the beginning and end of the lecture.

- **Write clear detailed notes for yourself.** Especially when first teaching a class, write out key ideas, example problem solutions, and specific applications so that you don’t leave out important things or get confused while in front of the class. Include questions you want to ask, directions for activities and points where you expect to take a break.

- **Prepare lots of visuals: graphic organizers (like the one for this notebook), charts, graphs, flowcharts, cartoons.** Find visual images for any topic by searching on Google Images or in the databases on p. x of this notebook.

- **Plan demonstrations whenever possible.** Real demonstrations in class are ideal, but don’t overlook videotapes, CD-ROMs, and the Internet for valuable demonstrations.

- **If it isn’t written down, it will be ignored.** Plan what you will write on the board or on a transparency with an eye toward what you want students to have in their notes.

- **Give out handouts with gaps.** Turn some or all of your lecture notes into handouts that the students bring to class, leaving gaps for students to fill in, and sprinkle the handouts with questions. Tell students that some of the gaps and questions will be included on tests, then do it. Let students read through straightforward material by themselves during the lecture, and when you come to a gap, either lecture on it, use it as the basis for an in-class activity, or leave it as an exercise for the students to do after class.
  - After you’ve taught a class a few times, consider putting the handouts into a course pack that student purchase as a supplement to—or replacement for—the text.
  - Even if you don’t normally use this technique, when you fall behind in your lectures, put next week’s material in handouts, use them in class as described above. You’ll catch up.
  - An excerpt from a course pack is shown on p. A4.

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T.L. Cornelius and J. Owen-DeSchryver [“Differential effects of full and partial notes on learning outcomes and attendance,” *Teaching of Psychology, 35*(1), 6–12 (2008)] carried out research showing that relative to students who received complete lecture notes, students who only got partial notes got higher exam grades, higher course grades, and higher marks on conceptual questions that required mastery of material beyond definitions.
Steady-state laminar flow: Incompressible Newtonian fluid in a horizontal circular pipe

Read Geankoplis, Sect. 2.9B, pp. 78–80

Water enters a 5.0-cm ID x 10.0 m long pipe at a volumetric flow rate of $2.0 \times 10^{-3}$ m$^3$/s and a pressure $P = 1.5 \times 10^5$ N/m$^2$ (150 kPa ~ 1.5 atm). Our goal is to find out as much as we can about relations among system variables at steady state.

- $\dot{v}(z)$ – volumetric flow rate
- $u(r, z)$ – local velocity profile
- $P(r, z, \theta)$ – local fluid pressure

- Calculate the mass flow rate, $\dot{m}$ (kg/s), at the inlet.

- Does $\dot{m}$ vary with $z$? Explain.

- Does $\dot{v}$ vary with $z$? Explain.
During the lecture

- **Come to the classroom a little before class begins to talk informally with students.** This technique sends a positive message to students that you are interested in them, allows you to answer questions for students who might not come to your office, and may reduce your nervousness before class.

- **Learn the students’ names and use them.** (1) Print out students’ photo id’s from Registration & Records, study in your office; (2) Prepare a seating chart, use it to call on students, study it during tests & activities; (3) Have students put their names on tent cards or large manila folders; photograph them in groups of four holding up their cards, study photos in office.

- **Make eye contact.** Don’t read notes or talk to the board. Consciously think about scanning the room as you talk; it will help you see if students are confused, bored, or restless.

- **Cue students on important points.** When you say something you think students should note, draw attention to it by using phrases like, “This is a key point” or “Be sure to get this in your notes” or the clincher, “This could be on the exam!” (Don’t overuse that one.)

- **Make effective use of the board.** Be sure you are writing legibly and large enough for students at the back to see. (To find out, ask them!). Use different colors to highlight key ideas.

- **Don’t be afraid to pause periodically.** Pausing after presenting key content allows students to get material into their notes and to reflect on the information. Pausing after asking a high-level question will give everyone a chance to think about the answer before taking responses. Research indicates that this type of pause increases the number and quality of student responses.

- **Ask questions periodically, not just, “Is that clear?” or “Do you have any questions?”**
  - What next? Why? What if? What could be wrong? What could go wrong?
  - What should the solution look like?
  - What have we assumed in writing this formula?
  - Suppose I follow this procedure, and the product yield is 25% low. What could be responsible? How can I find out? How can I correct the problem? How could I have avoided it?
  - What are possible safety problems here? Environmental problems? Ethical problems?

  (Check out “Any Questions?” on p. B7 for more ideas.)

- **Avoid calling on individual students cold (with no time to think of a response)—many find it intimidating.** Do call on individuals (1) to report on small group exercise results or (2) after the whole class has had time to formulate a response.

- **Use technology wisely.** The keys are interactivity (getting students actively involved) and variety (don’t just do one thing for an hour). Interactive tutorials, multimedia presentations, hands-on simulations, and anything else that actively engages students can greatly enhance learning; on the other hand, don’t turn your lectures into PowerPoint shows. (See “Is Technology a Friend or Foe of Learning” on p. B22 and “Death by PowerPoint” on p. B24).

- **Have students individually write responses to questions in class.** Writing is a valuable tool for students to organize material, brainstorm ideas, or work out a problem. After a few moments to reflect on a question, many more students will be ready to respond.

- **Respond with respect to student comments, questions, and answers.** Even if a student response is wrong, a respectful response helps to foster a better atmosphere for discussion.

- **Don’t bluff in response to student questions.** It’s ok to tell your students you aren’t sure of the answer to a question. Tell them you’ll check it out and then let them know what you found. (Then do it!)

- **Summarize occasionally during the lecture and always at the end...or get students to do it.**

- **Remember the colleague who will follow you in the classroom.** End on time. Erase the board. Have students return chairs to their original positions if you’ve rearranged them.
Improving your lecture effectiveness

- **Have students complete a midterm course evaluation and respond to it in the next class session.** A few weeks into the course, ask students to respond anonymously to at least three prompts: “What features of this course and its instruction are helping you learn?” “What features of the course and instruction are hindering your learning?” “What other comments do you have?” (You might also include a request for comments on a specific feature of the course, such as in-class activities, and requests for the students to list things they might do to improve their performance.)

That same day, skim through the evaluations and note the two or three most common responses to each prompt. (Even if there are several hundred students in the class, this should not take long.) In the next session, share your summary with the students, and indicate how you’re going to respond to each request for change. Say what you plan to do in response to their requests, and explain why you are not willing to make other requested changes.

Reading the students’ responses will give you a good idea of how the class is going, and you may find some items you can adjust to improve things. The evaluations give you good input on how the course is going while you still have a chance to make changes in it, and your response gives the students the powerful message that you’re concerned about their learning and willing to listen to them.

- **Observe other teachers.** It’s amazing what you can learn by watching your colleagues teach. Find out who the best teachers are in your department or school and ask to sit in on a lecture or two. Then arrange to meet with them over lunch or a cup of coffee and get more ideas. (Also, to see some outstanding lecturers, check out the TED Talks, <http://www.ted.com>.)

- **Find a colleague or two who also want to work on their teaching.** Agree to visit one another’s classes and provide feedback. Get together periodically to talk about how your classes are going.


- **Videotape yourself teaching.** By viewing a recording of your teaching, you’ll see yourself the way students see you. After you get over the shock (especially if you’ve never seen yourself on tape before), you’ll start to see good things you’re doing and points that need improvement. Some university teaching centers will set up a camera and will even sit down with you to analyze your performance. If you’d rather do it privately, it’s a relatively easy matter to set up the camera in one corner of the room and let it run.

- **Work with university teaching center personnel (if available) to improve your teaching.** Many campuses now have centers devoted to helping faculty improve their teaching. Knowledgeable colleagues will talk with you about your goals, observe your class or a videotape, and give concrete suggestions that can make a big difference in your success in the classroom. They can also help you analyze student feedback in course evaluations that will lead to positive teaching improvements.

- **Use active learning** (p. B10 – B18).
ANY QUESTIONS?
Richard M. Felder

Most questions asked in engineering classes follow one of two models:

1. "If a first-order reaction \( A \rightarrow B \) with specific reaction rate 3.76 \( \text{min}^{-1} \) takes place in an ideal continuous stirred-tank reactor, what volume is required to achieve a 75.0% reactant conversion at steady state if the throughput rate is 286 liters/s?"

2. "Do you have any questions?"

While these may be important questions to ask, they don't exactly stimulate deep thought. "What's the volume?" has only one possible correct answer, obtained by mechanically substituting values into a formula. "Do you have any questions?" is even less productive: the leaden silence that usually follows makes it clear that the answer for most students is always "No," whether or not they understand the material.

Questions lie at the heart of the learning process. A good question raised during class or on a homework assignment can provoke curiosity, stimulate thought, illustrate the true meaning of lecture material, and trigger a discussion or some other form of student activity that leads to new or deeper understanding. Closed (single-answer) questions that require only rote recitation or substitution don't do much along these lines, and questions of the "Any questions?" variety do almost nothing.

Following are some different things we can ask our students to do which can get them thinking in ways that "Given this, calculate that" never can.

Define a concept in your own words

- Using terms a bright high school senior (a chemical engineering sophomore, a physics major, your grandmother) could understand, briefly explain the concept of vapor pressure (viscosity, heat transfer coefficient, ideal solution).

Explain familiar phenomena in terms of course concepts

- Why do I feel comfortable in 65°F still air, cool when a 65°F wind is blowing, freezing in 65°F water, and even colder when I step out of the water unless the relative humidity is close to 100%?

- A kettle containing boiling water is on a stove. If you put your finger right next to the kettle but not touching it, you'll be fine, but if you touch the kettle for more than a fraction of a second you'll burn yourself. Why?

Predict system behavior before calculating it

- Without using your calculator, estimate the time it will take for half of the methanol in the vessel to drain out (for all the water in the kettle to boil off, for half of the reactant to be converted).

- What would you expect plots of \( C_B \) vs. \( t \) to look like if you ran the reactor at two different temperatures? Don't do any calculations—just use logic. Explain the shapes of your plots.

- An open flask containing an equimolar mixture of two miscible species is slowly heated. The first species has a normal boiling point of 75°C and the second boils at 125°C. You periodically measure the temperature, \( T \), and the height of the liquid in the flask, \( h \), until all of the liquid is

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1 Warning: Don't ask your students to give a comprehensible definition of something like \( \tau_{\text{eq}} \) or entropy or temperature or mass unless you're sure you can do it.
gone. Sketch plots of $T$ and $h$ vs. time, labeling the temperatures at which abrupt changes in system behavior occur.\textsuperscript{2}

Think about what you've calculated

- Find three different ways to verify that the formula we just derived is correct.

- Suppose we build and operate the piping system (heat exchanger, absorption column, VLE still, tubular reactor) exactly as specified, and lo and behold, the throughput rate (heat duty, solvent recovery, vapor phase equilibrium composition, product yield) is not what we predicted. What are at least 10 possible reasons for the disparity?\textsuperscript{3}

- Why would an intermediate reactor temperature be optimal for this pair of reactions? (Put another way, what are the drawbacks of very low and very high temperature operation?)

- The computer output says that we need a tank volume of 3657924 cubic meters. Any problems with this solution?

Brainstorm

- What separation processes might work for a mixture of benzene and acetone? Which one would you be tempted to try first? Why?

- What are possible safety (environmental, quality control) problems we might encounter with the process unit we just designed? You get double credit for an answer that nobody else thinks of. The longest list gets a three-point bonus on the next test. Once a list of problems has been generated, you might follow up by asking the students to prioritize the problems in terms of their potential impact and to suggest ways to minimize or eliminate them.

Formulate questions

- What are three good questions about what we covered today?

- Make up and solve a nontrivial problem about what we covered in class this week (about what we covered in class this month and what you covered in your organic chemistry class this month). Memory and plug-and-chug problems won’t be worth much—for full credit, the problem should be both creative and challenging.

- A problem on the next test will begin with the sentence, “A first-order reaction $A \rightarrow B$ with specific reaction rate 3.76 (min\textsuperscript{-1}) takes place in an ideal continuous reactor.” Generate a set of questions that might follow. Your questions should be both qualitative and quantitative, and should involve every topic the test covers. I guarantee that I will use some of the questions I get on the test.

I could go on, but you get the idea.

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

\textsuperscript{2}You will be amazed and depressed by how many of your students—whether they're sophomores or seniors—say the level remains constant until $T=75^\circ C$ and then the liquid boils.

\textsuperscript{3}Be sure to provide feedback the first few times you ask this critically important question, so that the students learn to think about both assumptions they have made and possibilities for human error.
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.

Another effective strategy is to put questions like those listed above into homework assignments and pre-test study guides, promising the students that some of the questions will be included on the next test, and then include them. If such questions only show up in class, many students tend to discount them; however, if the questions also routinely appear in homework and on tests, the students take them seriously. It's a good idea to provide feedback on their initial efforts and give examples of good responses, since this is likely to be a new game for most of them and so at first they won't know exactly what you're after. After a while they'll start to get it, and some of them may even turn out to be better at it than you are. This is not a bad problem to have.4

Active Learning

What is it? Getting all students to do something course-related in class other than just watching and listening to the instructor and taking notes.

Why do it?

