Effective Teaching: A Workshop

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THE TEN WORST TEACHING MISTAKES. I. MISTAKES 5–10[*]

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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.*[1] 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.[2]

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.[3] 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,[2] 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

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[*] *Chemical Engineering Education, 42*(4), 201–202 (2008).

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 resistance[7] 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!

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3. R.M. Felder and R. Brent, "Death by PowerPoint," *Chem. Engr. Education, 39*(1), 28-29 (2005), <*www.ncsu.edu/felder-public/Columns/PowerPoint.pdf*>.
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THE TEN WORST TEACHING MISTAKES. II. MISTAKES 1–4*

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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 negligible[2]; students who drop out of engineering have the same academic profile as those who stay[3]; 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 (*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

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**Chemical Engineering Education, 43*(1), 15–16 (2009).

two changes in the course whenever you teach it. If you do that, the course won't get stale, and neither will you.

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.[5] 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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Prologue

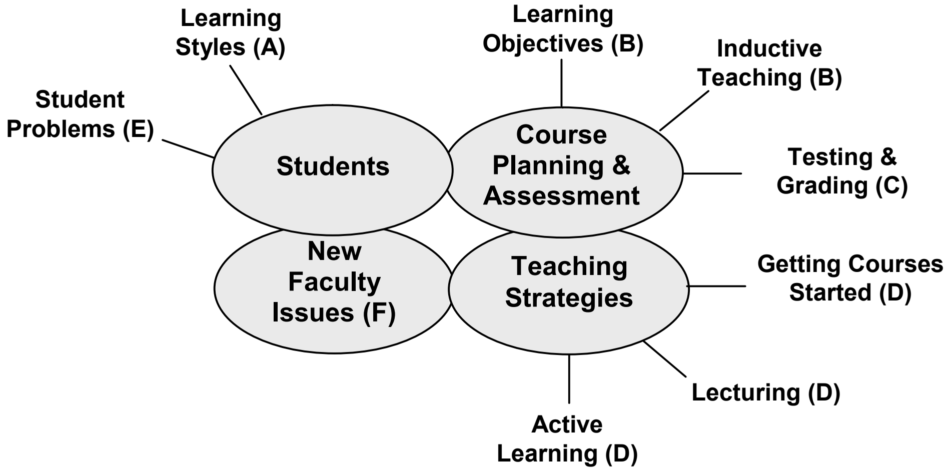
A. How do students learn? How do I learn? What do I do to reach students whose learning styles are different from mine?

B. How do I plan a course?

C. How can I assess learning reliably and fairly? How can I be both rigorous and fair in grading?

D. How can I be an effective lecturer and get students actively involved in class?

*Effective Teaching Workshop**



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*Letters in parentheses refer to sections in notebook.

Workshop Goals

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

- use a wide variety of effective teaching strategies
- find resources for continuing to improve their teaching

Workshop Learning Objectives

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

- identify critical characteristics of different student learning styles and specify instructional methods that address the needs of students with different styles.
- 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.
- design tests and other assessments that are both challenging and fair and a grading system that provides positive motivation for learning without lowering standards.
- 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

- **Felder, R.M., & Brent, R. (2016). *Teaching and learning STEM: A practical guide.* San Francisco: Jossey-Bass.** Primary reference for workshop. <*www.ncsu.edu/felder-public/TeachSTEM/TeachSTEM.html*>.

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Digital Resources on Learning and Teaching

- **Resources in Science and Engineering Education (*www.ncsu.edu/effective_teaching*)**

  Richard Felder's website. From the home 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
  - The *Index of Learning Styles*, a questionnaire students can take and self-score to give them information about their preferences on the Felder-Silverman learning styles model
  - Reprints of all of the *Random Thoughts* columns from *Chemical Engineering Education* on specific topics relating to education and some additional articles
  - A website for the introductory chemical engineering course (material and energy balances) with handouts for lectures and related resources
  - Handouts for students on a variety of topics

- **Education Designs, Inc. (*http://educationdesignsinc.com*)**

  Rebecca Brent's and Richard Felder's consulting website. From the home page, you can access:

  - Their blog with entries on education-related topics
  - Links to their publications
  - Information about Rebecca's program evaluation services
  - Information about their workshops

- **How Stuff Works (*www.howstuffworks.com/*)**
  How Everything Works (*www.howeverythingworks.org/home.html*)
  Sites with several thousand answers to questions of the type "How does ___ work?" Sections on familiar devices and phenomena, computers and the Internet, and many other topics. The "How Everything Works" website contains a link to a free MOOC (massive open online course) with the same name given by Lou Bloomfield, who maintains the site.

- **Everyday Engineering Examples (*realizeengineering.wordpress.com/everyday-engineering-examples/*).** Familiar examples with which to introduce topics in basic engineering courses.

- **IDEA Center (*ideaedu.org/research-and-papers/idea-papers*)**.
  A series of short well written papers covering many aspects of instruction and assessment of teaching and learning.

- **Tomorrow's Professor Listserv (*www.stanford.edu/dept/CTL/Tomprof/index.shtml*)**.
  Synopses of articles and books about higher education sent to subscribers' by email twice a week. Subscription is free.

Digital Resource Libraries

- **AAHLE Sample Rubrics (*course1.winona.edu/shatfield/air/rubrics.htm*).** Rubrics (grading forms) for almost everything you might ever want to grade, including written and oral reports, lab reports, critical and creative thinking, teamwork, etc.
- **Image Libraries.** Google Images (*google.com/images*), Bing Images (*bing.com/images*), Flickr Photos (*www.flickr.com*), Pixabay Photos (*pixabay.com*), Wikimedia Commons Images and Videos (*commons.wikimedia.org*), YouTube (*youtube.com*)
- **Khan Academy (*khanacademy.org*).** An incredible library of thousands of generally well-constructed mini-lectures on many topics at all levels in math, science, and other subjects. Professors are using the videos for students having trouble with prerequisite skills, for "flipping" the classroom, and to incorporate into online and hybrid courses.
- **MERLOT (*www.merlot.org/merlot/index.htm*)**, Multimedia Educational Resource for Learning and Online Teaching. 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.
- **MIT OpenCourseWare (*ocw.mit.edu*).** An educational resource containing MIT course materials. There is no registration requirement or fee for use. Courses from almost every discipline are included. You can access lecture notes and in some cases tests, online textbooks, visuals and simulations.
- **National Center for Case Study Teaching in Science (*sciencecases.lib.buffalo.edu*).** Over 500 case studies in different sciences (with a heavy concentration in the life sciences) and engineering, with guidance on using them for instruction.
- **National Science Digital Library (*nsdl.org*).** A repository of resources and tools that support innovations in teaching and learning of science, technology, engineering, and mathematics education.
- **Science Education Resource Center (*serc.carleton.edu*).** The SERC "Higher Ed" repository has resources for enhancing students' active engagement and helping them develop higher-order thinking, quantitative reasoning, and problem-solving skills in most STEM disciplines, including geosciences and geotechnical engineering.

Digital resource libraries also exist for specific fields and specific subjects, such as LearnChemE for chemical engineering (screencasts and simulations: *www.learncheme.com*), the Concept Warehouse for chemical and mechanical engineering (ConcepTests and concept inventories, *jimi.cbee.oregonstate.edu/concept_warehouse*), and efluids for fluid mechanics (tutorials, videos, images, and other resources, *efluids.com*). You can find others by entering "____ screencast," "____ tutorial," "_____ simulation," "____ images," "____ ConcepTest," or "____ concept inventory" into a search engine, where ____ denotes whatever topic you plan to teach or phenomenon you wish to illustrate.

Workshop Facilitator Biographies

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Dr. Brent is President of Education Designs, Inc., a consulting firm in Cary, North Carolina. She has more than 35 years of experience in education and specializes in staff development in engineering and the sciences, teacher preparation, and evaluation of educational programs at both precollege and college levels, and has authored or coauthored roughly 120 papers on those topics. She holds a Certificate in Evaluation Practice from the Evaluators' Institute at George Washington University. Prior to entering private consulting, she was an Associate Professor of Education at East Carolina University where she won an outstanding teacher award. In 2014, Dr. Brent was named a Fellow of the American Society for Engineering Education.

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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 roughly 90% of all chemical engineering departments in the United States and many abroad, and he has authored or co-authored over 300 papers on chemical process engineering and engineering education. He has won numerous awards for his teaching, research, and publications, including the American Institute of Chemical Engineers Warren K. Lewis Award for Contributions to Chemical Engineering Education, the American Society for Engineering Education Lifetime Achievement Award in Engineering Education (first recipient), and the International Federation of Engineering Education Societies Global Award for Excellence in Engineering Education (first recipient).

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Drs. Brent and Felder are coauthors of *Teaching and Learning STEM: A Practical Guide* (Jossey-Bass, 2016), <*www.ncsu.edu/felder-public/TeachSTEM/TeachSTEM.html*>. Separately and together, they have presented over 450 workshops on effective teaching, course design, mentoring and supporting new faculty members, and faculty development, on campuses around the world. They co-directed the American Society for Engineering Education National Effective Teaching Institute from 1991 to 2015. Visit their website, <*educationdesignsinc.com*>, and their Facebook page, <*www.facebook.com/felderandbrent*>.

A. How do students learn? How do I learn? What do I do to reach students whose learning styles are different from mine?

Instruction begins when you, the teacher, learn from the learner. Put yourself in his place so that you may understand what he learns and the way he understands it.

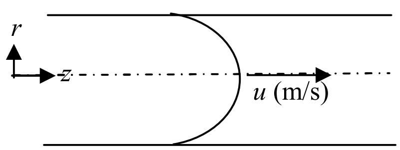
Kierkegaard

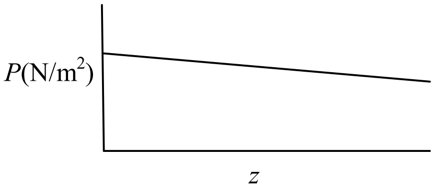
Course Example (Fluid Dynamics)

Derive the velocity profile and pressure drop of a Newtonian fluid in a circular pipe. (Takes about 1-2 weeks at the beginning of the course.)

Plan A (All steps completed in lectures except for the homework.)

- Derive the differential mass and momentum balance equations for a fluid flowing in a pipe—coupled partial differential equations in cylindrical coordinates.
- Make simplifying assumptions & solve the simplified equations for velocity [$u(r)$] and pressure [$P(z)$] in the pipe.
- Show plots of the solutions.

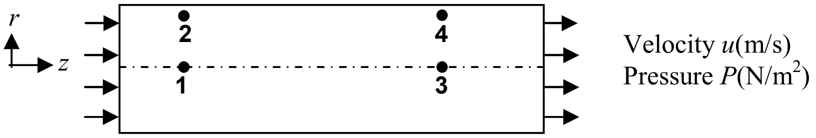




- Homework: Have students calculate velocities & pressure drops, and derive expressions for u and P in a rectangular flow channel.

Plan B

- Divide the class into groups of two and three at their seats. Ask groups for everyday situations that involve fluid flow in channels. Allow a couple of minutes and then collect answers. Groups will think of things like fluid flowing from the water heater to the sink tap, blood flowing in the body, oil circulating in the engine block, etc. This sets the stage for why they are learning about fluid flow.
- Sketch a horizontal pipe with a liquid flowing in it, and label four points—two on the axis, and two near the wall.



  Ask groups to speculate on differences between u and P at the four points. Allow about a minute, collect responses. Collectively infer that u should vary with r and P should vary with z.
- If possible, show a video, animation, or photo illustrating the phenomenon to be studied (laminar flow of a Newtonian fluid in a circular pipe).
- Sketch and describe pitot tubes to measure $u(r)$ and bourdon gauges to measure $P(z)$. Describe measurements taken from each device and sketch plots of u vs. r and P vs. z. The parabolic profile and pressure drop make their appearances as the result of measurements.
- Homework: Give students data for $u(r)$ and $P(z)$ in the context of real-world applications. Have them derive the corresponding formulas, and then use them to solve problems.
- In a combination of lectures and active exercises, write a force balance on a cylindrical fluid element in the pipe, derive formulas for $u(r)$ and $P(z)$. Compare with the experimental results.
- Exercise: Suppose $u(r)$ and $P(z)$ are measured & the results don't agree with the derived formulas. Ask groups to brainstorm possible explanations. (Mistakes in measurements, instrument error, mistakes in calculations, fluid not Newtonian, pipe not circular,…)
- Homework: Have students derive expressions for u and P in an annular flow channel.