- Get full student involvement
- Get many more responses to questions from more than the usual 2–3 responders
- Energize class
- Excellent for multilingual classes (lets non-native speakers help each other, gives them a chance to catch up with the lecture)
- Straight lectures lead to cognitive overload—conditions for lecture material in working memory to be stored and retained in long-term memory (especially activity & reflection) are not met for most students.*
- Experimental study: Class given 50-minute lecture, & immediately afterwards students tested on lecture content. Tests scored, percentage of correct answers to questions plotted vs. time in class when the information had been presented.

% Correct

0                        t (min)                    50

% Correct

0                        t (min)                    50

t = time in lecture when information was presented

Similar results reported in three different studies (70% and 20% figures come from first one):


For more extensive evidence that active learning promotes both short-term and long-term learning, see


* See Ambrose et al., reference on p. ix.
Active Learning Structures

- **In-Class Teams.** Get class to form teams of 2-4 and choose team recorders. Give teams 15 seconds-3 minutes to
  - Recall prior material
  - Answer or generate a question
  - Start a problem solution or analysis
  - Work out the next step
  - Think of an example or application
  - Explain a concept
  - Figure out why a predicted outcome turned out to be wrong
  - Brainstorm a list (goal is quantity, not quality)
  - Summarize a lecture

Collect some or all answers by randomly calling on several individuals first before taking responses from volunteers. *This activity works for all class levels and sizes.*

- **Think-Pair-Share.** Students think of answers individually, then form pairs to produce joint answers, and then share answers with class. (Optional) Pairs may discuss answers with other pairs before general sharing.

- **Minute paper**: Stop the lecture with two minutes to go and ask students to anonymously write
  1. the main point(s)
  2. the muddiest (least clear) point(s).

Collect the papers. Look through the responses to check for understanding. Begin the next lecture by addressing common questions from the minute papers. *Variation:* Provide students the option of including their names so that you can address individual questions via email.

- **Guided Reciprocal Peer Questioning.** Students work in groups of three or four and are provided with a set of generic question stems:
  
  - How does … relate to what I’ve learned before?
  - What conclusions can I draw about …?
  - What are the strengths and weaknesses of …?
  - What is the main idea of …?
  - What is a new example of …?
  - What is the best … and why?
  - What if…?
  - Explain why …?
  - How are … and … similar?
  - Why is … important?
  - How would I use … to …?
  - How does … affect …?

  - Each student individually prepares two or three thought-provoking questions on the content presented in the lecture or reading. The generic question stems are designed to encourage higher level thinking skills.
  
  - Questions are discussed in small groups at the beginning of class, and the whole class then discusses questions that were especially interesting or controversial in the group discussions.

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Cooperative Note-Taking Pairs. Students form pairs to work together during the class period. After a short lecture segment, one partner summarizes his or her notes to the other. The other partner adds information or corrects. The goal is for everyone to improve his or her notes.

Concept tests with clickers. Ask class challenging multiple-choice conceptual questions, with distractors that reflect common misconceptions. Have students vote individually, then pair and discuss, then vote again. Discuss why wrong answers were wrong.

Pair programming. Two students actively collaborate on a task that involves computer usage. The pilot does the keyboarding, and the navigator identifies problems and thinks strategically. The two switch roles frequently.

Writing assignments provide opportunities for students to reflect on their learning both in and out of class and are a powerful way of making sense of new material.

- Tell students why you are using the writing assignments and what benefits they can expect.
- In class, ask students to
  - write what they know about a topic before you lecture on it
  - generate a list of practical applications of new material
  - summarize the last 15 minutes of class
- In the lab, ask students to
  - summarize their results and reflect on what they might mean
  - connect lab activities with material presented in lecture
- In assignments, ask students to
  - summarize readings and write questions about the material (have them use the question stems under guided reciprocal peer questioning on the preceding page)
  - reflect on how homework or project team (or anything else in the course) is working
- If there are many writing assignments in a course, consider having students keep them together in a learning log. Include the learning log as a requirement of the course and assign it a small percentage of credit in your evaluation scheme.

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TAPPS\(^8\) (Thinking Aloud Pair Problem-Solving) Student pairs solve a problem, work out a derivation, or work step-by-step through a solved problem or derivation or case study or article or passage of text. Time-consuming, but powerful.

- Students form pairs (*dyads, learning cells*), one problem-solver (or explainer, if the solution is available), one listener (or questioner).
- Instructor defines activity.
- Problem solver talks though first step of solution or first passage of text. Listener questions, gives hints when necessary, and keeps the problem solver talking.
- After several minutes, instructor stops activity, collects solutions from several randomly chosen students to make sure everyone in class understands up to that point. Pairs reverse roles and continue.

Implementing Active Learning in Class

- *Explain what you’re doing and why up front.*
- *For pair or group activities, have the students form into groups of 2-4 where they are sitting.*
- *Assign recorders when appropriate.* If something must be written in the course of an activity, use a scheme to arbitrarily designate a recorder (student with the next birthday, second student from the left,…) or let the teams select one themselves.
- *Explain the task.* The explanation can usually be done orally. For more complicated exercises, make a transparency noting the steps to be taken or write them on the board.
- *Make activities challenging.* Don’t waste class time on trivial questions & exercises.
- *Keep activities short (15 seconds – 3 minutes).* This technique keeps students from wandering off-task and reduces the frustration level for groups that are struggling.
- *After some activities, call randomly on individuals to report.* If you don’t, the students have no incentive to do what you asked them to do.
- *For longer exercises, circulate around the classroom listening in, giving hints, and checking for understanding.*
- *Remember the value of variety.* Don’t get into a pattern with in-class exercises of always doing the same thing (lecture 10 minutes, 2-minute exercise,…). Mix it up by using different structures (individual reflection, groups, think-pair-share,…) to keep the class interesting.
- *Put some course material on handouts, leaving gaps and inserting questions.* Doing this will save enough class time for you to do all the active learning exercises you want to.

What might happen if you start using active learning?

- Initial awkwardness (the students and you) and noncompliance
- Rapidly increasing comfort level except for a few students who remain resistant
- Much higher levels of energy and participation
- More and better questions and answers from students
- Improved class attendance
- Greater learning

You’re about 30 minutes into your Monday morning energy systems class, and things are not looking good. At least a third of the students are texting or sleeping. Many of them clearly don’t understand much of what you’re saying (their midterm exam grades prove it), but they never ask questions.

It’s been like this since the beginning of the semester and you are getting desperate, so you decide to try something different. You complete your determination of the energy output of a power plant boiler furnace and suddenly say “Suppose they build this exact furnace and the power output is only 380 MW instead of the 550 MW we just calculated. Get into groups of two or three, pick one recorder, and list as many possible reasons as you can think of for the difference, including violations of at least three assumptions in the calculation. I’ll give you one minute and then call on a few of you. Go!”

The students quickly get into groups—some waking their neighbors in the process—and go to work. You stop them after about a minute, call randomly on several individuals for responses, get more responses from volunteers, and proceed with your lecture. The whole process takes less than three minutes, during which most or all of your students are awake and actively engaged with the course material. When you later ask them to do something similar on a test, surprisingly many of them can do it.

That’s active learning. Most college instructors have heard of it and know that pedagogical experts say they should do it in their classes. If you bring it up with colleagues, though, they will immediately tell you why it’s a bad idea (an educational fad, a waste of class time, spoon-feeding, lowering academic standards, a radical conspiracy to destroy the American System of Higher Education, etc.). In this paper, we offer our definition of active learning; say a few things about how to do it; and try to persuade you that it’s none of those evil things listed in the last sentence but just a simple, effective, and easy teaching strategy with a solid foundation in research and common sense.

**What is active learning?**

If you think of anything a teacher might ask students to do—answer questions in class, complete assignments and projects outside class, carry out lab experiments, or anything else other than sitting passively in a classroom—you will find people who would classify it as active learning. We find that a more restricted definition limited to in-class activities is more useful:

> Active learning is anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes.

*ASQ Higher Education Brief, 2(4), August 2009.*
You are doing active learning in your class when you ask a question, pose a problem, or issue some other type of challenge; tell your students to work individually or in small groups to come up with a response; give them some time to do it; stop them, and call on one or more individuals or groups to share their responses. You are not doing active learning when you lecture, ask questions that the same few students always answer, or conduct discussions that engage only a small fraction of the class.

We are not about to propose that you throw out lecturing and make every class you teach a total active learning extravaganza. You know more than most of your students do about your subject, and you need to spend part of your class time teaching them what you know—explaining, clarifying, demonstrating, modeling, etc. What we are suggesting is to avoid making lecturing the only thing you do. If a lecture or recitation session includes even a few minutes of relevant activity—a minute here, 30 seconds there—the students will be awake and with you for the remaining time in a way that never happens in a traditional lecture, and most will retain far more of what happens in those few minutes than of what you say and do in the rest of the session. If you do that in every course session, at the end of the semester you’ll see evidence of high-level learning unlike anything you’ve seen before. (Research cited in Reference 5 of the bibliography supports that claim.)

**What can you ask students to do?**

It’s limited only by your imagination. You can ask them to answer a question; explain a complex concept or a physical or social phenomenon in terms a high school student could understand; sketch a flow chart or diagram or plot or time line or concept map; solve a short problem or outline the solution of a longer problem; get started on or carry out the next step of a case study analysis or long problem solution or derivation; predict or interpret the outcome of a scenario or experiment; critique a report or proposal or design or article or op-ed column; troubleshoot a malfunctioning system; brainstorm a list; formulate a question about the material you just lectured on for the past 20 minutes…we could go on, but you get the idea.

When you’re deciding what to ask students to do, avoid trivial questions that the whole class should be able to answer immediately. Instead, focus on the hard stuff—the things students always have trouble with on assignments and exams. If you simply lecture on those things and you’re a good lecturer, the students may leave class thinking that they understood everything, but when they get to the assignments they soon learn otherwise. If you use active learning, those brief interludes of practice and feedback in class will make the assignments and exams go a whole lot smoother for most of them.

**What formats can you use for activities?**

Here is the basic active learning structure.

1. Tell the students to organize themselves into groups of 2–4 and randomly appoint a recorder in each group if writing will be required (e.g., the one born closest to the classroom, or the one farthest to your right, or the one who woke up earliest that morning,…). Alternatively, tell the groups to appoint their own recorders, preferably someone who has not yet recorded that day.

2. Pose a challenging question or problem and allow enough time for most groups to either finish or make reasonable progress toward finishing. The time you give them should...
normally be between 15 seconds and three minutes. If they will need much more time than that, break the problem into several steps and treat each step as a separate activity.

3. Call on several individuals or groups to share their responses, and ask for volunteers if the complete response you are looking for is not forthcoming. Then discuss the responses or simply move on with your planned lecture.

The active learning literature offers many variations of this approach. Here are three particularly effective ones.

- **Think-pair-share.** Pose the problem and have students work on it individually for a short time; then have them form pairs and reconcile and improve their solutions; and finally call on several individuals or pairs to share their responses. This structure takes a bit more time than a simple group activity, but it includes individual thinking and so leads to greater learning.

- **Concept tests.** Ask a multiple-choice question about a course-related concept, with distractors (incorrect responses) that reflect common student misconceptions. Have the students respond using personal response systems (“clickers”) and display a histogram of the responses. If clickers aren’t available and the class isn’t huge, have the students hold up cards with their chosen responses in large letters and scan the room to estimate the response distribution. Then have the students get into pairs and try to reconcile their responses and vote again. Finally, call on some of them to explain why they responded as they did and then discuss why the correct response is correct and the distractors are not.

- **Thinking-aloud pair problem solving (TAPPS).** This is a powerful technique for helping students work through and understand a problem solution, case analysis, or text interpretation or translation. Have the students get into pairs and designate one pair member as the explainer and the other one as the questioner. Give the explainers a minute or two to explain the problem statement line by line (or explain the first paragraph of the case history or interpret or translate the first paragraph of the text) to their partners, and tell the questioners to ask questions when explanations are unclear or incomplete and to give hints when necessary. Stop the students after the allotted time and call on several individuals to explain things to you. Once you get a satisfactory explanation, have the pairs reverse roles and continue with the next part of the problem solution or case analysis or text interpretation or translation. Proceed in this manner until the exercise is complete. In the end, your students will understand the exercise material to an extent that no other instructional technique we know of can match.

**Frequently-asked questions**

**Q:** What mistakes do instructors make when they implement active learning?

**A:** The two most common mistakes are (1) making exercises too long (more than three minutes), and (2) calling for volunteers to respond after every activity. If you give students, say, ten minutes to solve a problem, some groups will finish in two and waste eight minutes of valuable class time, and others will struggle for the full ten minutes, which is extremely frustrating and also a waste of class time. Keeping the activities short avoids both problems. If you always call for volunteers, the students quickly learn that they don’t have to think about what you asked them to do—they can just relax and talk about the football game, and eventually someone else will supply the answer. On the other hand, if they know that any of
them could be called on for a response after a minute or two, most or all of them will do their best to be ready. Avoid these two mistakes and active learning is almost guaranteed to work.

**Q:** If I spend all this time on activities in class, how will I ever cover my syllabus?

**A:** You can spend as much or as little time as you want to. Just a few minutes of activity in each class period will make a substantial difference in the learning that occurs in the class with at most a minor impact on the syllabus. To avoid losing any syllabus content at all, take most of the material you now spend a lot of time on—long prose passages, complex derivations and diagrams, etc.—and put it in handouts sprinkled with questions and gaps. Have the students read through the straightforward material in class (they can read much faster than you can write or drone through PowerPoint slides), and either lecture on the gaps or (better) use them as bases for activities. You’ll cover more material than you ever did when you said every word and did every calculation yourself, and the quality of learning will be much greater. (For more details on this strategy, see Reference 3 in the bibliography.)

**Q:** Won’t it take me a lot of time to plan activities?

**A:** Preparing good lesson plans for a new course is a huge task, whether or not the lessons include activities, but adding activities to lesson plans should not take much time. Just look over your lecture notes a few minutes before class, think of some things you might ask the students to do, and jot them down in the notes. You’ll always come up with as many activities as you want, and after one or two iterations the ones that work well will become a permanent part of the lesson plans.

**Q:** What if some of my students don’t like being asked to work in class?

**A:** Some probably won’t, especially when you first start doing it. Many students want their instructors to tell them everything they need to know for the exam—not one word more or less—and if they are made to work in class they resent it. The key is to let them know up front that you are doing active learning not for your own selfish purposes but because you have research showing that students taught this way have an easier time with homework and do better on exams. Reference 4 in the bibliography (“Sermons for Grumpy Campers”) gives details on how to make that case persuasively, and Reference 5 reviews the research. It won’t take the students long to find out that you’re telling them the truth, at which point the complaining will stop.

**Q:** What should I do if some of my students refuse to get into groups when I ask them to?

**A:** The first time you do an active exercise in a class unaccustomed to active learning, many students might just stare straight ahead, and you will have to personally encourage some of them to work with each other. By the second or third time you do it, there should be few if any holdouts. At that point, stop worrying about it. The research shows that students learn much more by doing things and getting feedback than by watching and listening to someone tell them what they’re supposed to know (Reference 5). In your class activities, you’re providing practice and feedback in the things you know the students will find difficult on the homework and tests. If some choose not to take advantage of those opportunities, it’s their loss—don’t lose five seconds of sleep worrying about it.

And that’s all there is to it. Instructors who switch to active learning and follow those recommendations almost always say that their classes are much more lively and enjoyable and
the quality of learning goes up dramatically. Try it in the next course you teach, and see if you
don’t have a similar story to tell by the end of the semester.

Acknowledgment

The authors are indebted to Kenny and Gary Felder for invaluable critiques of an early
draft of this paper.

Bibliography

SERMONS FOR GRUMPY CAMPERS*

Richard M. Felder
North Carolina State University

In workshops, I push teaching methods like active and cooperative learning that make students more responsible for their own learning than they are when instructors simply lecture.1-2 I believe in truth in advertising, though, and make it clear that the students will not all be thrilled with the added responsibility and some may be overtly hostile to it.3 If you use those methods, you can expect some of your students to complain that you’re violating their civil rights by not just telling them everything they need to know for the test and not a word more or less.

When you use a proven teaching method that makes students uncomfortable, it’s important to let them know why you’re doing it. If you can convince them that it’s not for your own selfish or lazy purposes but to try to improve their learning and grades, they tend to ramp down their resistance long enough to see the benefits for themselves. I’ve developed several mini-sermons to help with this process. If any look useful, feel free to appropriate them.

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Student: “Those group activities in class are a waste of time. I’m paying tuition for you to teach me, not to trade ideas with students who don’t know any more than I do!”

Professor: “I agree that my job is to teach you, but to me teaching means making learning happen and not just putting out information. I’ve got lots of research that says people learn through practice and feedback, not by someone telling them what they’re supposed to know. What you’re doing in those short class activities are the same things you’ll have to do in the homework and exams, except now when you get to the homework you will have already practiced them and gotten feedback. You’ll find that the homework will go a lot smoother and you’ll probably do better on the exams. (Let me know if you’d like to see that research.)”

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S: “I don’t like working on homework in groups—why can’t I work by myself.”

P: “I get that you’re unhappy and I’m sorry about it, but I’ve got to be honest with you: my job here is not to make you happy—it’s to prepare you to be a chemical engineer. Here’s what’s not going to happen in your first day on the job. They’re not going to say ‘Welcome to the company, Mr. Jones. Tell me how you like to work—by yourself or with other people?’ No. The first thing they’ll do is put you on a team, and your performance evaluation is likely to depend more on how well you can work with that team than on how well you solve differential equations and design piping systems. Since that’s a big part of what you’ll be doing there, my job is to teach you how to do it here, and that’s what I’ll be doing.”

S: “Okay, but I don’t want to be in a group with those morons you assigned me to. Why can’t I work with my friends?”

P: “Sorry—also not an option. Another thing that won’t happen on that first day on the job is someone saying ‘Here’s a list of everyone in the plant. Tell me who you’d like to work with.’ What will happen is they’ll tell you who you’re working with and you won’t have a vote on it. Look, I can show you a survey in which engineering alumni who had been through extensive group work in college were asked what in their education best prepared them for their careers. The most common response was ‘the groups.’ One of them said ‘When I came to work here, the first thing they did was put me on a team, and you know those annoying teammates back in college who never pulled their weight—well, they’re here too. The difference between me and people who came here from other colleges is that I have some idea what to do about those guys.’ In this class you’re going learn what to do about those guys.”

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S: “I hate these writing assignments and oral reports you keep making us do. One reason I went into engineering was to get away from that stuff.”

P: “I’m afraid there’s no getting away from it—quite the contrary. Let me give you an example. A few years ago an engineer who was on campus interviewing students for jobs and summer internships came in to talk to an engineering class that was getting frequent communication assignments and complaining bitterly about it. He started by writing on the board a list of everything he did on his job, from designing and pricing process equipment to writing reports and memos and talking to people. Then he had the students get in groups and speculate on what percentage of his time he spent on each of those activities. They all thought 90% of his time went to the technical stuff but it was actually more like 10%. He said that in fact about 75% of his time was spent on writing and speaking—to coworkers, his boss, people reporting to him, people in other divisions, and customers and potential customers—and that his advancement on the job depended heavily on how effectively he communicated with those people. He also said—and this was what really got the students’ attention—that the main thing he was looking for when he interviewed students for jobs was the ability to communicate effectively. Most industrial recruiters we bring in here will tell you the same thing. Since communication skill is something you’ll need to get a job and succeed in it, you’d better acquire it while you’re here, and you will in this class.”

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And that’s that. My suggestion is to put your own spin on those sermonettes and trot them out when the right occasion presents itself. While I don’t guarantee that they will immediately convert all students into believers—in fact, I guarantee they won’t—my experience is that at least they’ll keep student resistance down enough to enable the teaching methods we’ve been talking about to achieve their objectives.

Let me give you one more encouraging word about student resistance to learner-centered teaching methods. My colleague Lisa Bullard uses cooperative learning in both an introductory sophomore engineering course and the capstone senior design course. She once told me that she has always had problems with group work in the sophomore class but never
with the seniors until one semester, when she got the Design Class from Hell. The students complained constantly about having to work in groups, many teams were dysfunctional, and things generally went the way they always had in the sophomore class only worse.

Lisa racked her brains trying to figure out what was different about the design class that semester and couldn’t think of a thing—and then she got it. Up until that year the seniors had previously been in her sophomore class and so were accustomed to group work. She had not taught this group of seniors before, however, and so she was experiencing the headaches that normally come when students first encounter active and cooperative learning. So if you find yourself experiencing those headaches, remember two things. First, you’re equipping students with skills that will serve them well throughout their careers, whatever those careers may be. Second, you’re making life much easier for yourself or colleagues who teach those students in subsequent courses using the same methods. It’s worth a few headaches.

References

IS TECHNOLOGY A FRIEND OR FOE OF LEARNING?

Richard M. Felder and Rebecca Brent
North Carolina State University

In almost every teaching workshop we give, someone asks if the rise of instructional technology and distance learning signals the end of higher education as we know it. As it happens, we believe it does, but we regard this as good news, not bad. Consider the following two scenarios.

Scenario 1

Sharon boots up her computer, connects to her heat and mass transfer course web site, checks out the assignment schedule, sighs heavily, and gets to work. In the next hour and a quarter, she

- quickly reviews last week’s multimedia tutorial that presents material on convective heat transfer, asks questions and poses problems, and provides feedback on her responses and corrections if she misses;
- watches a video of her instructor lecturing on the same topic, advancing rapidly to his discussion of a particular homework problem that gave her a lot of trouble;
- begins working through this week’s tutorial, which deals with a shell-and-tube heat exchanger preheating the feed stream to a distillation column, and clicks on a hot link in the process description that takes her to supplementary material on heat exchangers, including a cutaway schematic, photos of commercial exchangers and tube bundle assemblies, and outlines of exchanger operating principles and design procedures;
- returns to the tutorial and builds the steady-state energy balance and heat transfer equations, branching to a linked database to retrieve needed physical properties of the process fluids;
- uses linked numerical analysis software to solve the equations, size the exchanger, and generate plots of shell-side and tube-side temperatures vs. axial position along the tubes;
- brings up a heat exchanger simulation and first predicts and then explores the effects of system parameter changes on exchanger performance;
- closes the tutorial, checks her e-mail and finds a message from her instructor clearing up a point of confusion she had e-mailed him about late the previous night, sends a message to the other members of her class project group reminding them of their scheduled chat room conference at 7:30 that night, and logs off.

Scenario 2

Fred goes to his 8 a.m. heat and mass transfer class, drops his homework on the front desk, takes his seat, yawns, and wonders if he’ll be able to stay awake until 9:15. Professor Maxwell greets the class and asks the students if they have any questions. One of them asks about a homework problem and she goes through the solution on the board. She then draws a block diagram of a heat exchanger and writes the energy balance and heat transfer equations. When she finishes writing the last equation she asks the class how they would determine the film coefficients in the expression for the overall heat transfer coefficient. Fred vaguely recalls something about correlations from the last lecture but doesn’t feel inclined to say anything. When no one volunteers a response the professor reminds the class about the correlations and writes the equation for one of them on the board, and then completes the calculations. She asks again if any of the students have questions, and they don’t. She then notes that different correlations must be used for laminar flow, and she writes an expression for one of them. While she is writing Fred glances at his watch, sees that it is 9:13, and closes his notebook. The instant she finishes he wakes his neighbor and heads for the door with the rest of the class.
These scenarios raise a question currently being pondered throughout the academic world. If Sharon and Fred are roughly equivalent in intelligence and knowledge of the course prerequisites, which of them will learn more—the one taught in the live classroom or the one taught with technology? There’s no way to know for sure, of course—how much a student learns in a course depends on many things—but technology is the way to bet in this example. The rich mixture of visual and verbal information, self-tests of knowledge and conceptual understanding, practice in problem-solving methods, and immediate individual feedback provided by the technology in Scenario 1 are far more likely to promote deep learning than the passive environment of the traditional lecture class...and the fact that Sharon lives 750 miles away from her instructor’s campus and has never seen him in person doesn’t change the likelihood that she will learn more and at a deeper level than Fred.

This speculation is not baseless: studies comparing technology-based and traditional course offerings are beginning to appear with regularity, and technology is looking better all the time. Universities that specialize in distance education are learning how to use multimedia courseware and the Internet effectively and the quality of their offerings is gaining increasing recognition. When students in the near future have a choice between (a) attending passive lectures at fixed locations and times in a campus-based curriculum and (b) completing interactive multimedia tutorials at any convenient place and time in a distance-based curriculum, guess which alternative more of them will begin to choose.

This is not to say that technology is a panacea. Passive instructional technology—e.g., simply pointing a video camera at a conventional lecture or using the Web only to display text and pictures—does not promote much learning, no matter how dynamic the lecturer or how colorful the graphic images. Moreover, even at its best technology will never be able to do some things that first-rate teachers do routinely, such as advising, encouraging, motivating, and serving as role models for students, helping them develop the communication and interpersonal skills they will need to succeed in their careers, and getting them to teach and learn from one another. Most successful people can think back to at least one gifted teacher who changed their lives by doing one or more of these things; it is unlikely that anyone will ever be able to do the same for a software package.

Here, then, is what our crystal ball says about the future of higher education. An increasing share of undergraduate degrees will be earned in well-designed distance-based programs at conventional universities and institutions without walls like the British Open University and an increasing number of people will bypass college altogether and seek competency-based certification in fields like information technology. Some highly ranked research universities will still teach traditionally and continue to attract undergraduates by virtue of their prestige, serving primarily as training grounds for graduate schools. Many of the much greater number of less prestigious universities will try to keep doing business as usual, but having to compete for a shrinking pool of undergraduates will force them to either change their practices or close their doors. And a growing number of universities will systematically incorporate interactive multimedia-based instructional software in their live classroom-based courses, making sure that the courses are taught by professors who serve as true mentors to their students and not just transmitters of information. These universities will continue to thrive—and they will provide the best college education anyone can get.