Learning Styles

Fact of Life 1: What students learn is always less than what we teach.

Fact of Life 2: How much they learn is determined by their

1. Native ability
2. Background in the course topic
3. Motivation for taking the course
4. Match between their learning style and our teaching style.

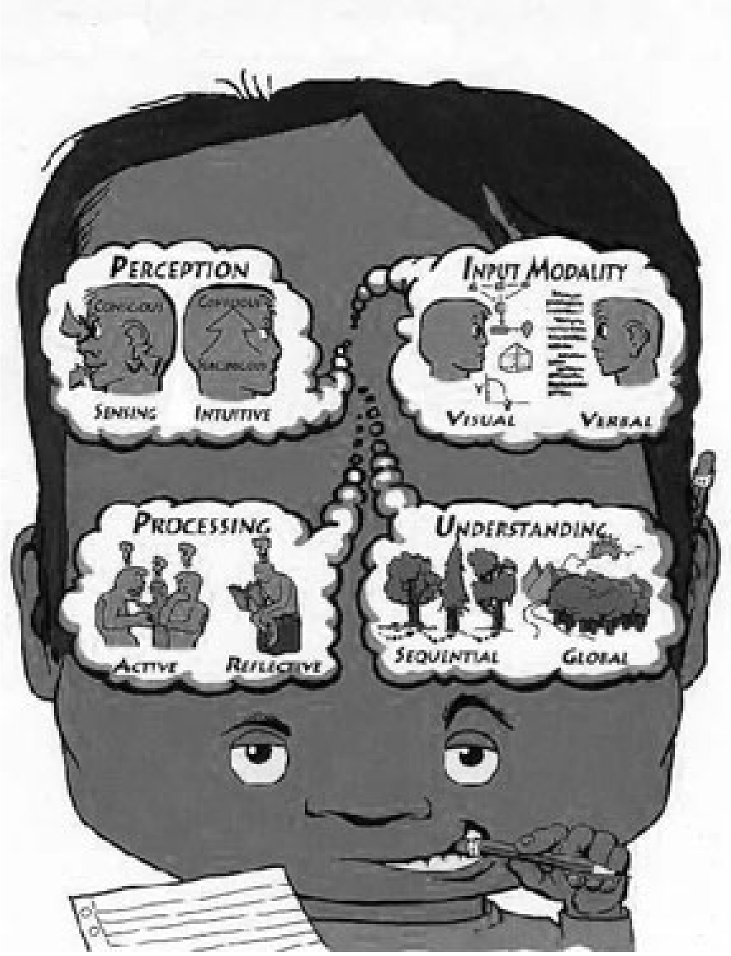
Fact of Life 3: We can't do much about their ability, background, motivation, or learning style.

Conclusion: *To maximize student learning, all we have to work with is our teaching style.*

Questions to be explored:

1. What are the different ways students take in information and process it? (*Learning styles*)
2. Which learning styles are favored by (i) most students, (ii) the teaching styles of most professors?
3. What are the consequences of mismatches between teaching and learning styles?
4. What can we do to reach students with the full spectrum of learning styles?

A Model of Learning Styles*



Sensing (S) Learners	**Intuitive (N) Learners**
• Focus on external input (see, hear, taste, touch, smell) • Practical • Observant (notice details of environment) • Concrete thinking (facts, data, hands-on work) • Learn through repetition (drills, numerous examples, replication of experiments) • Methodical • Like working with details • Complaint about courses: No apparent connection to real world • Problem with exams: Run out of time	• Focus on internal input (thoughts, memories, images) • Imaginative • Look for meanings (miss details) • Abstract thinking (theories, math models) • Like variety in learning experiences (bored with repetition) • Quick • Like working with concepts • Complaint about courses: “Plug & Chug” (Lots of memorization, repetitive formula substitution) • Problem with exams: Careless mistakes

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* See papers at R.M. Felder, “Learning Styles,” <*www.ncsu.edu/felder-public/Learning_Styles.html*>.

- Everybody is both sensor and intuitor, but everyone has a preference that may be mild (close to balanced), moderate, or strong.
- Most undergraduates are sensors. Most professors are intuitors, and many professors who are sensing learners teach intuitively (emphasizing "fundamentals," theories, mathematical models). The result is a mismatch between the teaching style and the learning style of most students.
- The balance between S and N varies from one field to another, and an individual's preference in a situation varies from one situation to another. However,
- Both may make excellent professionals, in all professions.

Tip: Integrate lectures and labs

Lectures (theory, mathematical analysis) favor intuitors. Labs (practical, hands-on) favor sensors. Each approach informs and clarifies the other one. When possible, integrate them in the same course & connect them closely. If that's not possible:

- Bring real experiments, simulated experiments, or experimental data into the lecture. Have students analyze & interpret data individually or in small groups.
- Give mini-lectures in the lab. Have student teams (a) discuss experimental design, equipment calibration and operation, underlying principles, expected results, data precision and possible sources of error; and/or (b) troubleshoot problems, interpret unexpected results. Collect responses, give feedback.

Visual (Vs) Learners	**Verbal (Vb) Learners**
• "Show me." – pictures – diagrams – sketches – schematics – flow charts – plots	• "Explain it to me." – spoken words – written words, symbols (seen, but translated by brain into their oral equivalents)

- *Bias dominance.* Visual and verbal information are processed differently by the brain in different locations. You learn more when information is presented in your preferred modality (visual or verbal), even more if you get it in both channels.
- Most people are visual learners, while 90–95% of most course content is verbal (lectures, readings) except in art and architecture. Mismatch!

Tip: Add visual content to lectures and presentations

- Find visual images online to illustrate almost any topic. Google Images, Google Videos, YouTube, Wikimedia Commons, and Flickr Commons are excellent sources, as are the digital libraries listed on p. *xi* of this notebook.
- Use graphic organizers or concept maps to provide a visual representation of verbal content.

Active (A) Learners	**Reflective (R) Learners**
• Tend to process actively (doing something physical with presented material, then reflecting on it) • Think out loud • "Let's try it out and see how it goes." • Tend to jump in prematurely • Like group work	• Tend to process reflectively (thinking about presented material, then doing something with it) • Work introspectively • "Let's think it through and then try it." • Tend to delay starting • Like solo or pair work

- All classes have both active and reflective learners. Most classes (except for labs) are passive—the active learners don't get to act on the material presented and the reflective learners don't do much reflecting during the lectures. Mismatch!

Tip: Use *active learning*

- Intersperse short ($\leq$ 3 min) course-related individual and small-group activities in lecture classes that provide practice and feedback in difficult concepts and methods. An activity may involve answering a question, brainstorming a list, starting a problem solution, completing the next step of a derivation or problem solution, predicting the outcome of an experiment, interpreting an observation, or anything else the students might be asked to do in an assignment or exam.
- After the allotted time has elapsed, call on one or more students to state what they came up with and see if anyone has additional ideas. When the correct response is forthcoming (or sufficient responses have been received), move on with the class. (Provides opportunities for both action and reflection.)
- See Section D of this notebook for details.

Sequential (Sq) Learners	**Global (G) Learners**
• Build understanding in logical sequential steps	• Absorb information randomly, then synthesize the big picture
• Function with partial understanding of information	• Need the big picture (connections to other subjects and personal experience) in order to function with information
• Make steady progress	• Large leaps in understanding with little progress between them
• Explain easily	• Can't explain easily
• Good at analytical thinking (the trees)	• Synthesis, holistic thinking (the forest)

- Most students, instructors, courses, curricula, and textbooks are sequential. Not strictly a mismatch. BUT
- The global minority is
  - extremely important (multidisciplinary thinkers, systems thinkers, top administrators)
  - at risk in school if their learning needs (help in seeing the big picture & the lateral connections to other subjects) are not met

Tip: Give the big picture up front

- Preview course and each topic (graphic organizer, concept map) before going into the details.
- Use an inductive approach (inquiry, problem- or project-based learning) and teach new material in the context of addressing a challenge.

<u>Test Yourself</u>: Who's Talking? (Answers on A-16)

Identify the learning style dimension indicated by each student comment. Dimensions may be used more than once. Some statements may have more than one possible answer.

____________________ 1. I don't see what this math garbage has to do with the real world.

____________________ 2. I can't do the homework unless I see how it all fits together.

____________________ 3. I hate all these repetitive calculations—they're boring!

____________________ 4. Even when I know how to do the problems, I always run out of time on tests.

____________________ 5. Everyone around me can do the problems and I can't and I fail. Then I get it, but by then the teacher is on to something else. I can never win.

____________________ 6. Don't just tell me stuff—tell me why I should care about it.

Consequences of Learning and Teaching Style Mismatches

- Many students can't get what's being taught. They may then
  - — become bored, inattentive, or disruptive in class
  - — do poorly on tests
  - — get discouraged about the course, the curriculum, and/or themselves
  - — change to another curriculum or drop out of school

- Professors observe low test scores, unresponsive or hostile classes, poor attendance, poor evaluations, dropouts—and know something's wrong. They may
  - — get defensive or hostile (making things even worse)
  - — question whether they're in the right profession

- Society loses potentially excellent professionals.
  - — visual, active learners (most students)
  - — sensing learners
  - — global learners

Course Example (Fluid Dynamics)

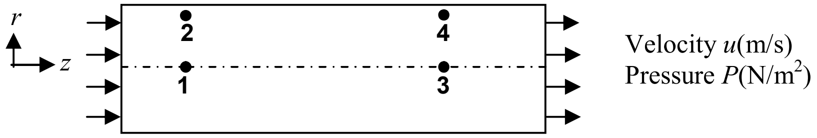
Plan A (Conventional approach)

> *Derive the differential mass and momentum balance equations for a fluid flowing in a pipe—coupled partial differential equations in cylindrical coordinates. Make simplifying assumptions & solve the simplified equations for velocity [$u(r)$] and pressure [$P(z)$] in the pipe. Show plots of the solutions. Homework: Have students calculate velocities & pressure drops, and derive expressions for u and P in an annular flow channel.*

Addresses intuitive, verbal, reflective (sort of), and sequential learners. The sensing, visual, active, & global learners might as well stay home and copy someone else's lecture notes.

Plan B (Addresses all learning style preferences)

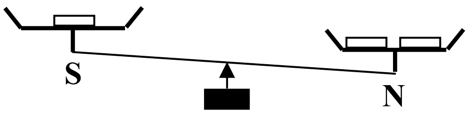
- Divide the class into groups of two and three at their seats. Ask groups for everyday situations that involve fluid flow in channels. Allow a couple of minutes and then collect answers. Groups will think of things like fluid flowing from the water heater to the sink tap, blood flowing in the body, oil circulating in the engine block, etc. This sets the stage for why they are learning about fluid flow. [**Sensing**, *intuitive, verbal,* **active**, **global**]
- Sketch a horizontal pipe with a liquid flowing in it, and label four points—two on the axis, and two near the wall.