DEATH BY POWERPOINT
Richard M. Felder and Rebecca Brent

It’s a rare professor who hasn’t been tempted in recent years to put his or her lecture notes on transparencies or PowerPoint. It takes some effort to create the slides, but once they’re done, teaching is easy. The course material is nicely organized, attractively formatted, and easy to present, and revising and updating the notes each year is trivial. You can put handouts of the slides on the Web so the students have convenient access to them, and if the students bring copies to class and so don’t have to take notes, you can cover the material efficiently and effectively and maybe even get to some of that vitally important stuff that’s always omitted because the semester runs out.

Or so the theory goes. The reality is somewhat different. At lunch the other day, George Roberts—a faculty colleague and an outstanding teacher—talked about his experience with this teaching model. We asked him to write it down so we could pass it on to you, which he kindly did.

* * *

“About five years ago, I co-taught the senior reaction engineering course with another faculty member. That professor used transparencies extensively, about 15 per class. He also handed out hard copies of the transparencies before class so that the students could use them to take notes.

“Up to that point, my own approach to teaching had been very different. I used transparencies very rarely (only for very complicated pictures that might be difficult to capture with freehand drawing on a chalkboard). I also interacted extensively with the class, since I didn’t feel the need to cover a certain number of transparencies. However, in an effort to be consistent, I decided to try out the approach of the other faculty member. Therefore, from Day 1, I used transparencies (usually about 8 -10 per class), and I handed out hard copies of the transparencies that I planned to use, before class.

“After a few weeks, I noticed something that I had not seen previously (or since)—attendance at my class sessions was down, to perhaps as low as 50% of the class. (I don’t take attendance, but a significant portion of the class was not coming.) I also noticed that my interaction with the class was down. I still posed questions to the class and used them to start discussions, and I still introduced short problems to be solved in class. However, I was reluctant to let discussions run, since I wanted to cover the transparencies that I had planned to cover.

“After a few more weeks of this approach, two students approached me after class and said, in effect, ‘Dr. Roberts, this class is boring. All we do is go over the transparencies, which you have already handed out. It’s really easy to just tune out.’ After my ego recovered, I asked whether they thought they would get more out of the class and be more engaged if I scrapped the transparencies and used the chalkboard instead. Both said ‘yes.’ For the rest of the semester, I went back to the chalkboard (no transparencies in or before class), attendance went back up to traditional levels, the class became more interactive, and my teaching evaluations at the end of the semester were consistent with the ones that I had received previously. Ever since that experience, I have never been tempted to structure my teaching around transparencies or PowerPoint.”
The point of this column is not to trash transparencies and PowerPoint. We use PowerPoint all the time—in conference presentations and invited seminars, short courses, and teaching workshops. We rarely use pre-prepared visuals for teaching, however—well, hardly ever—and strongly advise against relying on them as your main method of instruction.

Most classes we’ve seen that were little more than 50- or 75-minute slide shows seemed ineffective. The instructors flashed rapid and (if it was PowerPoint) colorful sequences of equations and text and tables and charts, sometimes asked if the students had questions (they usually didn’t), and sometimes asked questions themselves and got either no response or responses from the same two or three students. We saw few signs of any learning taking place, but did see things similar to what George saw. If the students didn’t have copies of the slides in front of them, some would frantically take notes in a futile effort to keep up with the slides, and the others would just sit passively and not even try. It was worse if they had copies or if they knew that the slides would be posted on the Web, in which case most of the students who even bothered to show up would glance sporadically at the screen, read other things, or doze. We’ve heard the term “Death by PowerPoint” used to describe classes like that. The numerous students who stay away from them reason (usually correctly) that they have better things to do than watch someone drone through material they could just as easily read for themselves at a more convenient time and at their own pace.

This is not to say that PowerPoint slides, transparencies, video clips, and computer animations and simulations can’t add value to a course. They can and they do, but they should only be used for things that can’t be done better in other ways. Here are some suggested dos and don’ts.

- **Do** show slides containing text outlines or (better) graphic organizers that preview material to be covered in class and/or summarize what was covered and put it in a broader context. It’s also fine to show main points on a slide and amplify them at the board, in discussion, and with in-class activities, although it may be just as easy and effective to put the main points on the board too.

- **Do** show pictures and schematics of things too difficult or complex to conveniently draw on the board (e.g., large flow charts, pictures of process equipment, or three-dimensional surface plots). **Don’t** show simple diagrams that you could just as easily draw on the board and explain as you draw them.

- **Do** show real or simulated experiments and video clips, but only if they help illustrate or clarify important course concepts and only if they are readily available. It takes a huge amount of expertise and time to produce high-quality videos and animations, but it’s becoming increasingly easy to find good materials at Web sites such as SMETE, NEEDS, Merlot, Global Campus, and World Lecture Hall. (You can find them all with Google.)

- **Don’t** show complete sentences and paragraphs, large tables, and equation after equation. There is no way most students can absorb such dense material from brief visual exposures on slides. Instead, present the text and tables in handouts and work out the derivations on the board or—more effectively—put partial derivations on the handouts as well, showing the routine parts and leaving gaps where the difficult or tricky parts go to be filled in by the students working in small groups.¹²
If there’s an overriding message here, it is that doing too much of *anything* in a class is probably a mistake, whether it’s non-stop lectures, non-stop slide shows, non-stop activities, or anything else that falls into a predictable pattern. If a teacher lectures for ten minutes, does a two-minute pair activity, lectures another ten minutes and does another two-minute pair activity, and so on for the entire semester, the class is likely to become almost as boring as a straight lecture class. The key is to mix things up: do some board work, conduct some activities of varying lengths and formats at varying intervals, and when appropriate, show transparencies or PowerPoint slides or video clips or whatever else you’ve got that addresses your learning objectives. If the students never know what’s coming next, it will probably be an effective course.

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Portable computers are getting more powerful and cheaper all the time. Most college students now own one, and many engineering and science curricula require all their students to have them. Once colleges do that, though, they are also obliged to give the students enough to do with the computers to justify that requirement. True, homework involving computers is routinely assigned in technical curricula, but the computer labs at most colleges are more than adequate to serve the students who don’t have their own computers. Few institutions have enough computer-equipped classrooms to host all their classes, however, and so it makes sense to have the students use their own computers in class. The question is, to do what?

Taking notes in class is not the answer. Lecture notes in engineering, science, and math courses normally involve equations and diagrams, which students cannot enter on a computer nearly as fast as instructors can write them on a board or project them on a screen. Unless the students are given better options, they are more likely to use their computers during lectures to work on homework, play games, surf the Web, and e-chat with their friends. It’s hard enough for instructors to hold students’ attention in a lecture class under normal circumstances; adding computers with all of the tempting diversions they offer can make it hopeless.

The remedy for attention drift in class—with or without computers—is to use active learning, periodically giving the students things to do (answer questions, solve problems, brainstorm lists,…) related to the course content. Extensive research has established that students learn much more through practice and feedback than by watching and listening to someone telling them what they are supposed to know.

Computers can be effectively incorporated into classroom activities in many ways for a variety of purposes. Several examples follow.

Working through interactive tutorials

Computer-based tutorials can be highly instructive, especially if they are interactive, prompting users for responses to questions and correcting mistakes. Tutorials are increasingly common on CDs bundled with course texts, and they may also be obtained from software companies and multimedia libraries such as MERLOT or SMETE. A problem is that students worry about how much time they will take and so tend to ignore them. An effective way to deal with their concern is to have them work through the first of a set of tutorials. If it is well designed, they will then be much more likely to work through the others voluntarily. (A recent research study illustrates this phenomenon.)

Getting started with new software and building skill in its use

Many students—even those comfortable with e-mail and computer games—feel intimidated when unfamiliar software is introduced in a course. To help them over this psychological barrier, have them run the software in class, working through the same kinds of tasks they will be called on to carry out in assignments. When they get confused or make common beginners’ mistakes, they will get immediate assistance instead of having to struggle for hours by themselves and will then be prepared...
to run the software on their own. Several in-class activities may subsequently be used to help them gain expertise in the software, such as:

- **What will happen?** Give one or more statements or commands and ask students to predict what the program will do in response. Then have them enter and execute the commands and verify their predictions or explain why they were wrong.

- **What's wrong?** Give statements or program fragments with errors and ask the students to identify and correct the mistakes.

- **How might you do this?** State desired outcomes and ask the students to write and test programs to achieve them.

### Carry out web-based research

Answers to many research questions can be obtained in a few keystrokes using powerful search engines such as Google. To help your students develop computer research skills, you might ask them to do several things in class and then in homework assignments:

- Gather information about a specified device, product, or process.
- Locate a visual image to illustrate a concept or include in a report.
- Verify or refute an assertion in the popular press related to science or technology.
- Assemble supporting arguments for different sides of a controversial current issue.

### Explore system behavior with simulations

Computer simulations allow students to explore system behavior at conditions that might not be feasible for hands-on study, including hazardous conditions. Having students build their own simulations of complex systems in class may be impractical, but prewritten simulations (which might include random measurement errors and possibly systematic errors) can be used for a number of worthwhile activities:

- **Study simulated experimental systems in lecture classes.** Ask students to (a) apply what they have learned in class to predict responses of a simulated system to changes in input variables and system parameters; (b) explore those changes, interpret the results, and hypothesize reasons for deviations from their predictions, and possibly (c) explore or optimize system performance over a broad range of conditions.

- **Prepare for and follow up real laboratory experiments.** Have students in a laboratory course design an experiment and test their design using a simulation before actually running the experiment. Following the run, have them formulate possible explanations for discrepancies between predicted and experimental results.

### Implementation tips

Several formats for computer-based activities in class should be used on a rotating basis. If all students have computers, they may work individually, or in pairs or trios, or individually first and then in pairs to compare and reconcile solutions. If there are only enough computers for every other student, the students may work in pairs with one giving instructions and the other doing the typing, reversing roles in successive tasks. After stopping an activity in any of these formats, the instructor should first call on several individuals for responses and then invite volunteers to give additional responses. The knowledge that anyone in the class might be called on will motivate most of the students to actually attempt the assigned tasks.1
Finally, an indispensable device for effectively using portable computers in class is the simple command, “Screens down!” when you want the students’ attention for any length of time. As long as they can see their screens and you can’t, the temptation for them to watch the screens instead of you can be overwhelming. If you take away that option, at least you’ll have a fighting chance.

References


3. (a) MERLOT (Multimedia Educational Resource for Learning and On-Line Teaching), <http://www.merlot.org>; (b) SMETE (Electronic resources for science, math, engineering, and technology education), <http://www.smete.org>.

Additional Resources on Lecturing and Active Learning

Lecturing


Active Learning

- Prather, E., Rudolph, A., & Brissenden, G. (2011). “Using research to bring interactive learning strategies into general education mega-courses.” *Peer Review*, 13(3), Summer, <www.aacu.org/peerreview/pr-su11/UsingResearch.cfm>. Studied an introductory astronomy course taught to nearly 4000 students at 31 colleges & universities. Classes that spent 25% of their class time or more using active strategies averaged more than double the normalized gains of classes that spent 25% or less, independent of type of institution or class size (which was as large as 800 students).
INTRODUCTION TO COOPERATIVE LEARNING

Cooperative learning (CL): Students work in teams on structured learning tasks under conditions that meet five criteria:

1. **Positive interdependence.** Team members must rely on one another to accomplish goal.
2. **Individual accountability.** Members held accountable for (a) doing their share of the work and (b) mastering all material.
3. **Face-to-face interaction.** Some or all work done by members working together.
4. **Appropriate use of interpersonal skills.** Team members practice and receive instruction in leadership, decision-making, communication, and conflict management.
5. **Regular self-assessment of group functioning.** Teams periodically reflect on what they are doing well as a team, what they could improve, and what (if anything) they will do differently in the future.

Cooperative learning may be the most exhaustively researched instructional method in all of education. Thousands of research studies attest to its effectiveness, including many in engineering and science education. The results show that if CL is correctly implemented, relative to traditional instruction it leads to more and deeper learning and longer retention of information; greater development of high-level thinking, problem-solving, communication, and interpersonal skills; more positive attitudes toward engineering and science curricula and careers and greater retention in those curricula; and better preparation for the workplace.

Cooperative learning is not trivial to implement, however. Instructors must deal with the logistics of team formation, plan ways of establishing the five defining conditions of the method, help students work through the wide variety of team dysfunctions and interpersonal conflicts that commonly arise in teamwork, and possibly cope with vigorous resistance from some students who would much rather work independently.

A full discussion of cooperative learning strategies is beyond the scope of this workshop. The pages that follow provide resources for instructors who wish to learn more about the approach and perhaps to introduce it in their classes.
To get an overview of CL:

To find practical suggestions for CL structures and troubleshooting:

To assess the performance of individual members of project teams

10. Comprehensive Assessment of Team Member Effectiveness (CATME), [http://www.catme.org]. A powerful and extensively validated Web-based peer rating tool. CATME collects peer assessments for five important aspects of team functioning, uses the results to adjust team grades for individual performance, provides feedback to team members on things they are doing well and areas that need improvement, and provides a report to the instructor summarizing the outcomes and flagging potential problems that might call for his/her intervention. CATME now also includes TEAMMAKER, another on-line tool that can be used to form student teams using criteria specified by the instructor.
To explore the research base for CL:


To read about a longitudinal study of cooperative learning in engineering education:


For on-line resources:

20. *Forms for Cooperative Learning.* A set of forms that can be modified and used to form teams, establish course policies regarding teams, and help teams set expectations and assess their individual and team performance. Also checklists for implementing cooperative learning in lecture classes, project courses, and laboratories. <http://www.ncsu.edu/felder-public/CL_forms.doc>


22. *IASCE.* The web site of the International Association for the Study of Cooperation in Education. A collection of resources including a newsletter, list of related organizations and links, and a search engine. <http://www.iasce.net/>

23. *Innovations in SMET Education.* The web site of the National Institute for Science Education at the University of Wisconsin. Resources on collaborative learning (including Cooper and Robinson's outstanding annotated bibliography on cooperative learning), learning through technology, and assessment of learning. <http://www.wcer.wisc.edu/nise/CL1/>


26. *The University of Minnesota Cooperative Learning Center.* Information and references on different aspects of cooperative learning, including “Cooperative Learning Methods: A Meta-Analysis,” which summarizes the results of a large number of CL research studies. The site is maintained by David and Roger Johnson of the University of Minnesota. <http://www.co-operation.org/>
C. What student problems am I likely to face?
What problem students am I likely to face?
What can I do about them?
Crisis Clinic

All in a day’s work

It’s a typical day in your class. As you lecture

- a student strolls in 10 minutes late, the earliest arrival for the student all semester
- several are absorbed in the newspaper
- two students are talking to each other and laughing
- one has head back, eyes closed, and mouth open
- a cell phone rings

What might you do about all this? *

* To see our recommendations, go to <http://www.ncsu.edu/felder-public/Columns/Dayswork.html>.

One in every crowd

One of the students in your sophomore class goes out of her way to be obnoxious: she acts bored, sleeps in class, and makes constant semi-audible wisecracks that set everyone around her to snickering. She also loves to ask you questions you can’t answer and to point out flaws in everything you do and say in lectures.

What might you do about her?
Why me, Lord?

An agitated student comes into your office, begins to discuss the quiz he just did so poorly on, and then in a broken voice tells you that he had a B average coming into this semester and he’s now failing all his courses and doesn’t know what he’s going to do. He makes an effort to pull himself together, apologizes for taking up your time, and gets up to leave.

What might you do?*

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* To see our recommendations, go to <http://www.ncsu.edu/felder-public/Columns/WhyMeLord.pdf>.

The old switcheroo

The tests have been handed in, graded, and returned. A student comes in, shows you a page without a red mark on it that contains a perfect solution to Problem 3, and complains that the grader must have overlooked that page because points were taken off for Problem 3.

What might you do?
He knocks on my office door, scans the room to make sure no one else is with me, and nervously approaches my desk. I ignore the symptoms of crisis and greet him jauntily.

"Hi, Don—what's up?"

"It's the test tomorrow, Dr. Felder. Um...could you tell me how many problems are on it?"

"I don't see how it could help you to know, but three."

"Oh. Uh...will it be open book?"

"Yes—like every other test you've taken from me during the last three years."

"Oh...well, are we responsible for the plug flow reactor energy balance?"

"No, it happened before you were born. Look, Don, we can go on with this game later but first how about sitting down and telling me what's going on. You look petrified."

"To tell you the truth, sir, I just don't get what we've been doing since the last test and I'm afraid I'm going to fail this one."

"I see. Don, what's your GPA?"

"About 3.6, I guess, but this term will probably knock it down to..."

"What's your average on the first two kinetics tests?"

"92."

"And you really believe you're going to fail the test tomorrow?"

"Uh..."

Unfortunately, on some level he really does believe it. Logically he knows he is one of the top students in the department and if he gets a 60 on the test the class average will be in the 30's, but he is not operating on logic right now. What is he doing?

The pop psychology literature calls it the impostor phenomenon.** The subliminal tape that plays endlessly in Don's head goes like this:

_I don't belong here...I'm clever and hard-working enough to have faked them out all these years and they all think I'm great but I know better...and one of these days they're going to catch on...they'll ask the right question and find out that I really don't understand...and then...and then...._

The tape recycles at this point, because the consequences of them (teachers, classmates, friends, parents,...) figuring out that you are a fraud are too awful to contemplate.

I have no data on how common this phenomenon is among engineering students but when I speak about it in classes and seminars and get to “...and they all think I'm great but I know better,” the audience resonates like a plucked guitar string—students laugh nervously, nod their heads, turn to check out their neighbors' reactions. My guess is that most of them believe deep down that those around them may belong there but they themselves do not.

They are generally wrong. Most of them do belong—they will pass the courses and go on to become competent and sometimes outstanding engineers—but the agony they experience before tests and whenever they are publicly questioned takes a severe toll along the way. Sometimes the toll is too high:

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even though they have the ability and interest to succeed in engineering they cannot stand the pressure and change majors or drop out of school.

It seems obvious that someone who has accomplished something must have had the ability to do so (more concisely, you cannot do what you cannot do). If students have passed courses in chemistry, physics, calculus, and stoichiometry without cheating, they clearly had the talent to pass them. So where did they get the idea that their high achievements so far (and getting through the freshman engineering curriculum is indeed a high achievement) are somehow fraudulent? Asking this gets us into psychological waters that I have neither the space nor the credentials to navigate; suffice it to say that if you are human you are subject to self-doubts, and chemical engineering students are human.

What can we do for these self-labeled impostors?

- **Mention the impostor phenomenon in classes and individual conferences and encourage the students to talk to one another about it.**

There is security in numbers: students will be relieved to learn that those around them—including that hotshot in the first row with the straight-A average—have the same self-doubts.

- **Remind students that their abilities—real or otherwise—have sustained them for years and are not likely to desert them in the next 24 hours.**

They won't believe it just because you said so, of course—those self-doubts took years to build up and will not go away that easily—but the message may get through if it is given repeatedly. The reassurance must be gentle and positive, however: it can be helpful to remind students that they have gone through the same ritual of fear before and will probably do as well now as they did then, but suggesting that it is idiotic for a straight-A student to worry about a test will probably do more harm than good.

- **Point out to students that while grades may be important, the grade they get on a particular test or even in a particular course is not that crucial to their future welfare and happiness.**

They will be even less inclined to believe this one but you can make a case for it. One bad quiz grade rarely changes the course grade and even if the worst happens a shift of one letter grade changes the final overall GPA by about 0.02. No doors are closed to a student with a 2.84 GPA that would be open if the GPA were 2.86. (You may not think too much of this argument but I have seen it carry weight with a number of panicky students.)

- **Make students aware that they can switch majors without losing face.**

It is no secret that many students enter our field for questionable reasons—high starting salaries, their fathers wanted them to be engineers, their friends all went into engineering, and so on. If they can be persuaded that they do not have to be chemical engineers (again, periodic repetition of the message is usually necessary), the consequent lowering of pressure can go a long way toward raising their internal comfort level, whether they stay in chemical engineering or go somewhere else.

**Caution, however.** Students in the grip of panic about their own competence or self-worth should be deterred from making serious decisions—whether about switching curricula or anything else—until they have had a chance to collect themselves with the assistance of a trained counselor.

One final word. When I refer at seminars to feeling like an impostor among one's peers, besides the resonant responses I get from students I usually pick up some pretty strong vibrations from the row where the faculty is sitting. That's another column.
Students can be frustrating, as evidenced by the fact that the next two in our list of frequently asked questions at workshops are among the most common we get.

- I tried putting my students to work in groups but some of them hated it and one complained to my department head. *What am I supposed to do about student hostility to teaching methods that make them take responsibility for their own learning?*

- Many of my students are (a) unmotivated, (b) self-centered, (c) apathetic, (d) lazy, (e) materialistic, (f) unprepared, (g) unable to do high school math, (h) unable to write, (i) unable to read, (j) spoiled rotten. (Pick any subset.) *How can I teach people who don't have the right background or the willingness to work or even the desire to learn?*

We have written elsewhere about student resistance to non-traditional instruction—why it occurs, what forms it takes, and how to defuse it. The remainder of this column deals with the second question.

The problems of poor student motivation and preparation are challenging. Certainly there are some students in our courses who appear to be uninterested in the subject, unwilling to work at it, and clueless about things they were supposed to have learned in prerequisite courses or high school. There may be even more students like that now than there were 20 years ago (as many older professors claim), although this trend is more likely due to a shift in entering college student demographics than to a general weakening in the moral fiber of today’s youth. But while grumbling about the students (and the high schools or Ted Kennedy or Jesse Helms or whoever else we hold responsible for widespread moral fiber decay) may have some therapeutic benefit, it doesn’t solve anything. For better or worse, these students are the ones we have to work with—we can’t write off an entire generation and hope for better things from the next one.

A more productive approach is to take our students where they are and find ways to overcome whatever shortcomings in preparation or motivation they may have. It’s not impossible—professors at every university and college do it all the time. If you think about your faculty colleagues, you can surely come up with one or two who set high standards that most of their students regularly meet and exceed, who consistently get top ratings from students and peers, and about whom the alumni talk reverently years and decades after graduation. These professors are obviously doing something to reach the same students whose lack of motivation and deficient backgrounds their colleagues keep complaining about. What is it?

**Motivating students to learn**

Student motivation in a class generally falls into three broad categories. Some students have a high level of interest in the course topic and will study it intensively regardless of what the instructor does or fails to do. No special motivation is necessary for these students—the two of them will do fine on their own. Others have a complete lack of aptitude for the subject and/or a deep-seated antipathy toward it, but the course is required for their degree and so there they sit, defying the instructor to teach them anything. Trying to motivate these charmers may be more trouble than it’s worth, but (at least in engineering courses) there are fortunately not many of them either. Still others—usually a large majority—are in the third category: they don’t have a burning interest in the subject but they also don’t hate it and they have the ability to succeed in it. How the instructor teaches can profoundly affect how these students approach the course.

In another column we discussed what educational psychologists have termed a “deep approach” to learning. Students who take this approach do whatever it takes to gain a conceptual understanding of the
subject being taught. They routinely try to relate course material to other things they know, look for applications, and question conclusions—precisely the kinds of things that the students whose lack of motivation we complain about never do.

Certain course attributes have been found to correlate with students taking a deep approach, suggesting that the key to motivating students in that large third category might be to build as many of those attributes into our courses as we can. The attributes are (a) clear relevance of the course material to familiar phenomena, material in other courses the students have taken or are currently taking, and problems they will be called upon to solve in their intended careers; (b) explicit statements of the knowledge and skills the students are expected to acquire, which may take the form of instructional objectives or detailed study guides for exams; (c) assignments that provide practice in the skills specified in the objectives and are not too long, so that the students have time for the studying and reflection entailed in a deep approach; (d) some choice over learning tasks (e.g., a choice between problem sets and a project); and (e) well-designed tests that are clearly grounded in the objectives (no surprises or tricks) and can be finished in the allotted time. (For more details, see Reference 3.) Building those things into your course may take some work but will probably motivate enough of your students to allay any concerns you may have about their generation.

Teaching Underprepared Students

What about the students who come into your class having successfully completed prerequisite courses but apparently having absorbed little or nothing from them? Again, blaming the instructors who taught the prerequisites (who “passed students they clearly should have failed”) or the Math Department (which “doesn’t know how to teach calculus to engineers”) or the K–12 system (which “doesn’t know how to teach anything”) is easy but doesn’t help with the immediate problem. The fact is, these students are in your class now and somehow you've got to teach them, and you don’t want to spend the first three weeks of the course re-teaching what they were supposed to know on Day 1. What can you do?

Here’s a technique that works well. On the first day of class, announce that the first exam in the course will be given in the following week and will cover only the prerequisite material. Hand out a study guide containing instructional objectives for that exam, including only the knowledge and skills required for your course and not everything in the prerequisite course text. Further announce that you will not lecture on that material but will be happy to answer questions about it in class or during your office hours. (You may also choose to hold an optional review session.) Then start the course. Most of the students will manage to pull the required knowledge back into their consciousness by the day of the exam, and the few who fail will be on notice that they could be in deep trouble and might think about dropping the course and doing whatever it takes to master the prerequisites by next semester.

You might also try to persuade your colleagues who teach the prerequisite courses to adopt some of those methods that induce students to take a deep approach to learning. If they do that, the problem in your course could take care of itself.

References

Cheating*

**Question:** Is there likely to be cheating on exams in the course I’m about to teach?

**Answer:** Yes

**Question:** How will they do it?

**Answer:**
1. **The Sneak Preview.** (They get advance copies.)
2. **The Eyes Have It.** (They scan their neighbor’s paper.)
3. **I Get By with a Little Help from My Friends.** (They text-message on their cell phone or instant-message on their laptop to a classmate or a person outside of the class.)
4. **The Note of Precaution.** (They bring crib sheets or store information on their personal data assistant/cell phone/calculator/laptop)
5. **The Call of (a Warped) Nature.** (They leave the test room and get help.)
6. **Quick Change Artistry.** (They pick up your worked-out solution at the front of the room and correct the paper before handing it in.)
7. **Now You See It, Now You Don’t.** (They don’t hand in the test and later claim you lost it.)
8. **Three-Page Monte.** (They substitute correct solutions for incorrect ones after the graded tests are handed back.)
9. **Hire a Substitute.**
10. **History Repeating Itself.** (They memorize solutions to the same questions on past tests.)