  Ask groups to speculate on differences between u and P at the four points. Allow about a minute, collect responses. Collectively infer that u should vary with r and P should vary with z. [***Sensing, Visual,*** *Verbal,* ***Active***, *Reflective*]
- If possible, show a video, animation, or photo illustrating the phenomenon to be studied (laminar flow of a Newtonian fluid in a circular pipe). [*Sensing,* ***visual***]
- Sketch and describe pitot tubes to measure $u(r)$ and bourdon gauges to measure $P(z)$. Describe measurements taken from each device and sketch plots of u vs. r and P vs. z. The parabolic profile and pressure drop make their appearances as the result of measurements. *Sensing,* ***visual***]
- Homework: Give students data for $u(r)$ and $P(z)$ in the context of real-world applications. Have them derive the corresponding formulas, and then use them to solve problems. [*Sensing,* ***intuitive, active, reflective,*** *sequential, global*]
- In a combination of lectures and active exercises, write a force balance on a cylindrical fluid element in the pipe, derive formulas for $u(r)$ and $P(z)$. Compare with the experimental results. [***Intuitive, active, reflective,*** *verbal, sequential*].
- Homework: Have students calculate velocities and pressures for specific cases. Have them work through partially complete derivations of the formulas from laws of conservation of mass and momentum, explaining worked-out parts and filling in missing parts. [***Intuitive, active, reflective,*** *verbal, sequential*].
- Exercise: Suppose $u(r)$ and $P(z)$ are measured & the results don't agree with the derived formulas. Ask groups to brainstorm possible explanations. (Mistakes in measurements, instrument error, mistakes in calculations, fluid not Newtonian, pipe not circular,…) [***Sensing,*** *intuitive, verbal,* ***active, global*****]**
- Homework: Have students derive expressions for u and P in an annular flow channel. [***Intuitive,*** *global*]

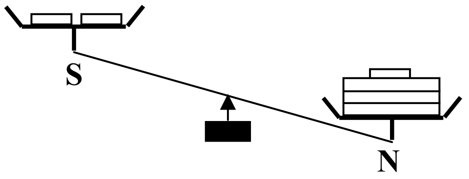
Summary

- Students may be sensors or intuitors, visual or verbal, active or reflective, sequential or global. *All types are needed in every profession.*
- Most teaching is abstract (intuitive), verbal, and sequential, and most classrooms are passive. *We need to address all 16* (2^4) *styles, not just one.* The key to doing that is *balance.*
- Professionals need to function sometimes as sensors (careful, methodical, practical, observant,…) and sometimes as intuitors (analytical, critical, creative); they need to receive and understand verbal information and visual information, etc.
- If students are taught only in their less preferred modes, they will be too uncomfortable to learn effectively and will not gain skills in either mode.



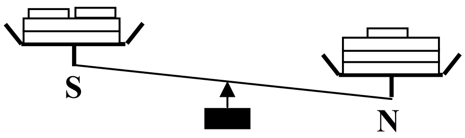
⇨ Weak in both categories

- If they are taught only in their preferred modes, they will gain skills in those modes but will not develop equally important skills in their less preferred modes.



⇨ Strong in preferred category, weak in less preferred one

- Solution: Teach to both sides of each dimension.



⇨ Strong in both categories

Recommendations

- Establish relevance and provide applications for all course material. Before presenting theoretical material, provide graphic examples of the phenomena that the theory describes or predicts. *(sensing, global)*
- Balance concrete information (facts, observations, data) *(sensing)* and abstract information (principles, theories, models) *(intuitive)* in all courses.
- Integrate labs and lectures to the greatest extent possible. *(sensing, intuitive)*
- Make extensive use of relevant visuals (pictures, schematics, graphs,…) before, during, and after presenting verbal material. Use *Google Images* and *Wikimedia Commons* to find suitable visuals. *(sensing, visual)*
- Use multimedia presentations *(sensing, visual, global)*, which you may find by searching the digital resource libraries listed on p. *x* of this notebook, *Google Videos*, and *YouTube*. Provide demonstrations *(sensing, visual)*, hands-on if possible.
- Use some numbers in illustrative examples, not just algebraic variables. *(sensing)*
- Give students time to think about what they have been told. Assign "minute papers" (Write the main point of this lecture and the muddiest point) *(reflective).*
- **Give small-group exercises in class** ("active learning")**.** *(active, reflective)*
- Use computer-assisted instruction if you have software that allows for experimentation and provides feedback. *(sensing, active)*
- Assign some practice exercises in homework *(sensing, active)* but don't overdo repetition of the same straightforward procedures *(intuitive, reflective).*
- Assign some open-ended problems and exercises that call for creative thinking and critical judgment. Recognize and encourage creative solutions. *(all styles)*
- Have students cooperate on homework using techniques that promote positive interdependence, individual accountability, face-to-face interaction, interpersonal skills, and self-assessment of team functioning ("cooperative learning")**.** *(all styles)* This one is not trivial—find out about cooperative learning methods before trying it (see pp. D31–D35).
- **Tell students about their learning styles or let them assess their own style.** Click on the link to *Index of Learning Styles* at <*www.ncsu.edu/felder-public*>**.** Knowing their styles helps them understand strengths they may not even know they have and areas that might cause problems for them in courses that aren't meeting their needs. It also helps them better understand and work with others who have styles different from theirs, which will help them both in school and later in their professional careers.
- **Make changes gradually.** If you try to do everything on this page starting next Monday, you'll fail.
  - Try just a couple of new strategies at a time.
  - Give new methods a fair trial—don't expect to get it perfect the first time. There's a learning curve for you and for the students.
  - Adopt strategies that work and drop the others. Then try another one or two new ones.

To find out more about learning styles, go to Richard Felder's website at

www.ncsu.edu/effective_teaching

and click on the link to *Learning Styles.*

MEET YOUR STUDENTS: STAN AND NATHAN[*]

Stan and Nathan are juniors in chemical engineering and roommates at a large midwestern university. They are similar in many ways. Both enjoy partying, video games, and midnight pizza runs. Both did well in science and math in high school, although Nathan's grades were consistently higher. Both found their mass and energy balance course tough (although they agreed the text was superb), thermodynamics incomprehensible, and most humanities courses useless. Both have non-engineer friends who occasionally accuse them of being "too logical."

For all their similarities, however, they are fundamentally different. Stan is an electronics wizard and is constantly sought after by friends with ailing computers, while changing a light bulb is at the outer limits of Nathan's mechanical ability. Stan notices his surroundings, always knows where his cell phone is, and remembers people he only met once; Nathan notices very little around him, misplaces things constantly, and may not recognize someone he has known for years. Stan often has trouble following lectures; Nathan follows them easily, but when instructors spend a lot of class time going through derivations and problem solutions he already understands, he gets bored and his attention wanders.

When Stan takes a test, he reads the first problem, reads it again, and carefully works through the solution. When he has gone as far as he can on the first problem, he checks all the calculations, moves on to the second problem, and repeats the process. With his painstaking approach, he often runs out of time and gets a grade below class average. Nathan reads test problem statements only up to where he thinks he knows what to do and then plunges into solving them. He works quickly and usually finishes early and gets high grades, even though he doesn’t like to check his calculations and often makes careless mistakes.

The one place where Stan outshines Nathan academically is the laboratory. Stan is sure-handed and meticulous and seems to have an instinct for setting up and running experiments, while Nathan rarely gets anything to work right. Nathan almost had a nervous breakdown in analytical chemistry: he would repeat a quantitative analysis five times, get five completely different results, and finally average the two closest estimates and hope for the best. Stan, on the other hand, would do the analysis twice, get almost perfect agreement between the results, and head for a victory soda while Nathan was still weighing out the reagents for his second attempt.

Stan is a sensing learner and Nathan is an intuitive learner [Felder & Silverman, 1988; Felder *et al.,* 2002]. Sensors tend to be practical, attentive to details, and uncomfortable with abstract theories and mathematical models; intuitors can handle abstraction but tend to be bored by details and repetition. Sensors like well-defined problems that can be solved by standard methods; intuitors prefer problems that require innovation. A student who complains about courses having nothing to do with the real world is almost certainly a sensor. Individuals of both types may be excellent STEM professionals: many observant and methodical sensors are good experimentalists, and insightful and innovative intuitors are often good theoreticians and designers.

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[*] Adapted from R.M. Felder & R. Brent, *Teaching and Learning STEM: A Practical Guide, pp. 187–188.* San Francisco, Jossey-Bass (2016).

A mismatch exists between the teaching styles of most STEM professors, who tend to emphasize basic principles and abstract analysis, and the preferences of most STEM undergraduates, who favor observable phenomena, facts, and hands-on experimentation. Intuitive students would consequently be expected to enjoy a clear advantage in most STEM curricula, and on average intuitors have indeed been found to get consistently higher grades except in courses that emphasize factual knowledge and experimentation (see studies cited in Felder *et al.* [2002]).

Sensing and intuition are *learning style preferences* that might be mild, moderate, or strong. The idea is not to teach each student in the way that he or he prefers; rather, it is to make sure instruction is balanced and not heavily biased in favor of one preference or its opposite. For suggestions on how to address the learning needs of both sensors and intuitors, see p. A12.

References

Felder, R.M., Felder, G.N., & Dietz, E.J. (2002). The effects of personality type on engineering student performance and attitudes. *Journal of Engineering Education, 91*(1), 3–17. Retrieved from <*www.ncsu.edu/felder-public/Papers/longmbti.pdf*>.

Felder, R.M., & Silverman, L.K. (1988). Learning and teaching styles in engineering education. *Journal of Engineering Education, 78*(7), 674–681. Retrieved from <*www.ncsu.edu/felder-public/Papers/LS-1988.pdf*>.

MEET YOUR STUDENTS: SUSAN AND GLENDA[1]

Susan and Glenda are seniors in chemical engineering at a private northeastern university. They are both bright and personable, like to study with friends, don't care for laboratory courses, and have almost identical grade point averages. The resemblance ends there, however. Susan was an outstanding student in junior high and high school, and in college she has gotten B's in almost all of her courses, with an occasional A. Her instructors have an easy time grading her homework and test papers: the solutions are neatly laid out, with each step clearly following the preceding one, and she gets a great deal of credit even when her answers are incorrect.

Glenda is another story. Her transcript is a mixture of A's and C's. She usually starts out in a class by doing poorly on the homework and failing the first quiz, and she may spend the rest of the semester trying to catch up. Her problem solutions are jumbles of apparently unrelated numbers and equations with the answer magically appearing at the end; she rarely gets much partial credit, and if anyone asks her to explain what she did she has an extremely difficult time doing so.

Sometimes, however, Glenda seems to undergo a transformation. She begins to solve homework and test problems with ease, occasionally using methods that were not taught in class. She may then go on to get an easy A in the course, or, if the class moves on to completely new material, she may revert to her previous performance level and struggle until either another breakthrough is achieved or the semester ends. Even after she makes a breakthrough, her problem solutions are frequently incomprehensible to anyone else; the difference is that the answer that suddenly appears at the end is correct. She has been hurt on several occasions by instructors who implied that she had cheated, although no one ever had any proof. (In fact, she never cheated.)

Susan is a *sequential learner*, Glenda is a *global learner.*[2] Sequential learners tend to gain understanding in a linear fashion, with each new piece of information building logically from previous pieces. They tend to solve problems the way they learn—in a linear, stepwise fashion—and their solutions make sense to others. They generally have little trouble in school because of their sequential way of learning and solving problems: their courses, books, and teachers are all geared to their style.

Global learners function in a much more all-or-nothing fashion. They absorb information almost randomly, in no apparent logical sequence. In consequence, when they are first learning a subject nothing may make sense to them, and they may be incapable of solving trivially simple problems. But then at some point a key piece of data is taken in, a critical connection is made, the light bulb goes on, and they "get it." They may be fuzzy about details after that, but they see the big picture in a way that most sequential learners never achieve. Thereafter, when presented with new material that they can fit into this picture they may appear to assimilate it instantly, and when solving problems they may leap directly to the solution without seeming to go through the required intermediate steps. They may also see surprising connections between newly-learned material and material from other subjects and disciplines.

Strongly global learners often have difficulty in school. Before they make their mental breakthrough in a given subject, their struggle to solve problems that their sequential counterparts handle with ease makes them feel stupid. Even after they make breakthroughs, their inability to explain their problem-solving processes can get them into trouble, as when Glenda was suspected of cheating. These difficulties—which most of them experience from the first grade on—are truly unfortunate, since global learners collectively

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[1] Adapted from *Chem. Engr. Education, 24*(1), 7–8 (1990).

[2] See R.M. Felder and L.K. Silverman, "Learning and Teaching Styles in Engineering Education," *Engineering Education 78*(7),674(1988) (<*www.ncsu.edu/felder-public/Papers/LS-1988.pdf*>). Susan is a representative sequential learner and Glenda is a representative global learner, but not all sequentials are just like Susan and not all globals are just like Glenda. These labels simply denote tendencies that may be strong or weak in any given individual, and everyone exhibits characteristics of both types to different degrees.

constitute one of society's most valuable and underutilized resources. If they are allowed to progress in their seemingly disjointed manner, some of them will go on to become our most creative researchers, our systems analysts—our global thinkers.

Felder and Silverman[1] suggest ways that engineering instructors can accommodate the learning styles of global learners. Most of these suggestions involve providing a broad perspective on the course material, relating it to material in other courses and disciplines and to the students' prior experience. Perhaps the best thing we can do for these individuals, however, is to watch for them, and when we find them (which we will), explain and affirm their learning process to them. They probably already know all about the drawbacks of their style but it usually comes as a revelation to them that they also have advantages—that their creativity and breadth of vision can be exceptionally valuable to future employers and to society. Any encouragement we provide could substantially increase the likelihood that they will succeed in school and go on to apply their unique abilities after they graduate.

Postscript: 10 years later. Susan graduated and went on to get a masters degree in chemical engineering, got a number of good job offers, and went to work in the process design division of a large petrochemical company. She did extremely well, and is now making rapid progress up the technical management ladder. Glenda went through a lengthy job search when she graduated—all those C's on her transcript worried prospective employers—and finally found a position with a small firm of design consultants. Her first project involved designing and installing process simulation software for a pharmaceuticals manufacturer. She did almost nothing on the project for months, despite increasing pressure from her supervisor. Then she came up with a package that not only did the required simulation but also used it to schedule production, manage inventory, and determine production bottlenecks and the best methods of eliminating them. The company estimated that the program led to savings of two million dollars in its first year of use. Glenda now gets the problems too difficult for anyone else in the firm to solve. Sometimes long periods go by without any apparent results, but no one pressures her any more.

Answers: Who's Talking (p. A8)

Underline indicates high probability.

1. *I don't see what this math garbage has to do with the real world*.

   Sensing (real world), visual (*see*), global (wants big picture), intuitive (wants meaning)

2. *I can't do the homework unless I see how it all fits together*.

   Global (wants big picture), visual (*see*), intuitive (wants meaning)

3. *I hate all these repetitive calculations—they're boring!*

   Intuitive (bored by too much repetition)

4. *Even when I know how to do the problems, I always run out of time on tests.*

   Sensing (works methodically and carefully but not fast)

5. *Everyone around me can do the problems and I can't and I fail. Then I get it, but by then the teacher is on to something else. I can never win.*

   Global (has difficulty using information before getting the big picture)

6. *Don't just tell me stuff—tell me why I should care about it.*

   Sensor (wants real-world connections), intuitor (wants meaning), global (wants big picture), verbal (*tell* me)

Additional Resources on Learning Styles

1. Ebner, M. & Bruff, D. (n.d.) "Visual Thinking," <*cft.vanderbilt.edu/teaching-guides/teaching-activities/visual-thinking/*>. A variety of approaches to integrating images into teaching.
2. Felder, R.M. (n.d.) "Learning Styles," <*www.ncsu.edu/felder-public/Learning_Styles.html*>. Links to articles about learning styles (including a series of "Meet Your Students" columns).
3. Felder, R.M. (2010). "Are Learning Styles Invalid? (Hint: No!)" *On-Course Newsletter*, Sept. 27. <*www.ncsu.edu/felder-public/Papers/LS_Validity(On-Course).pdf*>. A response to articles that regularly appear in the academic psychology literature arguing that there are no such things as learning styles, and even if there are they should not be taken into account when designing instruction.
4. Felder, R.M., & Brent, R. (2005). "Understanding Student Differences," *J. Engr. Education, 94*(1), 57–72 (2005). <*www.ncsu.edu/felder-public/Papers/Understanding_Differences.pdf*>. A survey of models of learning styles, approaches to learning, and levels of intellectual development.
5. Felder, R.M., and Silverman, L.K. (1988). "Learning and Teaching Styles in Engineering Education," *Engr. Education, 78*(7), 674-681. <*www.ncsu.edu/felder-public/Papers/LS-1988.pdf*>. The article that originally defined the Felder-Silverman model and identified teaching practices that should meet the needs of students with the full spectrum of styles. The online paper is preceded by a 2002 preface that states and explains changes in the model that have been made since 1988.
6. Felder, R.M., and Spurlin, J. (2005). "Applications, Reliability, and Validity of the Index of Learning Styles," *Intl. J. Engr. Education*, *21*(1), 103–112. <*www.ncsu.edu/felder-public/ILSdir/ILS_Validation(IJEE).pdf*>. A compilation of evidence for the validity of the Index of Learning Styles, including learning style profile data for students in different institutions and disciplines.
7. Felder, R.M., Felder, G.N., and Dietz, E.J. (2002). "The Effects of Personality Type on Engineering Student Performance and Attitudes," *J. Engr. Education, 91* (1), 3–17. <*www.ncsu.edu/felder-public/Papers/longmbti.pdf*> Differences between performance and attitudes of students with different Myers-Briggs Type Indicator® profiles in a longitudinal study of engineering education.

B. How do I plan a course?

"*To begin with the end in mind means to start with a clear understanding of your destination. It means to know where you're going so that you better understand where you are now so that the steps you take are always in the right direction*."

Stephen Covey, *The 7 Habits of Highly Effective People*

Learning Objectives

Learning objective (or instructional objective): A statement of something *observable* and *clear* 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. "Observable" → instructor should be able to watch students doing it or see the results. "Clear" → students should be able to look at the objective (after they have been taught the relevant material) and know whether or not they can do what the objective specifies.

Form: *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,...).

Possible Scopes of Learning Objectives

- ***Course-level objectives.*** What students should be able to do by the end of the course. General and few in number, suitable to include on the course syllabus. (See p. B14).

  *Upon completion of this course, students will be able to **calculate** magnitudes and directions of all forces acting on externally loaded bodies in static equilibrium.*

- ***Section-level objectives.*** Applicable to a section of the course syllabus, a specified time interval (e.g., Weeks 6–8 of the course), or the time from the last midterm exam to the next one. More specific and numerous than course-level objectives, suitable as an exam study guide. (See pp. B9–B10).

  *Given a stationary body subjected to applied forces, you should be able to **draw** a free body diagram, **determine** whether unknown forces are calculable, and if they are, **calculate** their magnitudes and directions.*

- ***Individual lesson objectives***. 1–3 (maximum), very specific. Show at the beginning of a lecture.

  *By the end of class today, you should be able to (a) **draw** a free body diagram of a block on an inclined plane, (b) **determine** the magnitude and direction of each force acting on the block, and (c) **calculate** the angle of inclination at which slippage will first occur.*

Illustrative Section-Level Objectives

Examples grouped according to their levels on Bloom's Taxonomy (p. B6):

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^{o}F air and cold in 70^{o}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 *forbidden four*)**:** …the student will

- ***know…***
- ***learn…***
- ***appreciate…***
- ***understand…***

Critically important goals, but *not observable* and therefore not valid learning objectives.

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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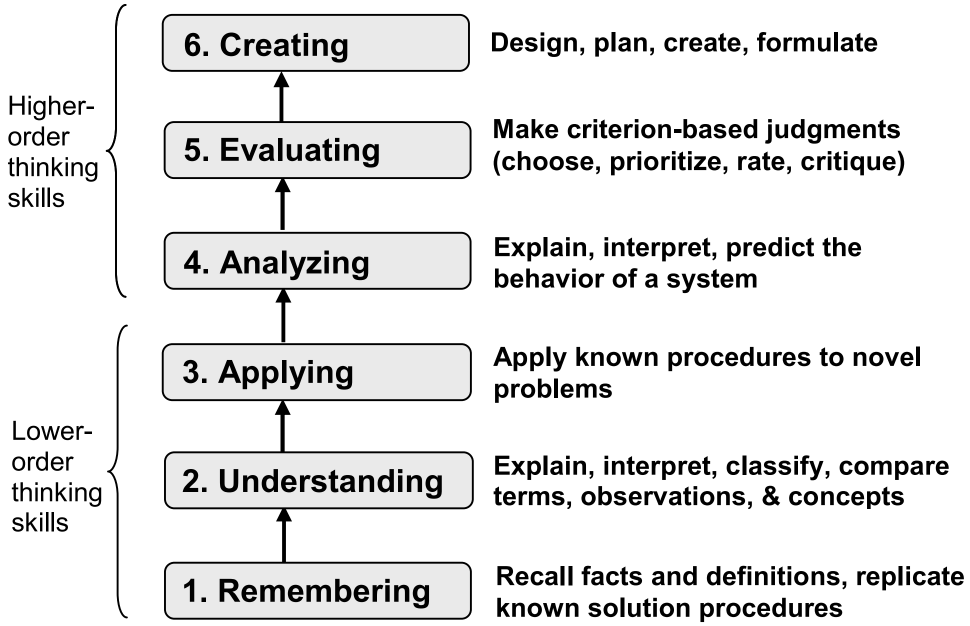
[1] Anderson, L. W. & Krathwohl, D. R. (Eds.). (2001) *A taxonomy for learning, teaching and assessing: A revision of Bloom's Taxonomy of educational objectives: Complete edition.* New York: Longman, pp. 67-68. Original reference: Bloom, B. S., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals by a committee of college and university examiners. Handbook 1. Cognitive domain.* New York: Addison-Wesley.

[2] Krathwohl, D.R., Bloom, B.S., Massia, B.B. (1984). *Taxonomy of educational objectives. Handbook 2. Affective domain.* New York: Addison-Wesley.

[3] Simpson, E. J. (1972). *The psychomotor domain. Vol. 3.* Washington: Gryphon House.

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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* Levels revised by Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's Taxonomy of educational objectives: Complete edition.* New York: Longman, from levels originally developed by Bloom, B. S. and Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals by a committee of college and university examiners. Handbook 1. Cognitive domain.* New York: Addison-Wesley.

Reasons for Writing Objectives

- *Identify & classify course material*. Use objectives as a basis to
  - plan content
  - 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
  - teachers of team-taught courses
  - 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 (or a similar one) 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. **After completing your analysis, 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.**

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[*] Higher-level objectives in boldface.

10. 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.
11. 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.
12. Use a *Txy* or *Pxy* 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.
13. 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.
14. 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.
15. 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.
16. **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.**

Illustrative Learning Objectives for ABET Outcomes 3a–3k*

Outcome 3a (apply knowledge of mathematics, science, and engineering)
Outcome 3k (use modern engineering techniques, skills, and tools)

The student will be able to (insert the usual engineering course objectives).

Outcome 3b (design and conduct experiments, analyze and interpret data)

The student will be able to

- *design an experiment to* (insert one or more goals or functions) *and report the results* (insert specifications regarding the required scope and structure of the report). Variants of this objective could be used in traditional lecture courses as well as laboratory courses.
- *conduct (or simulate) an experiment to* (insert specifications about the goals of the experiment) *and report the results* (insert specifications regarding the scope and structure of the report).
- *develop a mathematical model or computer simulation to correlate or interpret experimental results* (insert specifications regarding the experiment and the data). The results may be real data from a laboratory experiment or simulated data given to students in a lecture course.
- *list and discuss several possible reasons for deviations between predicted and measured results from an experiment, choose the most likely reason and justify the choice, and formulate a method to validate the explanation*.

Outcome 3c (design a system, component, or process)

The student will be able to

- *design a system (or component or process*) *to* (insert one or more goals or functions) *and report the results* (insert specifications regarding the required scope and structure of the report). Variants of this objective could be included in traditional lecture courses (including the freshman engineering course) as well as the capstone design course.
- *use engineering laboratory data to design or scale up a system (or component or process).*
- *build a prototype of a design and demonstrate that it meets performance specifications.*
- *list and discuss several possible reasons for deviations between predicted and measured results from an experiment or design, choose the most likely reason and justify the choice*, *and formulate a method to validate the explanation*.

Outcome 3d (function on multi-disciplinary teams)

The student will be able to

- *identify the stages of team development and give examples of team behaviors that are characteristic of each stage.*
- *summarize effective strategies for dealing with a variety of interpersonal and communication problems that commonly arise in teamwork*, *choose the best of several given strategies for a specified problem, and justify the choice*.
- *function effectively on a team, with effectiveness being determined by instructor observation, peer ratings, and self-assessment.*
- *explain aspects of a project related to specified engineering and non-engineering disciplines*.