*This one is not cheating—it’s your fault for repeating questions.*

**Question:** How can I minimize cheating?

**Answer:**
1. Don’t leave copies of the test lying around, *including in computer files.*
2. Know how many copies were run off. Count them before the test is given.
3. Announce that cell phones, PDA’s, etc., will be confiscated if they are used during the test.
4. Make sure the exam is carefully proctored.
5. Don’t hand out worked-out solutions until you are sure all the papers have been collected.
6. Log in the papers as soon as you collect them.
7. Use exam booklets if possible.
8. Make photocopies of some or all graded solution papers, particularly those of anyone you have suspicions about, before handing them back.
9. Require complete solutions. Don’t give credit for the right answer magically appearing.
10. Give open-book tests as much as possible.
11. Give tests that are easy to read and possible to solve. *Students are much more likely to cheat on tests they regard as unfair.*
12. Don’t repeat exams!

Suggestions for Addressing Academic Integrity Issues*

1. **Integrate the concept** of academic integrity into the content of the course, as opposed to talking about it once and forgetting about it. Think about how you could relate the issue to course content or professional practice.

2. **Decide that you are going to be proactive** and do something about it. Recognize that this will take time and effort on your part. However, time and effort spent up front will hopefully prevent incidents later that require more time and effort to address.

3. **Establish clear expectations** about behavior
   a. Use specific language in the syllabus (see attachment with examples).
   b. In-class discussion – discuss scenarios of what is acceptable and not acceptable as related to the specific class. (Note: it is not possible to describe every unacceptable scenario. You can only try to distinguish the “spirit of the law” and give students guidance on your expectations, not define every unacceptable act. They can always think of another you have not mentioned). We have developed these specific examples into a skit and subsequently a video.*
   c. Discuss consequences and risks of these behaviors.
   d. Discuss your university’s Code of Student Conduct and/or the Code of Ethics of your professional society.

4. **Document control**
   a. Avoid repeating homework and exam problems. Students keep and pass around hard copies and electronic versions of assignments. Keep a spreadsheet of problems from the text that you assign, and try to not repeat problems too often.
   b. Avoid posting solutions to homework or tests in electronic form. (Some students will print out solutions to the course they are taking next semester, and anything on the web becomes available to the world). If you must post solutions, use a locked bulletin board.
   c. Have students hand in a CD with their lab, design report, project, etc. so that you can compare with subsequent reports if necessary. This is particularly important with lab experiments that are performed every semester.

5. **Tests**
   a. Have students complete tests in blue books or colored paper that you distribute.
   b. No cell phones or electronic devices.
   c. Be sure to have sufficient proctor coverage. Actively walk around the room and make eye contact with individual students. Following the exam, log in which students took the exam.

6. **Train TA’s and faculty graders to recognize cheating**
   a. Handwritten homework assignments – have one person grade all of one problem. Draw a red line down the rest of a blank page. Have students write only on one side of their paper.
   b. Excel assignments – check authorship of files, time and date created.
   c. Lab write-ups – compare against lab manual and other reports.

7. **Hold students accountable if there are incidents of misconduct**
   a. Initiate student conduct proceedings.
   b. Give feedback to the class about violations right away instead of waiting to see if other students will make the same mistake.

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Examples of syllabus language that addresses academic integrity

Example 1:

**Academic integrity.** Students should refer to the University policy on academic integrity found at [http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php](http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php)

It is the instructor’s understanding and expectation that the student's signature on any test or assignment means that the student contributed to the assignment in question (if a group assignment) and that they neither gave nor received unauthorized aid (if an individual assignment). **Authorized aid on an individual assignment includes discussing the interpretation of the problem statement, sharing ideas or approaches for solving the problem, and explaining concepts involved in the problem.** Any other aid would be unauthorized and a violation of the academic integrity policy. All cases of academic misconduct will be submitted to the Office of Student Conduct. If you are found guilty of academic misconduct in the course, you will receive a zero for that component of the grade (e.g. if you are found guilty of cheating on a homework assignment, you will receive a zero for 20% of your grade). In addition, you will be on academic integrity probation for the remainder of your years at NCSU and may be required to report your violation on future professional school applications. It’s not worth it!

Example 2:

All work that you turn in for grading must be your own (this means that it is an independent and individual creation by you). Any attempt to gain an unfair advantage in grading, whether for oneself or for another, is a breach of academic integrity and will be reported to the Office of Student Conduct. **Penalties for cheating can be as severe as suspension from the university. Students who are found cheating on a project or test will receive a grade of –100% (negative 100 percent) for that work. Turning in code that is written by other students is considered cheating. Giving code for other students to turn in is considered cheating.** Cheating is simply not worth it. Cheating is much worse than not turning in an assignment at all. Cheating penalties are severe. They are permanent. The CSC department used special software to detect cheating violations for programming projects. In Spring 2004, approximately 60 students were charged with academic integrity violations. All of those students are on permanent academic probation. We will be using that same software this semester.

**Examples of cheating.** Some examples of behaviors that constitute cheating are as follows:

- It is cheating to give any student access to any of your work which you completed for class assignments. Your campus account is for your use alone.
- It is cheating to use another person's work, either an assignment or a test, and claim that it is your own. In all cases, you are expected to complete an assignment on your own.
- It is cheating to attempt to interfere with other students' use of computing facilities or to circumvent system security.
- It is cheating to mail copies of your work to another student, to use ftp to get another student's work, or to put your work out for others to obtain via the World Wide Web or other bulletin board type services.
- It is cheating to give another student access to your directories and/or the password to your account.
- It is cheating for you and another student to work on the same file to turn in for an assignment. You may not work in conjunction with other students on the EOS system or on home computing system files to be ported to EOS.

**Useful Resource:** Center for Academic Integrity, [http://www.academicintegrity.org/index.asp](http://www.academicintegrity.org/index.asp). A Duke University facility that provides numerous resources for addressing misconduct problems at institutional levels and in individual classrooms.
HOW TO STOP CHEATING (OR AT LEAST SLOW IT DOWN)*

Richard M. Felder
North Carolina State University

A: Will there be cheating in the course I’m about to teach?  
B: It depends. Will there be more than five students in the class?  
A: Yes.  
B: Then, yes.  
A: I don’t believe it—not my students! How much would you care to bet?  
B: How much do you have?  

While B could conceivably lose that bet, I wouldn’t bet on it. Cheating has existed on campuses since there were campuses, but it’s now as much a part of student culture as sleeping through 8 a.m. classes. In recent surveys of over a thousand undergraduates, 80% of the respondents at 23 institutions—82% of those in engineering—reported that they cheated at least once in college, and in just the previous term most of the engineers cheated more than once on exams (33%) and/or assignments (60%).\(^1\) In other studies, 49% of engineering and science students surveyed engaged in unauthorized collaboration on assignments (up from 11% 30 years earlier) and 75% copied homework solutions from bootlegged instructors manuals.\(^2\)

Why is cheating so common? Because grades do matter, and everyone knows it. You can’t tell students otherwise when they know many companies interviewing on campus won’t even look at them if their GPA is less than 3.5, and if it’s below 3.8 they can pretty much kiss their chances of going to a top graduate school goodbye.

However compelling the pressures to do it may be, cheating is clearly a bad thing. Cheaters get grades they don’t earn and sometimes diplomas that wrongfully certify them as qualified entry-level professionals. Also, there is no reason to expect students who take unethical shortcuts in school to stop taking them later in life, such as when they run plant safety inspections and design toxic waste treatment facilities. In fact, they don’t stop: cheaters in college are relatively likely to continue cheating in the workplace.\(^1\)

In recent years, researchers have begun to study cheating and the effectiveness of deterrents to it. Carpenter et al.\(^1\) summarize results from a decade of such studies, and Bullard and Melvin\(^2\) describe a program that has substantially decreased cheating in a course where it has been chronic. The rest of this column presents a few highlights of these papers.

Carpenter et al.\(^1\) listed a number of questionable actions and asked students which ones they would regard as cheating. The results include copying from another student on an in-class exam (96%), copying from a crib sheet on a closed-book test (92%), copying another student’s homework (73%), and unauthorized collaboration on web-based quizzes (41%) and take-home exams (39%). Most survey respondents felt that instructors (79%) and the institution (73%) are responsible for preventing cheating, but only 22% thought students had any obligation to challenge or report it if they saw it.

At N.C. State University, the introductory chemical engineering course (CHE 205—Chemical Process Principles) has historically been a prime target for cheating attempts. Lisa

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Bullard, a faculty member who frequently teaches CHE 205, and Adam Melvin, a graduate student who has taught it several times, have developed an effective system for reducing cheating in the course. The syllabus provides detailed descriptions of the activities that count as cheating and the procedure followed when students are caught at them. To reinforce the message, Bullard and Melvin and an instructor in the NCSU Communications Department produced a 15-minute video of student actors engaged in activities that might or might not count as cheating. The students watch the video on-line and complete a reflection assignment in which they state whether each of a number of specified activities would count as cheating, citing the rule in the syllabus or the NCSU Code of Student Conduct that supports their conclusion.

When a CHE 205 student is suspected of cheating, the course instructor has a conversation with him or her, decides whether the circumstances warrant filing a formal charge, and if the decision is to file, fills out a form stating the infraction and the proposed penalty. If the student signs the form, thereby admitting guilt and accepting the penalty, it goes on file with the Office of Student Conduct. If no subsequent violations occur prior to graduation, nothing goes on the student’s permanent record, but if there is one, the automatic penalty is suspension for at least one semester. The student may instead decline to sign the form, contest the charge, and have a hearing before either a student-faculty judicial board or an OSC administrator. The outcome of the hearing may be to dismiss the charge, uphold the proposed penalty, or impose a more stringent penalty. At hearings, the course syllabus, video, and reflection assignment effectively refute students’ claims that they didn’t know their infractions would be considered cheating.

To evaluate the effectiveness of this approach, Bullard and Melvin tabulated the frequency of cheating incidents and contested charges in the two years before the video was produced (2004–2005) and the first four years in which it was shown (2006–2009). The average percentage of enrolled students with reported violations dropped by 40% from 10% (2004–2005) to 6% (2006–2008). (It spiked up again in the fall of 2009 when the authors devised a way to catch students copying problem solutions from unauthorized solution keys.) The percentages of accused students who contested the charges dropped from 24% pre-video to 1% post-video (one out of 63 students, who was subsequently found guilty at the hearing). A fringe benefit of the system’s success is that other department faculty members have begun to use the institutional process for dealing with academic dishonesty instead of handling it on their own or simply ignoring it. Students who cheat in a course and are reported are now much less likely to try it again, knowing they are likely to be suspended and get a permanent stain on their transcript if they are caught.

There are several morals to be drawn from these two excellent studies.

- Define explicitly what you consider cheating and what kinds of collaboration are acceptable. As the statistics in Reference 1 suggest, your students’ ideas about it are almost certain to be different from yours. If you don’t make your definitions clear, they will invariably default to theirs. In addition, consider giving the students a voice in formulating cheating policies. Students are more likely to follow rules they help establish than rules they have no say about.

* [http://www.che.ncsu.edu/bullard/Academic_integrity.htm](http://www.che.ncsu.edu/bullard/Academic_integrity.htm) contains links to clips from the video and the policy statements and reflection assignment.
• **Follow your institution’s procedures for dealing with suspected cheating.** When you yield to the strong temptation to handle it entirely by yourself, students you catch may not cheat again in your course, but since no one will be keeping track of their violations they will be almost certain to cheat in other courses. Plus, *if there is an institutional honor code, support and enforce it.* Strictly enforced honor codes reduce cheating.¹

• **Be fair to your students and they will be more likely to be honest with you.** When instructors give assignments and exams that are much too long or make any of the other “top four worst teaching mistakes,”³ students feel they are being cheated and many have no reservations about returning the favor.

These recommendations won’t eliminate academic dishonesty, but if you and most of your colleagues follow them, you might succeed in moving the frequency of cheating from out-of-control to tolerable. Like getting old, it’s not ideal but it beats the alternative.

**References**


Additional Resources

Classroom Management


Advising


Academic Misconduct (Cheating)


- Center for Academic Integrity, <http://www.academicintegrity.org/index.asp>. A Duke University facility that provides numerous resources for addressing misconduct problems at institutional levels and in individual classrooms.


D. How can new faculty members get off to a good start?
Success Strategies for New Faculty

Message:

- People are not born knowing how to be professors. Trial-and-error may not be the most efficient way to learn.
- Most new professors take five years to reach full effectiveness. Some (“quick starters”) do it in 1–2. We know a lot about what makes the difference.
- Low productivity in research is costly. So is ineffective teaching. Quick starters are valuable.
- Research productivity and teaching effectiveness both involve teachable skills. Faculty development can produce quick starters.