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* R.M. Felder & R.Brent, Designing and teaching courses to satisfy the ABET Engineering Criteria, *J. Engr. Education, 92*(1), 7–25 (2003). <*www.ncsu.edu/felder-public/Papers/ABET_Paper_(JEE).pdf*>.

Outcome 3e (identify, formulate, and solve engineering problems)

The student will be able to

- *troubleshoot a faulty process or product* (insert specifications regarding the nature of the process or product) *and identify the most likely sources of the faults.*
- *create and solve homework or test problems and identify their levels on Bloom's Taxonomy.*
- *examine a description of a problematic technology-related situation and identify ways that engineers might contribute to a solution.*

Outcome 3f (understand professional and ethical responsibility)

Given a job-related scenario that requires a decision with ethical implications, the student will be able to

- *identify possible courses of action and discuss the pros and cons of each one.*
- *decide on the best course of action and justify the decision.*

Outcome 3g (communicate effectively)

The student will be able to

- *critique writing samples and identify both strong points and points that could be improved in grammar, clarity, and organization.*
- *critique oral presentations and identify both strengths and areas for improvement.*
- *write an effective memo (or letter, abstract, executive summary, project report) or give an effective oral presentation...* (insert specifications regarding the length and purpose of the communication and the intended audience).

Outcome 3h (understand the global/societal impact of engineering solutions)

The student will be able to

- *discuss historical situations in which technology had a major impact on society, either positively or negatively or both, and speculate on ways that negative results might have been avoided.*
- *propose a solution or critique a proposed solution to an engineering problem, identifying possible negative global or societal consequences and recommending ways to minimize or avoid them*

Outcome 3i (recognize the need for life-long learning and be able to engage in it)

The student will be able to

- *find relevant sources of information about a specified topic in the library and on the World Wide Web (or perform a full literature search).*
- *identify his or her learning style and describe its strengths and weaknesses. Develop strategies for overcoming the weaknesses.*
- *participate effectively in a team project and assess the strengths and weaknesses of the individual team members (including himself or herself) and the team as a unit.*

Outcome 3j (know contemporary issues)

The student will be able to

- *identify important contemporary regional, national, or global problems that involve engineering.*
- *propose and discuss ways engineers are making or might make important contributions to the solution of specified regional, national, and global problems.*

Choosing a Text (Paper or Online)

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? Slides? A test bank? Software? Other online material? 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 <u>should</u> be included? (Be sure to check university requirements.)

- 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

What <u>may</u> 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 Text: R.M Felder and R.W. Rousseau, Elementary Principles of Chemical Processes, 4th edition, Wiley (2015).

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:

Score	≥97	92 – 96.9	89 – 91.9	82 – 88.9	77 – 81.9	72 – 76.9	67 – 71.9	62 – 66.9	60 – 61.9	< 60
Grade	A+	A	A– or B+	B	B– or C+	C	C– or D+	D	D–	F

  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.

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; you’ll have no time for interactivity in class; and you’ll end up skimming some important

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[*] *Chem. Engr. Education, 41*(2), 121–122 (Spring 2007).

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 (*<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[3,4] and show an illustrative study guide for a midterm exam.[5]

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[6]) and assignments that provide instruction and practice in the tasks specified in the objectives. As you get new ideas

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[3] R.M. Felder and R. Brent, "Objectively speaking," *Chem. Engr. Education, 31*(3), 178–179 (1997), <*www.ncsu.edu/felder-public/Columns/Objectives.html*>.

[4] R.M. Felder and R. Brent, "How to teach (almost) anyone (almost) anything," *Chem. Engr. Education, 40*(3), 173–174 (2006), <*www.ncsu.edu/felder-public/Columns/TeachAnything.pdf*>.

[5] R.M. Felder, Study guide for a midterm exam in the stoichiometry course, <*www.ncsu.edu/felder-public/cbe205site/studyguides/studyguide2.htm*>.

[6] R.M. Felder and R. Brent, "Learning by doing," *Chem. Engr. Education, 37*(4), 282–283 (2003), <*www.ncsu.edu/felder-public/Columns/Active.pdf*>.

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.

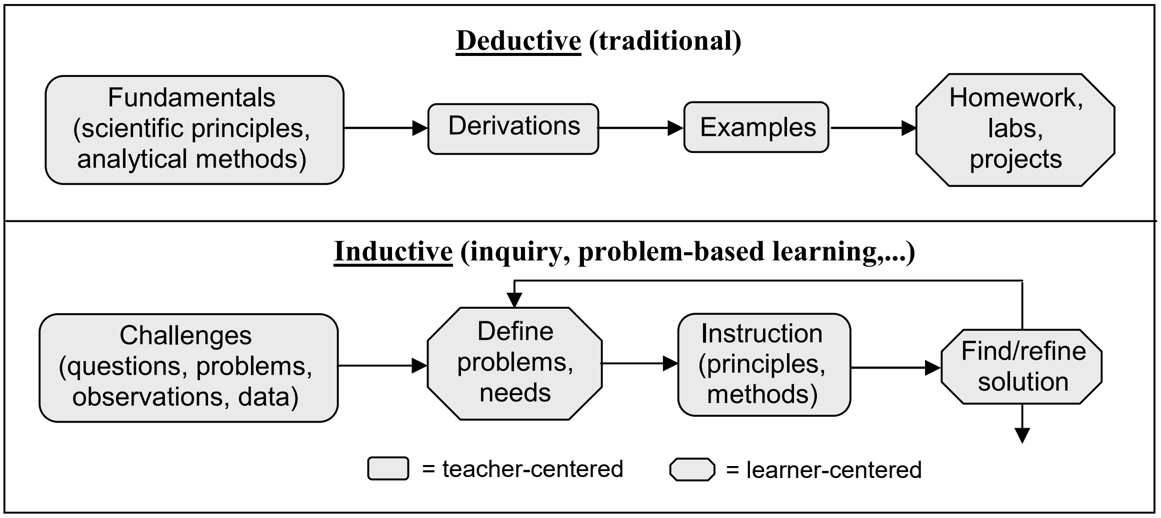
4. *Get feedback during the course.*

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.

INDUCTIVE TEACHING AND LEARNING*



Course topics and entire courses can be taught

- Deductively — start with principles, deduce & derive methods & applications. Traditional in science and engineering education. Efficient at promoting short-term retention of information.
- 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

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

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

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* M.J. Prince and R.M. Felder, "Inductive Teaching and Learning Methods," *J. Engr. Education, 95*(2), 123–138 (2006), <*www.ncsu.edu/felder-public/Papers/InductiveTeaching.pdf*>.

Why teach inductively?

Teachers unfamiliar with inductive learning are understandably nervous about challenging students to do something before they've been taught to do it. Here are several reasons for doing it.

- Traditional deductive instruction (teacher presents something, students copy and memorize it and try to reproduce it on assignments and tests) leads to very little meaningful learning of difficult concepts and methods. Confronting students with reasonable challenges up front (*desirable difficulties*) motivates them to learn and promotes learning.[*] If they figure out how to meet the challenge on their own, they've clearly learned how to meet it. Even if they don't, they're much more likely to get it when the instructor presents and explains the solution.
- For most inductive methods (such as inquiry-based instruction), the challenges are low-stakes. The students struggle fairly briefly and then get affirmation or corrective feedback. Those brief struggles can help them avoid much greater struggles on assignments and tests.
- Mountains of classroom research have demonstrated that inductive teaching works better than traditional instruction. (See references at the end of this section.)

Inquiry-Based Instruction

Any inductive teaching method that does not fall into any of the other categories in Columns 3–7 of the table on p. B23 can be called inquiry-based instruction (aka inquiry-based learning, inquiry-based science, guided inquiry, or just inquiry). To teach with an inquiry-based approach, keep the following suggestions in mind:

- Introduce each major course topic with a challenge (an open-ended 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).
- 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.
- *Choose the appropriate level of teacher involvement.* If you are teaching students who have never been taught using an inquiry-based approach, provide extensive modeling and guidance at every step of the instruction; as the students gain more experience, move increasingly toward just setting the stage and getting out of their way.

Where can you find appropriate opening challenges for inquiry-based teaching?

- *Take a problem from the course text or from an old homework assignment or exam.* Choose a problem—preferably one with real-world connotations to increase motivation—whose solution requires knowledge of the next body of material you plan to cover (a section, a chapter, several chapters, or the entire text).
- *Pose an open-ended question or assignment.*
  - Design an experiment to measure ____?
  - Explain the following experimental result: ____.

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[*] (P.C. Brown, H.L. Roediger III, M.A. McDaniel, *Make it Stick: The Science of Successful Learning,* Cambridge, MA: Belknap Press, 2014).

  - Predict the outcome of the following experiment (____), and justify your prediction.
  - A process or item of equipment was designed to ___, but instead it has begun to ___: figure out why.
  - The following design or procedure was submitted by someone in the department you head:________. Determine (or formulate a plan to determine) whether you should give it the go-ahead, obtain more information, or reject it.

- *Select a problem from the problem-based learning literature* (Section D) *and simplify it or provide more guidance to the students in solving it than you would normally provide in PBL.*

An inquiry-based strategy for getting a course off to a good start and conclusion

- *In the first week of class, present an open-ended real-world problem that will require material from the entire course to solve.* (For example, pick a problem from the end of the text.) *Have students briefly work in groups to itemize what they know and what they need to determine and outline how they would proceed. Have them sign their work and collect it, but don't grade it.* Some of the groups may do surprisingly well, especially if they include nontraditional students with professional experience, but most groups will just flounder, which is not a problem.
- *Use the problem to introduce each new topic and to provide context for the next body of course material.* Material taught on a need-to-know basis in the context of solving a significant problem is much more likely to be learned, understood, and retained than material motivated only by the need to follow a syllabus.
- *Repeat the opening exercise at the end of the course with the same student groups that did it on the first day. Afterwards, give them back what they did on the first day and have them compare the two efforts.* This time the students will have spent the entire semester learning how to approach the problem in question, and their responses should reflect their knowledge. If it does, most will come away with a strong and satisfying sense of how much they have learned in the course and perhaps an appreciation of the instructor who made all that learning possible for them.

What does the research show about the effectiveness of inquiry-based learning?

- A meta-analysis of 81 experimental studies found significant positive gains in academic achievement, student perceptions, process skills and analytical abilities associated with the use of inquiry.[7]
- A meta-analysis of 79 studies involving students from 7th grade through college found that inquiry improved academic achievement, critical thinking, and laboratory skills.[8]
- A recent study of guided inquiry labs in a college science course reported gains in science literacy and skills and improvement in students' confidence in doing science.[9]

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[7] Shymanski, J., Hedges, L., and Woodworth, G. (1990). A reassessment of the effects of inquiry-based science curricula of the 60's on student performance. *Journal of Research in Science and Teaching, 27* (2), 127-144.

[8] Smith, D. (1996). A meta-analysis of students outcomes attributable to the teaching of science as inquiry as compared to traditional methodology, Ph. D. Dissertation, Temple University, Department of Education.

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.

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[9] Brickman, P., Gormally, C, Armstrong, N, & Hallar, B. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. *International Journal for the Scholarship of Teaching and Learning, 3*(2), July 2009, <*wwww.georgiasouthern.edu/ijsotl*>.

Resources on Inductive Teaching and Learning

- Amador, J., Miles, L., and Peters, C.B. (2006). *The Practice of Problem-Based Learning: A Guide to Implementing PBL in the College Classroom.* San Francisco: Jossey-Bass.
- Bateman, W. (1990). *Open to Question: The Art of Teaching and Learning by Inquiry*, San Francisco: Jossey-Bass.
- Boud, D., and Feletti, G. (1997). *The Challenge of Problem-Based Learning*, 2nd ed., London: Kogan Page, 1997.
- Buch, N., and Wolff, T. (2000). "Classroom Teaching through Inquiry," *J. Prof. Issues Eng. Ed. Prac.*, Vol. 126, No. 3, p. 105.
- Case-based education library of cases, National Center for Case Study Teaching in Science, <*http://sciencecases.lib.buffalo.edu/cs/* >.
- Dochy, F., Segers, M., van den Bossche, P., and Gijbels. D. (2003). Effects of problem-based learning: A meta-analysis, *Learning & Instruction, 13,* 533-568.
- Duch, B.J., Groh, S.E., and Allen, D.E. (2001). *The Power of Problem-Based Learning*. Sterling, VA: Stylus Publishing.
- Felder, R.M., and Brent, R. (1996). "Navigating The Bumpy Road to Student–Centered Instruction," *College Teaching, 44* (2), 43–47. <*www.ncsu.edu/felder-public/Papers/Resist.html*>.
- Felder, R.M., and Brent, R. (2016). *Teaching and Learning STEM: A Practical Guide,* Sect. 12.2. San Francisco: Jossey-Bass.
- Just-in-Time Teaching Web site, <*webphysics.iupui.edu/jitt/jitt.html*>.
- Lee, V.S., ed. (2004). *Teaching and Learning through Inquiry*, Sterling, VA: Stylus Publishing.
- Lundeberg, M., Levin, B., and Harrington, H. (1999). *Who Learns What from Cases and How? The Research Base for Teaching and Learning with Cases*, Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Lynn, Jr., L.E., *Teaching and Learning with Cases*. (1999). New York: Chatham House Publishers.
- Svinicki, M., & McKeachie, W.J. (2014). *McKeachie's teaching tips: Strategies, research, and theory for college and university teachers* (14th ed.). Belmont, CA: Wadsworth. Broad coverage of every aspect of teaching, Ch. 15. (Problem-based learning).
- Novak, G.M., Patterson, E.T., Gavrin, A.D., and Christian, W. (1999). *Just-in-Time Teaching: Blending Active Learning with Web Technology*, Upper Saddle River, N.J.: Prentice-Hall.
- Prince, M., and Felder, R.M. (2006). Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. *J. Engr. Education*, *95*(2), 123–138. <*www.ncsu.edu/felder-public/Papers/InductiveTeaching.pdf*>
- Prince, M.J., and Felder, R.M. (2007). "The Many Faces of Inductive Teaching and Learning," *J. Coll. Sci. Teaching*, *36*(5), 14–20. <*www.ncsu.edu/felder-public/Papers/Inductive(JCST).pdf*>.
- Ricards, L.G., Gorman, M. Scherer, W.T., and Landel, R.D. (1995). "Promoting Active Learning with Cases and Instructional Modules," *J. Engr. Education*, *84*(4), pp. 375–381.
- Tan, O.S. (2003). *Problem-Based Learning Innovation*, Singapore: Thomson.
- Thomas, J.W. (2000). *A Review of Research on Project-Based Learning*, San Rafael, CA: Autodesk Foundation.
- University of Delaware Problem-Based Learning Web Site*, <www.udel.edu/pbl/ >*.

Additional Resources on Course Design & Developing High-Level Skills

Course design

- Anderson, L.W., & Krathwohl, D.R. (Eds.). (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's Taxonomy of Educational Objectives: Complete edition.* New York: Longman.
- Biggs, J., & Tang, C. (2011). *Teaching for quality learning at university,* 4th edn. Maidenhead, UK: Open University Press.
- Brent, R., & Felder, R.M. (1999). It's a start. *College Teaching, 47* (1), 14–17. Ideas for starting a course effectively. <*www.ncsu.edu/felder-public/Papers/Getting_started.html*>.
- *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.
- Felder, R.M., & Brent, R. (2003). "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria," *J. Engr. Education, 92*(1), 7–25. <*www.ncsu.edu/felder-public/Papers/ABET_Paper_(JEE).pdf*>
- Felder, R.M., and Brent, R. (2016). *Teaching and Learning STEM: A Practical Guide,* Ch. 2–3. San Francisco: Jossey-Bass.
- 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.
- Forehand, M. (2005). Bloom's Taxonomy: Original and revised. In M. Orey (Ed.). *Emerging perspectives on learning, teaching, and technology*. <*www.coe.uga.edu/epltt/bloom.htm*>
- Gronlund, N.E. (2008). *How to write and use instructional objectives* (8th ed.). Upper Saddle River, NJ: Prentice-Hall.
- Stice, J.E. (1976). A first step toward improved teaching. *Engineering Education, 66*(5), 394-398. A classic paper that introduced learning objectives (then called instructional objectives) into the engineering education literature.

Developing higher level thinking skills:

- Felder, R.M. (1990). Meet your students: Michelle, Rob, and Art. *Chemical Engineering Education, 24* (3), 130-131. A short column about different approaches to learning and ways to motivate students. <*www.ncsu.edu/felder-public/Columns/Michelle.html*>
- Felder, R.M. (1987). On creating creative engineers. *Engineering Education, 77*(4), 222 (1987). Ideas for developing creativity and higher level thinking skills in students. <*www.ncsu.edu/felder-public/Papers/Creative_Engineers.pdf.*
- Felder, R.M., and Brent, R. (2016). *Teaching and Learning STEM: A Practical Guide,* Ch. 8 (conceptual understanding), Ch. 9 (analytical problem-solving skills), Ch. 10 (creative thinking, critical thinking, communication skills, self-directed learning), Ch. 11 (teamwork skills). San Francisco: Jossey-Bass.

C. How can I assess learning reliably and fairly? How can I be both rigorous and fair in grading?

Examinations are formidable even to the best-prepared; for the greatest fool may ask more than the wisest man can answer.

Charles Colton

Assessment: Gathering information that will be used to improve students' learning (*formative assessment),* make judgments about the quality of their learning and assign grades (*summative assessment),* or both. **Evaluation:** Interpreting assessment data, drawing conclusions.

- **Summative assessments:** Exams, quizzes, assignments, lab reports, written and oral project reports.
- **Formative assessments**
  - **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.
  - **Other classroom assessment techniques[1]:** In a classic reference, Angelo and Cross list and describe a variety of methods—the best known being the minute paper—for determining areas of weakness in students' mastery of their instructors' learning objectives.
  - **ConcepTests:** Multiple-choice questions that address students' understanding of course-related concepts and identify their misconceptions. Students register their answers electronically using some form of clickers. More details are given on p. D18.
  - **Online quizzes:** Quizzes built into online tutorials can relay information to the instructor about areas of weakness that should be addressed in the next class session.
  - **Midterm evaluation:** ***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, or one 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.
  - **All summative assessments can have a formative component, depending on what instructors and students do with the results.** When instructors find out what their students missed, they can modify their teaching to address the deficiencies, and when students find out what they missed, they can go back and study those things.

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[1] Angelo, T.A., & Cross, K.P. (1993). *Classroom assessment techniques: A handbook for college teaching* (2nd ed.). San Francisco: Jossey-Bass.

Model Exam

Given below is the first test in an introductory sophomore engineering course followed by the instructor's worked-out solution. The students have been exposed to the concepts of unit conversions, density and specific gravity, and Archimedes' Principle. Individually read the test and skim the solution key. In your group, critique the test.

CHE 203–Exam #1. 50 minutes—Closed Book. (Refer to handout with conversion factors.)

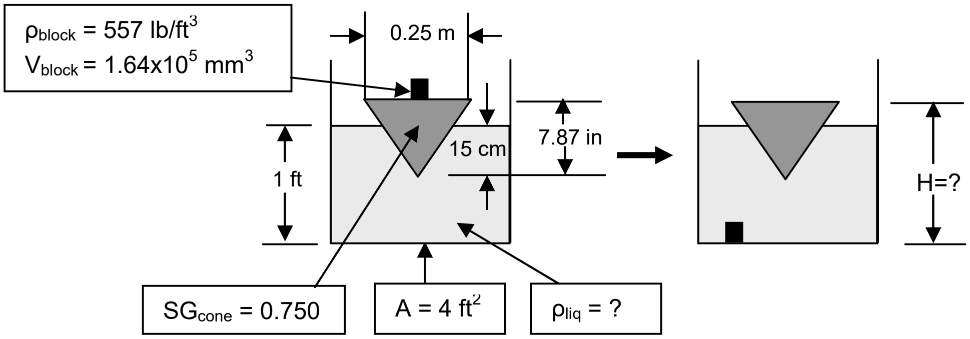
A copper block with a volume of 1.64x10^5 mm^3 and a density of 557 lb/ft^3 rests on the base of a solid cone of base diameter 0.25 m and height 7.87 in, which floats point downward in a liquid the determination of whose density is part of this problem and is immersed to a depth of 15.0 cm in a cubical tank 2.00 ft on each side. At a certain time the copper block is picked up and immersed in the tank. The liquid level before the immersion of the block is half the height of the tank. The specific gravity of the cone is 0.750.

(a) Calculate the density of the liquid (g/cm^3).

(b) Calculate the vertical distance (cm) from the bottom of the tank to the base of the cone after the block is immersed in the liquid. If you have no time to work out the numbers, outline a solution procedure.

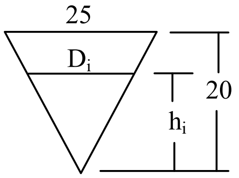
<u>Exam 1: Solution</u> (Numbers in circles are point values)

(a)



<u>Volume of liquid</u>: V_{liq} = (30.48 cm)(3716 cm^2) – $V_{immersed}$ = 113,263–1381 = 1.119x10^5 cm^3 ⑤

<u>Immersed volume of cone</u>



$$\frac{D_i}{h_i}=\frac{25}{20}\Rightarrow D_i=\frac{5h_i}{4}\Rightarrow V_{DL}=\frac{\pi}{3}\left(\frac{5h_i}{8}\right)^2 h_i=(0.4091\,h_i^3)\text{cm}^3$$ ⑤

<u>Mass of liquid displaced by cone & depth of immersion</u>

$$M_{DL}=[0.4091h_i^3\ (\text{cm}^3)]\left(2.836\ \frac{\text{g}}{\text{cm}^3}\right)=1.390h_i^3\,(\text{g})$$ ⑤

Archimedes $\Rightarrow M_C=M_{DL}\Rightarrow 2454=1.390h_i^3\Rightarrow h_i=12.09$ cm

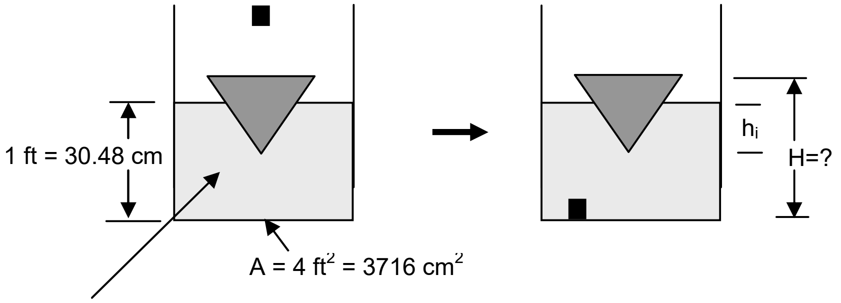
$\Rightarrow$ Base of cone is (20.0-12.09) = 7.91 cm above liquid surface ⑮

<u>Mass of displaced liquid and liquid density</u>

⑩ ⑩ ⑤

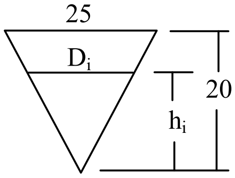
$$M_D = V_D\rho_{liq} = 1381\rho_{liq} \xrightarrow{Archimedes} (M_C + M_B) = 1381\rho_{liq} \Rightarrow \rho_{liq} = \frac{(2454+1463)\text{g}}{1381\ \text{cm}^3} = \boxed{2.84\ \text{g/cm}^3}$$

(b)



Volume of liquid: V_{liq} = (30.48 cm)(3716 cm^2) – $V_{immersed}$ = 113,263–1381 = 1.119x10^5 cm^3 ⑤

Immersed volume of cone



$$\frac{D_i}{h_i} = \frac{25}{20} \Rightarrow D_i = \frac{5h_i}{4} \Rightarrow V_{DL} = \frac{\pi}{3}\left(\frac{5h_i}{8}\right)^2 h_i = (0.4091\ h_i^3)\text{cm}^3$$ ⑤

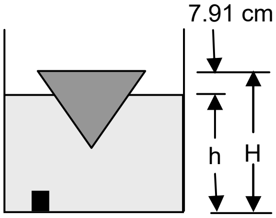
Mass of liquid displaced by cone & depth of immersion

$$M_{DL} = [0.4091h_i^3\ (\text{cm}^3)]\left(2.836\ \frac{\text{g}}{\text{cm}^3}\right) = 1.390h_i^3(\text{g})$$ ⑤