Untenured faculty stress points\(^a\)

- Not enough time
- Inadequate feedback and recognition
- Unrealistic expectations
- Lack of collegiality
- Balancing work and life outside work

plus, for non-majority faculty (including women in traditionally male fields)\(^b\)

- Chilly climate
- Excessive committee assignments
- Excessive student demands

Faculty in their first four years: Common mistakes and strategies for avoiding them\(^c\)

- 95% of new faculty members make certain mistakes that cost them time, productivity, and sanity!
- We can identify the things the other 5%—the “quick starters”—do to avoid making these mistakes.
- **Mistake #1:** Giving proposal and paper writing their highest verbal priority while spending relatively little time on them and producing relatively little.
  - Concentrating on most pressing tasks (putting out fires).
  - Waiting for “blocks of time” to do “real writing.”
  - Results: Lack of productivity, anxiety about it. Long warm-up time when blocks come.
- **Success Strategy #1:** Schedule regular time for scholarly writing and keep track of it in time log.
  - Schedule 30–45 minutes daily or 2–3 longer blocks weekly, at times of peak working efficiency.
  - Periodically keep log of time spent on all activities.
  - Results: Regular writing sessions help maintain momentum & minimize warm-up time; make steady progress, experience less anxiety. Time log helps keep priorities straight.

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\(^c\) The information about quick starters, the first three mistakes to be listed, and the strategies to avoid them are based on material in R. Boice, *Advice for New Faculty Members: Nihil Nimus*, Boston: Allyn & Bacon, 2000.
• **Mistake #2: Overpreparing for classes.**
  – Spend up to 27 preparation hours per week for a 3-credit course; equate good teaching with correct and complete content; try to be ready for any question.
  – **Results:** Rush to cover material, little chance for student questions and activities; little time for anything else (research, personal life).

• **Success Strategy #2. Limit preparation time for class (especially after the first offering).**
  – **Target:** 2 hours preparation per hour of lecture. Keep track of time in time log.
  – **Results:** Less material in lecture notes, more time for questions and activities; less preparation time leaves more time for other professional and personal activities.

• **Mistake #3: Working non-stop and alone**
  – Wait for colleagues to make the first move.
  – **Results:** Few opportunities to learn the culture of the department, college, and university; failure to get support and help when both are available; sense of isolation.

• **Success Strategy #3. Network at least two hours a week**
  – Visit colleagues, go to lunch, have a cup of coffee with colleagues in and out of the department; discuss research, teaching, campus culture. If you’re facing a specific problem (writing a paper for a journal with a high rejection rate, approaching a tight proposal deadline, dealing with an unproductive graduate student or a rebellious undergraduate class,…), find out which colleagues are likely to be helpful and seek them out.
  – **Results:** Quickly get needed help, learn culture, discover campus resources, cultivate allies and advocates.

• **Mistake #4: Working without clear goals and plans**
  – Accepting too many commitments that won’t help achieve long-term goals; failing to take steps that will help.
  – **Results:** Becoming spread too thin; falling behind in tenure quest; uncertainty, anxiety, stress.

• **Success Strategy #4. Develop clear goals and a plan to reach them**
  – Identify long-term objectives & what needs to happen in next three years to achieve them
  – Get feedback on plans from department head, mentor, other colleagues, and make adjustments
  – Periodically review progress (at least annually)
  – **Results:** Make commitments wisely, maximize chance for reaching goals
THINGS I WISH THEY HAD TOLD ME

Richard M. Felder

Most of us on college faculties learn our craft by trial-and-error. We start teaching and doing research, make lots of mistakes, learn from some of them, teach some more and do more research, make more mistakes and learn from them, and gradually more or less figure out what we're doing.

However, while there's something to be said for purely experiential learning, it's not very efficient. Sometimes small changes in the ways we do things can yield large benefits. We may eventually come up with the changes ourselves, but it could help both us and our students immeasurably if someone were to suggest them early in our careers. For whatever they may be worth to you, here are some suggestions I wish someone had given me.

- **Find one or more research mentors and one or more teaching mentors, and work closely with them for at least two years.** Most faculties have professors who excel at research or teaching or both and are willing to share their expertise with junior colleagues, but the prevailing culture does not usually encourage such exchanges. Find out who these individuals are, and take advantage of what they have to offer, if possible through collaborative research and mutual classroom observation or team-teaching.

- **Find research collaborators who are strong in the areas in which you are weakest.** If your strength is theory, undertake some joint research with a good experimentalist, and conversely. If you're a chemical engineer, find compatible colleagues in chemistry or biochemistry or mathematics or statistics or materials science. You'll turn out better research in the short run, and you'll become a better researcher in the long run by seeing how others work and learning some of what they know.

- **Whenever you write a paper or proposal, beg or bribe colleagues to read it and give you the toughest critique they’re willing to give.** Then revise, and if the revisions were major, run the manuscript by them again to make sure you got it right. THEN send it off. Wonderful things may start happening to your acceptance rates.

- **When a paper or proposal of yours is rejected, don't take it as a reflection on your competence or your worth as a human being. Above all, don't give up.** Take a few minutes to sulk or swear at those obtuse idiots who clearly missed the point of what you wrote, then revise the manuscript, doing your best to understand and accommodate their criticisms and suggestions.

  If the rejection left the door open a crack, send the revision back with a cover letter summarizing how you adopted the reviewers’ suggestions and stating, *respectfully*, why you couldn't go along with the ones you didn't adopt. The journal or funding agency will usually send the revision back to the same reviewers, who will often recommend acceptance if they believe you took their comments seriously and if your response doesn't offend them. If the rejection slammed the door, send the revision to another journal (perhaps a less prestigious one) or funding agency.

- **Learn to identify the students in your classes, and greet them by name when you see them in the hall.** Doing just this will cover a multitude of sins you may commit in class. Even if you have a class of over 100 students, you can do it—use seating charts, labeled photographs,
R. M. Felder & R. Brent, *Effective Teaching*

whatever it takes. You'll be well compensated for the time and effort you expend by the respect and effort you'll get back from them.

- *When you're teaching a class, try to give the students something active to do at least every 20 minutes.* For example, have them work in small groups to answer a question or solve a problem or think of their own questions about the material you just covered.* In long class periods (75 minutes and up), let them get up and stretch for a minute.

Even if you're a real spellbinder, after approximately 10 minutes of straight lecturing you begin to lose a fraction of your students—they get drowsy or bored or restless, and start reading or talking or daydreaming. The longer you lecture, the more of them you lose. Forcing them to be active, even if it's only for 30 seconds, breaks the pattern and gets them back with you for another 10-20 minutes.

- *After you finish making up an exam, even if you KNOW it's straightforward and error-free, work it through completely from scratch and note how long it takes you to do it, and get your TA's to do the same if you have TA's.* Then go back and (1) get rid of the inevitable bugs and busywork, (2) make sure most of the test covers basic skills and no more than 10-15% serves to separate the A's from the B's, and (3) cut down the test so that the students have at least three times longer to work it out than it took you to do it.

- *Grade tough on homework, easier on time-bound tests.* Frequently it happens in reverse: almost anything goes on the homework, which causes the students to get sloppy, and then they get clobbered on tests for making the same careless errors they got away with on the homework. This is pedagogically unsound, not to mention unfair.

- *When someone asks you to do something you're not sure you want to do—serve on a committee or chair one, attend a meeting you're not obligated to attend, join an organization, run for an office, organize a conference, etc.—don't respond immediately, but tell the requester that you need time to think about it and you'll get back to him or her. Then, if you decide that you really don't want to do it, consider politely but firmly declining.* You need to take on some of these tasks occasionally—service is part of your professorial obligation—but no law says you have do everything anyone asks you to do.

- *Create some private space for yourself and retreat to it on a regular basis.* Pick a three-hour slot once or twice a week when you don't have class or office hours and go elsewhere—stay home, for example, or take your laptop to the library, or sneak into the empty office of your colleague who's on sabbatical.

It's tough to do serious writing or thinking if you're interrupted every five minutes, which is what happens in your office. Some people with iron wills can put a "Do not disturb!" sign outside their office door, let their secretaries or voice mail take their calls, and Just Do It. If you're not one of them, your only alternative is to get out of the office. Do it regularly and watch your productivity rise.

- *Do your own composing on a word processor instead of relying on a secretary to do all the typing and correcting.* If you're a lousy typist, have the secretary type your first draft but at least do all the revising and correcting yourself.

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* Many other ideas for active learning exercises are given in References 1 and 2.
* However, if your department head or dean is the one doing the asking, it's advisable to have a good reason for saying no.
Getting the secretary to do everything means waiting for your job to reach the top of the pile on his desk, waiting again when your job is put on hold in favor of shorter and more urgent tasks, waiting yet again for the corrections on the last version to be made, and so on as the weeks roll merrily by. If a job is really important to you, do it yourself! It will then get done on your time schedule, not someone else's.

- Get copies of McKeachie [1] and Wankat and Oreovicz.[2] Keep one within easy reach in your office at school and the other in your home office or bathroom. You can open either book to any page and get useful pointers or answers to troubling questions, and you'll also get research backing for the suggestions presented.

- When problems arise that have serious implications—academic misconduct, for example, or a student or colleague with an apparent psychological problem, or anything that could lead to litigation or violence—don't try to solve them on your own. The consequences of making mistakes could be disastrous.

There are professionals at every university—academic advisors, trained counselors, and attorneys—with the knowledge and experience needed to deal with almost every conceivable situation. Find out who they are, and bring them in to either help you deal with the problem or handle it themselves.

References


I write when I'm inspired, and I see to it that I'm inspired at nine o'clock every morning.  
(Peter De Vries)

Here’s the situation. You’re working on a big writing project—a proposal, paper, book, dissertation, whatever—and in the last five weeks all you’ve managed to get done is one measly paragraph. You’re long past the date when the project was supposed to be finished, and you just looked at your to-do list and reminded yourself that this is only one of several writing projects on your plate and you haven’t even started most of the others.

If you’re frequently in that situation (and we’ve never met a faculty member who isn’t) we’ve got a remedy for you. First, though, let’s do some truth in advertising. Lots of books and articles have been written about how to write clear and persuasive papers, proposals, dissertations, lab reports, technical memos, love letters, and practically everything else you might ever need to write. We’re not going to talk about that stuff: you’re on your own when it comes to anything having to do with writing quality. All we’re going to try to do here is help you get a complete draft in a reasonable period of time, because that usually turns out to be the make-or-break step in big writing projects. Unless you’re a pathological perfectionist (which can be a crippling obstacle to ever finishing anything), once you’ve got a draft, there’s an excellent chance that a finished document suitable for public consumption won’t be far behind.

We have two suggestions for getting a major document written in this lifetime: (1) commit to working on it regularly, and (2) keep the creating and editing functions separate.

- Dedicate short and frequent periods of time to your major writing projects

See if this little monologue sounds familiar. "I don’t have time to work on the proposal now—I’ve got to get Wednesday’s lecture ready and there’s a ton of email to answer and I’ve got to pick the kids up after school tomorrow...BUT, as soon as fall break (or Christmas or summer or my sabbatical) comes I’ll get to it."

It’s natural to give top priority to the tasks that can be done quickly or are due soon, whether they’re important (preparing Wednesday’s lecture) or not (answering most emails), and so the longer-range projects keep getting put off as the weeks and months and years go by. If a major project has a firm due date, you panic when it approaches and quickly knock something out well below the best you can do. If it’s a proposal or paper, subsequent rejection should not

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* Chemical Engineering Education, 42(3), 139-140 (2008).

** We didn’t invent either technique—you can find variations of both in many references on writing. A particularly good one is Robert Boice, Professors as Writers, Stillwater, OK: New Forums Press, 1990.
come as a surprise. If there is no firm due date, the project simply never gets done: the book you’ve been working on for the last ten years never gets into print, or your graduate students leave school with their research completed but without their Ph.D.s because they never finished their dissertations.

The strategy of waiting for large blocks of time to work on major writing projects has two significant flaws. When you finally get to a block, it’s been so long since the last one that it can take hours or days to build momentum again and you’re likely to run out of time before much gets written. Also, as soon as the block arrives other things rush in to fill it, such as your family, whom you’ve been neglecting for months and who now legitimately think it’s their turn.

A much more effective strategy is to make a commitment to regularly devote short periods of time to major writing projects. Thirty minutes a day is plenty, or maybe an hour three times a week. One approach is to designate a fixed time period on specified days, preferably at a time of day when you’re at your peak, during which you close your door, ignore your phone, and do nothing but work on the project. Alternatively, you might take a few 10–15 minute breaks during the day—times when you would ordinarily check your email or surf the Web or play Sudoku—and use them to work on the project instead. Either way, when you start to write you’ll quickly remember where you left off last time and jump in with little wasted motion. When you’ve put in your budgeted time for the day, you can (and generally should) stop and go back to the rest of your life.

These short writing interludes won’t make much difference in how many fires you put out each day, but you’ll be astounded when you look back after a week or two and see how much you’ve gotten done on the project—and when a larger block of time opens up, you’ll be able to use it effectively with very little warm-up. You can then be confident of finishing the project in a reasonable time...provided that you also take our next suggestion.