Archimedes $\Rightarrow M_C = M_{DL} \Rightarrow 2454 = 1.390h_i^3 \Rightarrow h_i = 12.09$ cm ⑮

$\Rightarrow$ Base of cone is (20.0-12.09) = 7.91 cm above liquid surface

Final solution:



$$V_{liq} = 1.119\times10^5 = 3716h - V_{(cone)immersed} - V_{block}$$

$$= 3716h - (0.4091)(12.09^3) - 164$$ ⑩

$$\Rightarrow h = 30.35\text{ cm} \Rightarrow \boxed{H = (30.35+7.91)\text{ cm} = 38.3\text{ cm}}$$ ⑩

Solution time = 35 minutes

Tips on Tests[*]

Tips on problem-solving tests

- *Let your learning objectives guide your design of lessons, assignments, and tests, and test only at the levels you teach.* Consider handing out a study guide a week containing your learning objectives before each test. There should be no surprises on tests.
- *Always work out a test from scratch when you have the "final version."* Time yourself when you do it. Then revise and do it again. If possible, have a colleague or graduate student read (or work through) the test for clarity. Revise again if necessary.
- *Design tests that most students can finish and check in the allotted time.* No one has ever shown that someone who takes 20 minutes to solve a problem will make a better professional than someone who needs 35. In fact, people who are careful but slow often do better work than people who are quick but sloppy. Here is a common rule of thumb:

  The test period should be at least three times longer than the time it takes you to work out the solution (or four or five times longer if the test is very difficult or requires a lot of calculations). If it isn't, cut down the test length.
- *Include some questions and problems on the test to discriminate between A-level and B-level performance, but not too much.* If you don't include any high-level material, students won't bother studying it. If you put too much (e.g., 50%), the A students will do well and the B, C, D, and F students will all fail. For undergraduate courses, some suggest that 10–15% of the test content should be at this level.
- *Closed-book exams test primarily memory; open-book exams test primarily understanding and simulate the professional environment.* If you have material you really want the students to memorize, give a closed-book test. If you don't care, give an open-book test. Allowing summary sheets in place of the text is a reasonable compromise.
- *If test grades are much lower than you anticipated, consider (1) scaling the grades by adding enough points to bring the top grade up to 100 or the average to a desired level; (2) allowing students to submit corrections to anything they missed to get a fraction of the lost points back; (3) if almost all students miss one problem, give a short quiz on a similar problem and add the points to the original test grades.*

  If the average is 35, at least consider the possibility that either the test was bad or you did a poor job of teaching the material being tested on.
- *Consider a time limit for requesting re-grading (e.g., one week). Have students make all requests in writing explaining their case.* Doing these two things will cut down substantially on requests for regrading, especially at the end of the semester when students are desperately seeking more points to raise their course grades.
- *Return graded tests promptly to maximize learning.*

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[*] R.M. Felder & R. Brent, *Teaching and Learning STEM: A Practical Guide,* Ch. 8. San Francisco: Jossey-Bass (2016).

- *Give students guidance in how to prepare for tests, take them, and learn from them.* Before your first test, give the students a preparation guide, such as "Tips on Test Taking" (p. C17). Alternatively, when you return the graded tests back, attach an *exam wrapper*—a short handout that students complete in which they reflect on how they prepared for the exam and how they might improve on future exams. A sample exam wrapper is given on p. C22, and examples of others can be found at <*www.cmu.edu/teaching/designteach/teach/examwrappers/*>.
- *Don't replace a study guide with something like "This test will consist of four of the following 10 problems. It will be open-book, open-notes."* Students will get together beforehand, work out solutions to all 10 problems (dividing the labor among themselves), make enough copies for everyone (perhaps with minor modifications so the solutions are not all identical), not bother studying anything else, and all get 100's.
- To avoid having to create multiple make-up tests, announce that there will be one comprehensive make-up test near the end of the semester. The test will serve to make up for any test missed during the semester for any reason.
- Give point values for each part of a multiple-part problem. Set up multiple-part problems so that if students miss Part (a) they can still solve the subsequent parts. For example, tell them to begin with a specified answer to (a), regardless of what they actually got. (Give practice on this type of problem before putting it on a test.)
- Beware of take-home exams, especially in undergraduate classes. It is too easy for students to cheat on them.
- *Prepare a detailed solution key before giving the test*. (This is often the only way to discover flaws in the test.) Give the key to whoever proctors the exam and whoever grades it. Consider posting it after the test is collected (but only if you don't plan to reuse it).
- *Be generous with partial credit on time-limited tests*. *Here is a possible scoring scheme for tests and assignments* (Jim Stice):
  - Method correct, no errors: 100%
  - Method correct, but contains arithmetic errors: –10% per error
  - Solution contains a minor theoretical error: –20%
  - Solution contains a more serious theory error: –30%
  - Solution contains a major theory error: –50%
  - Solution contains more than one theoretical error of any kind: –70%
  - I have no idea what you're trying to do: –100%
- Give the lowest test grade less weight than the others.
  - Advantages: Avoids make-up tests, keeps students from getting destroyed by one bad day.
  - Disadvantage: Works against students who do much better than average on a particularly hard test. (Remedy: Scale all grades to a common high score or a common average.)
  - *Unless you give a lot of tests in a course, don't drop the lowest grade*. Some students who are doing well before the last test won't bother to study for it, and you want them to.
- Consider providing opportunities to rework the test (individually or in groups) for additional credit.

Tips on Multiple-Choice Tests

- Write some items to assess higher levels of thinking.
- Options (brief, simply written, plausible)
  - Put most information in stem, minimum in options
  - List options on separate lines
  - Distribute correct answers randomly among option positions
  - The correct answer should not always be the longest one
  - Avoid negatives in stem, "all of the above," "none of the above," "always," "never"
- Consider showing a short paragraph, chart, or graph followed by several test items. (Leads to questions at a higher level of thinking)
- Provide space for students to briefly explain answers to questions. (Reduces test anxiety, helps you locate unfair or poorly worded questions)

For additional suggestions on constructing multiple-choice items, refer to Section 8.1 of Felder and Brent's *Teaching and Learning STEM* (full citation in reference list at the beginning of this notebook).

Tips on Essay Tests

- Preparing your class
  - Discuss types of questions and show sample answers
  - Announce how spelling, grammar, and handwriting will affect essay grades
- Designing the questions
  - Only try to test one or two objectives per item
  - Reserve essay questions for Bloom application level or higher
  - Have a colleague read each question for clarity
  - Indicate on test the point value and an appropriate response length or time
  - Allow students three times longer to answer a question than it takes you to answer it
- Grading essay questions
  - Develop a rubric to determine scores on each question. (See pp. C23–C26. For model rubrics, go to <*course1.winona.edu/shatfield/air/rubrics.htm*> or any of many other rubric repositories available online.)
  - Keep student identities anonymous
  - Score all Question 1's, then all Question 2's, etc.
  - Shuffle papers between grading of different questions
  - Provide written feedback and/or model answers
- When determining appropriate test length, allow about 2 minutes for a short-answer question requiring more than a sentence to answer, 10-15 minutes for a limited essay question, and a half-hour to an hour for a broader question requiring more than a page or two to answer.
- Some useful tips on grading essay questions (including the preceding rules of thumb for test length) can be found on pp. 102–104 in *McKeachie's Teaching Tips* (reference in front section).

DESIGNING TESTS TO MAXIMIZE LEARNING*

Richard M. Felder
North Carolina State University

It's the middle of December. A colleague of yours who teaches mechanics has just gotten the tabulations of his end-of-course student evaluations and he's steaming! His students clearly hated his course, giving him the lowest ratings received by any instructor in the department. He consoles himself by grumbling that student evaluations are just popularity contests and that even though his students don't appreciate him now, in a few years they'll realize that he really did them a favor by maintaining high standards.

He's probably kidding himself. Although bashing student ratings is a popular faculty sport, several thousand research studies have shown that student ratings are remarkably consistent with retrospective senior and alumni ratings, peer ratings, and every other form of teaching evaluation used in higher education.[1,2] Although there are always exceptions, teaching rated by most students as excellent usually is excellent, and teaching rated as atrocious usually is atrocious.

If your colleague decided to take a hard objective look at those evaluations instead of dismissing them out of hand, there is a good chance that he would find that his examinations play a major role in the students' complaints. Not the difficulty of the exams *per se*: the research also shows that the highest evaluations tend to go to some of the more demanding teachers, not the ones who hand out A's for mediocre work.[2] What students hate more than anything else except outright sadistic behavior are examinations that they perceive as unfair. Tests that fall into this category have any of the following features: (1) problems on content not covered in lectures or homework assignments; (2) problems the students consider tricky, with unfamiliar twists that must be worked out on the spur of the moment; (3) excessive length, so that only the best students can finish in the allotted time; (4) excessively harsh grading, with little distinction being made between major conceptual errors and minor calculation mistakes; (5) inconsistent grading, so that two students who make the identical mistake lose different points. Most students can deal with tests that they fail because they don't understand the material or didn't study hard enough; however, if they understand but do poorly anyway for any of those five reasons, they feel cheated. Their feeling is not unjustified.

If you teach a course in a quantitative discipline, there are several specific things you can do to minimize your students' perception that you are dealing with them unfairly on examinations.

- <u>*Test on what you teach*</u>. A common and unfortunate practice is to give fairly straightforward examples in lectures and homework and then to put high-level analysis problems or problems with unexpected twists on the test, with the argument being that "we need to teach students to think for themselves."

  The logic of this argument is questionable, to say the least. People acquire skills through practice and feedback, period: no one has ever presented evidence that testing students on unpracticed skills teaches them anything. Moreover, engineers and scientists are never presented with brand new varieties of quantitative problems and told that they have to solve them on the spot without consulting anyone. A student's ability to solve hard puzzles quickly should not be the main determinant of whether he or she should be certified to practice engineering or science. The way to equip students to solve open-ended or poorly defined problems or problems that call for critical or creative thinking is

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* Adapted from *J. Prof. Issues in Engr. Education & Practice, 128* (1), 1–3 (2002), and R.M. Felder and R. Brent, *Teaching and Learning STEM: A Practical Guide,* Section 8.3. San Francisco: Jossey-Bass (2016).

to work out several such problems in class, then put several more on successive homework assignments and provide constructive feedback, and *then* put similar problems on tests.

- Consider handing out a study guide one to two weeks before each test. It makes no sense to tell students "Here's the 574-page text—you're responsible for all of it. Guess what I'm going to put on the exam!" In the words of Jim Stice, teaching is not a mystery religion. *There should be no surprises on tests:* nothing should appear that the students could not have anticipated, no skill tested that has not been explicitly taught and repeatedly practiced.

  Suggestions such as this and the previous one are often equated with lowering standards or "spoon-feeding" students. They are nothing of the sort. Taking the guesswork out of expectations is not equivalent to lowering them: on the contrary, I advocate *raising* expectations to the highest level appropriate for the course being taught, knowing that only the best of the students will be capable of meeting all of them. The point is that the more clearly the students understand those expectations and the more explicit training they are given in the skills needed to meet them, the more likely those with the aptitude to perform at the highest level will acquire the ability to do so.

  A study guide is an effective way to communicate your expectations—among other reasons, because students are likely to pay attention to it. The guide should be thorough and detailed, with statements of every type of question you might include on the test—calculations, estimations, definitions and explanations, derivations, troubleshooting exercises, etc. The statements should begin with observable action words and not vague terms such as *know, learn, understand, or appreciate*. (You wouldn't ask students to understand something on a test—you would ask them to do something to demonstrate their understanding.) Draw from the study guide when planning lectures and assignments and constructing the test. No surprises!