Do your creating and editing sequentially, not simultaneously

Here’s another common scenario that might ring a bell. You sit down to write something and come up with the first sentence. You look at it, change some words, add a phrase, rewrite it three or four times, put in a comma here, take one out there...and beat on the sentence for five minutes and finally get it where you want it. Then you draft the second sentence, and the first one is instantly obsolete and you have to rewrite it again...and you work on those two sentences until you’re satisfied with them and go on to Sentence 3 and repeat the process...and an hour or two later you may have a paragraph to show for your efforts.

If that sounds like your process, it’s little wonder that you can’t seem to get those large writing projects finished. When you spend hours on every paragraph, the 25-page proposal or 350-page dissertation can take forever, and you’re likely to become frustrated and quit before you’re even close to a first draft.

At this point you’re ready for our second tip, which is to keep the creating and editing processes separate. The routine we just described does the opposite: even before you complete a sentence you start criticizing and trying to fix it. Instead of doing that, write whatever comes into your head, without looking back. If you have trouble getting a session started, write anything—random words, if necessary—and after a minute or two things will start flowing. If you like
working from outlines, start with an outline; if the project is not huge like a book or dissertation and you don’t like outlines, just plunge in. If you’re not sure how to begin a project, start with a middle section you can write easily and go back and fill in the introduction later.

Throughout this process, you will of course hear the usual voice in your head telling you that what you’re writing is pure garbage—sloppy, confusing, trivial, etc. Ignore it! Write the first paragraph, then the next, and keep going until you get as much written as your budgeted time allows. Then, when you come back to the project the next day (remember, you committed to it), you can either continue writing or go back and edit what you’ve already got—and then (and only then) is the time to worry about grammar and syntax and style and all that.

Here’s what will almost certainly happen if you follow that procedure. The first few sentences you write in a session may indeed be garbage, but the rest will invariably be much better than you thought while you were writing it. You’ll crank out a lot of material in a short time, and you’ll find that it’s much easier and faster to edit it all at once rather than in tiny increments. The bottom line is that you’ll find yourself with a completed manuscript in a small fraction of the time it would take with one-sentence-at-a-time editing.

We’re not suggesting that working a little on big projects every day is easy. It isn’t for most people, and days will inevitably come when the pressure to work only on urgent tasks is overwhelming. When it happens, just do what you have to do without beating yourself up about it and resume your commitment the next day. It may be tough but it’s doable, and it works.
Faculty Guide to Time Management

or

How to simultaneously write proposals, do research, write papers, teach classes, advise students, grade papers, serve on committees, eat, sleep, and occasionally visit your family.\(^{18}\)

Richard M. Felder and Rebecca Brent
North Carolina State University

- Set 2–3 year goals along with reasonable steps necessary to reach them. For example
  
  1. Stay in good health
     - Exercise 3 times a week
     - Get sufficient sleep
     - ...
  2. Get promoted to associate professor
     - Write __ papers in refereed journals
     - Write __ proposals.
     - ...
  3. Learn to wind-surf
  4. Remain married

- Prioritize goals. Find an order that satisfies you now—you can always change it. *Suggestion*: Make staying in good health top priority—it will make the others possible.

- Develop a Gantt chart to track your progress in meeting your professional productivity goals.

- Create and frequently update a to-do list. Use a 4-quadrant system\(^{19}\):
  
  I. Urgent and important. (Deadline-driven activities that further your goals.)
  
  II. Important but not urgent. (Long-term professional, family, and personal activities that further your goals.)
  
  III. Urgent but not important. (Much e-mail, many phone calls and memos, things that are important to someone else but don’t further your goals.)
  
  IV. Neither urgent nor important. (TV, computer games, junk mail.)

Commit to several hours a week on Quadrant II items, and cut down on time spent in Quadrants III and IV.

- Work on Quadrant I and II items when you’re at peak efficiency.

- If you’re trying to write a book, put it on the Quadrant II list, otherwise it will never get written.

- Keep a log for time spent writing (30-45 minutes daily or longer blocks 2-3 times a week) and preparing for lectures (2 hours or less for each lecture hour) until the work pattern becomes a habit.\(^ {20}\)

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Office Hours and Mail

- Set office hours and let students know you will be faithful in keeping them. When students come to see you outside of office hours and you’re busy, ask them if they can come back during office hours or make an appointment.

- Be mindful of time spent reading and responding to email. Limit response to email to one or two time periods each day. If you encourage email from students, have a special address set up for each class. Read and respond to student email no more than once or twice a day and let students know when you are likely to respond.

- Learn how to get people out of your office when you don’t have the time to spend. (“Good talking to you, but I’ve got something I need to attend to now.”)

- Meet in the other person’s office, not yours. (Easier to get away.)

- Handle each mail item once, if possible. Open, respond, file, or discard.

Working smarter

- Schedule blocks of uninterrupted time to complete larger tasks. If necessary, work at home, in the library, or at an out-of-the-way desk in the department.

- Learn to type if you don’t know how already and do your own manuscript composing on a word processor.

- Avoid perfectionism—don’t keep revising until the deadline, and don’t revise unimportant letters and memos at all. Be aware of the point of diminishing returns.

- Be careful of computer graphics—they’re a time sink.

- Piggyback work—use the same notes or manuscripts for multiple applications.

- Keep research projects in the pipeline. Well before a project ends, start writing the next proposal.

- Reward yourself—take breaks.

Learn how and when to say no!

- Always give yourself a chance to think about a commitment overnight before agreeing to it. The time will give you a chance to see if it fits in with your goals and priorities.

- Keep an updated list of all your service responsibilities. Refer to it when the next request comes in.

- Check out service requests with your mentor or department head. Consider showing the latter your list if he or she is the one making the request.

- Practice declining requests:

  1. “That sounds interesting, but can I call you back tomorrow? I need a little time to think about it before I can decide.”

  2. “I’m sorry, but I’ve just got too many other commitments right now.”

  3. “I’d love to help, but I really don’t have time for a formal commitment. Maybe we could just talk once or twice.”

  4. “I’m afraid I’m not the best person to help you with this. Have you thought about asking _____?”

(Penny Gold)
Additional Resources

Useful reading for administrators and senior faculty serving as mentors to new faculty:

  This book is a summary of Boice’s extensive research on new faculty across all disciplines. Sections deal with obstacles facing new faculty, ways to help them overcome the obstacles and building an institutional support system.

  Sections cover the recruitment and selection of new faculty and developing new faculty in the first year and beyond. It is full of practical suggestions and checklists.

  This working paper publication has an excellent section called “Principles of Good Practice: Supporting Early Career Faculty.” Copies of the publication and the principles can be ordered from Stylus Publishing at their Web site <http://styluspub.com>.

  Zachary takes an in-depth look at mentoring suitable for people in and out of academia. She includes exercises for reflection and mentor training.

Reading for new faculty on starting a career in academia:

  Boice has written a practical book for new faculty members based on his research reported in The New Faculty Member (1992) and experience with hundreds of new faculty. Sections deal with teaching, research, and fitting into the university.

  Sections on teaching and research give lots of suggestions for faculty in engineering and the sciences.

  Menges takes an in-depth look at the problems facing new faculty and offers practical suggestions for dealing with them. Special suggestions aimed at women and faculty of color are also included.
E. Epilogue
WHAT TO DO AFTER THE WORKSHOP

Richard M. Felder
Rebecca Brent

We have given many teaching workshops and find a consistent pattern of post-workshop participant responses. Most participants leave with the intention of trying some of the recommended teaching techniques and many do so, writing learning objectives for their courses, trying group exercises in class or homework, incorporating more real-world examples in courses that tend to be relatively theoretical, making tests clearer and less time-intensive, and so on. Others are perplexed by the profusion of ideas presented in the workshop and either try to do everything at once and fail or throw their hands up and don’t do anything. Neither of the latter two approaches is productive.

The goal of this postscript to the workshop is to suggest ways to make effective use of the workshop materials. We offer three sets of recommendations. The first set—intended primarily for new instructors and instructors who have always taught conventionally—contains ideas that can be adopted with relatively little expenditure of time and effort. The second set is aimed at instructors who are already comfortable with some nontraditional instructional methods but who are heavily engaged in disciplinary research or for other reasons do not wish to devote a major portion of their professional lives to teaching. The third set is for professors who plan to focus on education (teaching, classroom research, development of instructional materials, and faculty development) in the next phase of their careers.

Level I — New or traditional instructor.

The steps suggested below are intended to help instructors motivate learning of new material, make more effective use of class time by actively involving students, improve test construction, and begin to structure courses to upgrade the quality of learning. Relevant page numbers in the workshop notebook are given following each step.

- Provide motivation and context for each major topic in a course. Introduce each topic by outlining its connections to things the students already know about from their prior experience or course work. Try to come up with graphic organizers (like the one following the title page of the workshop notebook), visual examples, and physical demonstrations to illustrate the topic. Outline realistic examples of phenomena and problems the students will be able to deal with once the topic has been covered.

- Put some long derivations and prose passages from your course notes in handouts, leaving gaps and inserting questions or exercises. Don’t cover the handouts in detail in class—focus on the gaps and the most important or conceptually difficult material. Just doing this can save dozens of hours of class time that would normally be wasted on board stenography. [Notebook: p. B4.]

- In the time you save by not having to write everything out on the board, give small–group exercises in class. Take five minutes before each lecture to think of at least two questions or problems to be posed to groups or assigned as think-pair-share exercises. You will always be able to think of questions during this five-minute planning period, but you may not think of
them spontaneously during class. Use different types of questions in these exercises, so the students will never know what to expect in any given class. [Notebook: pp. B10–B21.]

- **Periodically do a “minute paper” in class.** Following a lecture, ask the students (sometimes individually, sometimes in pairs) to write the main point and the muddiest point in the lecture. Collect the responses and use them to plan the beginning of the next lecture. [Notebook: p. B11.]

- **Write detailed learning objectives (including some at higher Bloom levels) and give them to the students in the form of study guides for tests.** Provide practice in the required skills in class activities and homework assignments. (You may not want to write objectives for the whole course the first time you try this.) [Notebook: pp. A2–A7.]

- **Get feedback from the students on your teaching methods—especially the new ones—and watch for changes in class performance relative to previous classes.** Give an open-ended mid-term survey. (“List three features of this course and its instructor that helped you learn.” “List three features that hindered your learning.” “Did [new method] help or hinder your learning? Explain.”) Make notes on any differences you see between the current class and classes you taught without the new methods (e.g., differences in test scores, performance on difficult problems, class attendance, final grade distributions, and results of course-end evaluations.) Decide which new methods you want to try again and what you’ll do differently in your next course.

**Level II — Instructor accustomed to nontraditional methods but with significant research and/or administrative obligations**

The next steps extend the use of learning objectives, introduce exercises that help students develop critical and creative thinking skills, and initiate systematic classroom assessment and networking with colleagues with similar interests in teaching.

- **Do any or all of the things in the Level I category that you’re not already doing.**

- **Write detailed instructional objectives (including some at higher Bloom levels) for an entire course and give them to the students in the form of study guides for exams.** Adjust your syllabus and learning objectives to provide a reasonable balance between concrete material (facts, experimental data, physical phenomena) and abstract material (theories, mathematical models). Try to achieve a largely inductive presentation of course material that moves from the concrete to the abstract. [Notebook: pp. A2–A5, A13–A15.]

- **If the course notes are reasonably well worked out, consider adding learning objectives for each major section, gaps to be filled in by students, and self-tests, and giving or selling the complete package to the students at the beginning of the course.** Once you have done so, you can include as many active learning experiences in class as you want to and still cover more material than you ever did when you wrote everything on the board or on transparencies.

- **Write homework assignments to match your objectives, especially the objectives that involve higher-order thinking skills.** Routinely include questions that call for written explanations of observable—and preferably familiar—phenomena in terms of course concepts. Occasionally, assign students to make up and solve straightforward problems or problems that call for higher-level thinking skills.
• Pick a particularly important example or derivation and devote a complete class period to a TAPPS exercise on it. [Notebook: p. B13.]

• Carry out a midterm evaluation, asking specifically for student responses to nontraditional methods you might be using. Keep doing the things that are working well and think about modifying troublesome methods. [Notebook: p. B6]

• Find one or more colleagues (e.g., workshop alumni) interested in exploring teaching methodologies and arrange to compare notes with them periodically (for example, at a monthly lunch meeting).

• Once or twice each semester, look back at the workshop notebook and find a new idea to try.

**Level III — Instructor able to devote significant time to education**

The final steps involve undertaking full-scale cooperative learning and systematic involvement in education as a major career focus.

• Do any or all of the things in the Level II category that you’re not already doing.

• Undertake full-scale cooperative learning in a class, assigning projects and problem sets to be done by teams. Follow guidelines given in the literature for forming teams, promoting positive interdependence and individual accountability, and dealing with student resistance [Notebook: pp. B31–B34]

• Undertake problem-based learning, using complex, real-world, open-ended problems to provide context for the knowledge and skills to be learned in the course. [Notebook: pp. A13–A15]

• Undertake education-related professional activities. Subscribe to an education journal in your field. Get and read some books on teaching, such as those listed on p. vii of the workshop notebook. Attend education conferences and present papers about your instructional methods and materials. Submit papers to education journals. Seek funding for development of new instructional methods and materials.

• Develop and present teaching effectiveness workshops for colleagues in your field. Earn lucrative fees, travel to interesting places, meet nice people.