  A number of benefits follow from the formulation of such *learning objectives* for courses.[3,4] A well-written set of objectives helps the instructor make the lectures, assignments, and tests coherent, gives other faculty members a good idea of what they can expect students who pass the course to know, and gives new instructors an invaluable head start when they are preparing to teach the course for the first time. An additional benefit in engineering is that the objectives provide accreditation visitors with an excellent summary of the knowledge and skills being imparted to the students in the course (particularly those having to do with Outcomes 3a–3k of Engineering Criteria 2000).[5]

- Minimize speed as a factor in performance on tests. Unless problems are trivial, students need time to stop and think about how to solve them while the author of the problems does not. *If your test involves quantitative problem solving, you should be able to work out the test in less than one-third of the time your students will have to do it* (and less than one-fourth or one-fifth if particularly complex or computation-heavy problems are included). If you can't, cut it down by eliminating questions, presenting some formulas instead of requiring derivations, or asking for solution outlines rather than complete calculations.

  In my courses, the problems get quite long: by the end of the course, a single problem might take two or three hours to solve completely. There's no way I can put one of those problems on a 50-minute test, but I still have to assess my students' ability to solve them. I do it with the following generic problem:

  > *Given...*(describe the process or system to be analyzed and state the values of known quantities), *write in order the equations you would solve to calculate...*(state the quantities to be determined). *Just write the equations—don't attempt to simplify or solve them. In each equation, circle the variable for which you would solve, or the set of variables if several equations must be solved simultaneously.*

The students who understand the material can do that relatively quickly—it's the calculus and algebra and number-crunching that take most of the solution time. Moreover, I know that if they can write equations that can be solved sequentially for the variables of interest, given sufficient time they could grind through the detailed calculations.

One cautionary note, however. If students have never worked on a problem framed in this manner and one suddenly appears on a test, many of them will be confused and may do worse than they would have if the problem had called for all the calculations to be done. Once again, the rule is no surprises on tests. If you plan to use this device, be sure you work similar problems in class and then put some on homework, and *then* do it on the test.

- *Always work out a test from scratch when you have what you think is the final version, then revise it to eliminate the flaws you discover and try it again*. Consider giving the test to a colleague or teaching assistant to review.

  Professors don't want to do this—I certainly don't! There are only two choices, however. One is to write the test on Sunday night, give it a quick once-through to make sure there are no glaring errors, and administer it Monday morning. You'll usually find that the test is too long—only a handful of students have time to finish it, and some who really understand the material fail miserably because the only way they're capable of working is slowly and methodically. (Incidentally, people who work like that are the ones I want designing the bridges I drive across.) It may also happen—and frequently does—that 15 to 30 minutes into the test a puzzled student asks if something is missing from the statement of Problem 2, and you realize that you forgot to include an important piece of data. Telling the class at that point that they've been beating their heads against an impossible problem and then figuring out how to grade the test is not an experience you want to have.

  The only alternative is to do what I have suggested. I make up my test, think it's perfect, and then sit down with my stopwatch and take it. That's when the problems invariably surface. First, it's too long—in 32 years of teaching, I have yet to make up a test that wasn't too long on the first round. And there are underspecified problems and overspecified problems and poorly worded problems and problems that call for time-consuming but relatively pointless number-crunching. Then I revise—cleaning up some questions, eliminating busywork in others, eliminating others completely—and take the test again, and sometimes the revised version is acceptable and other times I have to go back and make still more changes.

- *Set up multiple-part problems so that the parts are independent*. For example, in Part (b) of a problem, say something like "*Assume the answer to Part (a) was 42.8 cm/s, regardless of what you actually got*." This technique provides two benefits. First, it decouples the parts of the problem, so that even if students can't get Part (a) they can show you whether or not they're able to do Part (b). Second, all the students will have the same starting point for Part (b), which will greatly simplify the grading. (This is a particularly important consideration in large classes.) The usual caution applies, however: give practice on problems like this before they show up on the exam.

- *Design 10–15% of the test to discriminate between A-level and B-level performance*. Much less and your better students will have little incentive to go for the highest levels of understanding they are capable of achieving; much more and the test loses discriminatory ability (the A students will do well and the B, C, and D students will be clustered together in the failing range). If you have included high level questions on your study guide—e.g., explanations of physical phenomena in terms of course concepts, troubleshooting exercises, or problems involving conceptual design or critical evaluation—use them to constitute this 10–15%.

- *Be generous with partial credit on time-limited tests for work that clearly demonstrates understanding and penalize heavily for mistakes on homework, where students have time to check their work carefully*. Instructors often get it backwards. They collect the homework, grade it superficially and check it as correct if it looks remotely like what they had in mind, and then take the test grading seriously and penalize students for making the same mistakes they got away with in the homework. If you have graders, tell them to count off enough for careless errors so that it stings. When the students come to you complaining about the harshness of the grading, say something like "Look, when you're a civil engineer, if you design 10 buildings and one of them collapses, they're not going to pat you on the back and give you a 90. Small mistakes can cost you a lot in the real world—this would be a good time for you to start learning to avoid them." In the artificial environment of an in-class exam, however, cut them some slack.

- *Don't deliberately design tests to make the average grade 60 or less*. Tests on which most grades are very low serve no useful purpose. While low grades in engineering, science, and math courses may on rare occasions reflect the students' wholesale laziness or incompetence (the default interpretation of instructors whose test averages are consistently low), they are much more likely to indicate that either the tests were poorly designed or the instructor did a poor job of teaching the students what they needed to know to do well. Low test grades are also demoralizing and can lead students who would be excellent professionals to conclude that they are in the wrong field.

- *If you give a test on which the grades are much lower than you anticipated and you believe some of the responsibility is yours, consider making adjustments*. The simplest method is to add the same number of points to everyone's grade so that the top grade is 100 or the average is 70. Another method is applicable when the grades are low because virtually everyone missed a particular problem, a situation almost certain to be the instructor's responsibility. When that happens in my class, I announce that I will give a variation of that problem as a quiz and that the students may add their quiz grade to their test score. By the time of the quiz, that class knows how to do that problem.

- *If you are teaching a large class and use teaching assistants to grade tests, take precautions to assure that the grading is consistent and fair*. Write out a detailed solution key and breakdown of the point values for every part of every problem (3 points for this, 1 point for that, etc.) and go over it carefully with the graders. Make sure that each problem is only graded by one person. Sit with the graders for the first hour or so and help them with difficult decisions about partial credit, tell them to consult with one another thereafter if they're not sure about something, and encourage them to contact you if they can't reach agreement among themselves. Glance through the graded tests to make sure that nothing strange has happened.

- *Institute a formal procedure for students to complain about test grades*. (This one is more to protect your time than to help the students.) Announce in your course guidelines that students have one week to register complaints about how a test was graded, after which complaints will not be heard. If the complaint is that the points were incorrectly totaled, the students simply have to show you (or the student grader) the graded exam, but if they think they deserve more points on one or more problems they must make their case in writing. Give such requests serious consideration and make the grade adjustments you believe are justified. The volume of complaints you have to deal with should drop by an order of magnitude, few or none of those you get will be frivolous, and never again will you have to deal with a flood of complaints on the last day of class about grading on a test given 12 weeks earlier.

In *Embracing Contraries,*[6] Peter Elbow notes that faculty members have two conflicting functions—gatekeeper and coach. As gatekeepers, we set and maintain high standards to assure that our students are qualified to enter the community of professional practice by the time they graduate, and as coaches we do everything in our power to help them meet and surpass those standards. Examinations are at the heart of both functions. By making our tests comprehensive and rigorous we fulfill the gatekeeper role, and by doing our best to prepare our students for them and ensuring that they are fairly graded, we satisfy our mission as coaches. The suggestions given in this paper are intended to help us serve well in both capacities. Clearly, adopting them can take time, but it is hard to imagine an expenditure of time more important to our students, their future employers, and the professions they will serve.

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TIPS ON TEST-TAKING[*]

Richard M. Felder, North Carolina State University
James E. Stice, University of Texas

Dear students,

In our combined 88 years of teaching, we noticed that many of our students made some serious mistakes when preparing for and taking our exams. They knew the material, solved the homework problems, and studied hard for the test, but their grades didn't reflect their knowledge or effort. We eventually put together a handout with some tips on exams and passed it out in our classes a week or two before the first midterm. We heard back from some students that the ideas helped them, and later heard from others who had ignored us and bombed the first test but then took the handout seriously and did much better on the second one. The tips follow—check them out and use what seems relevant.

Preparing for the test

1. ***Avoid cramming.*** Grinding away on problems for hours, especially the night before the exam, is a recipe for failure. Your brain needs time to process information, and a lot of the most important processing occurs subconsciously during sleep and breaks from studying. If you flood your brain with non-stop information, not much of it is likely to be stored in long-term memory and most of what is stored is unlikely to be retrievable on the test. Instead:
2. ***Start studying early and take breaks.*** Starting a few days before the exam, set a timer for about 30 minutes and focus exclusively on studying during that interval—no phoning, texting, surfing, email, computer games, TV, or anything else but studying. If possible, find a place to work where those distractions can't tempt you. When the time is up, stop, even if you're in the middle of a problem, and reward yourself with a break. Get a snack, take a walk, work on another course, or just relax. When you're ready, do another half hour. You'll be amazed at how often something that baffled you before seems clear now.
3. ***Don't waste time on useless activities.*** Several common test preparation strategies have been shown to have little or no effect on grades. Highlighting sentences in texts and passively reading worked-out problem solutions top the list. Highlighting is quick, and if it gives you the illusion that you're accomplishing something useful, go for it. Reading old solutions chews up time, though, and there are much better ways to spend the limited amount you have. So how *should* you prepare?
4. ***Practice solving as many different problems as you can***. Work through old homework problems, unassigned problems in the course text, and old exams. If you have solutions, don't look at them. *Set up the solutions, but don't bother doing all the algebra and number-crunching.* Those things take a lot of time and you don't learn much from them. If you get stuck, look back at the solution and then start again. Only when you can outline the entire solution without looking at one you have should you go on to another problem.
5. ***If you have old exams, don't limit your studying to them.*** The problems on the test coming up will almost certainly be different.

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[*] Adapted from *Chemical Engineering Education, 48*(1), 57–58 (2014). Some of the ideas to be presented were inspired by material in Oakley, B. (2014). *A Mind for Numbers.* New York: Tarcher-Penguin.

6. ***If you've been told to draw a diagram for a type of problem, do it again and again.*** While it's tempting to skip the preliminaries and just start writing equations, taking a few minutes to sketch that free-body diagram or flow chart or any other recommended visualization tool can turn killer problems into trivial ones.
7. ***After you've worked out a really hard problem, try outlining the solution without looking back.*** Once you can do that, you own that problem and others like it**.**
8. ***Study in small groups***. Make sure your study group contains only students who are serious about studying, ideally including some at your ability level or better. Leave the beer in the refrigerator until you're done studying.
9. ***Make up a one-page summary sheet of the key terms, ideas, formulas, etc., that you might need to know on the test***. If the test is closed-book, know what's on the sheet. If it's open-book, bring the sheet with you and add page numbers of key figures and tables.
10. ***Try to get a reasonable amount of sleep the night before the exam***. (See Item 1.) If that's not possible, at least try to get a brief nap: it might be enough to keep your brain functional long enough to get through the test.
11. ***If the exam is first thing in the morning, set up backups for your alarm clock and transportation.*** Set a second alarm, or arrange for a wake-up call. If you live off campus, leave early so you have time to call someone to pick you up if your car won't start.
12. ***Bring everything you need to the exam.*** Make a list the day before and go through it before you leave in the morning. Include your text if the exam is open-book, several pencils with erasers, handouts, and a *fully-charged* calculator, smartphone, or portable computer if you're allowed to use one on the test.

Taking the Test

13. ***Read over the whole test before writing anything***. Choose the problem or question that seems easiest to you and do it first, then choose the next easiest, and so on. You'll get the easiest points quickly and gain confidence as you move into the harder stuff.
14. ***Read each problem/question carefully and make sure you deliver everything asked for.*** Few things are more frustrating than wasting time on an impossible problem because you ignored a small detail in the problem statement, or losing major points because you forgot to do an easy calculation.
15. ***Show your work***. Give enough detail so that the grader can easily see what you're doing. Even if you can do the problem in your head and just write the answer down, don't. If you're wrong, you get a zero; if you're right, you could be suspected of cheating.
16. ***Watch the significant figures***. Some instructors don't appreciate answers like 23.694028, even though it's exactly what the calculator says.
17. ***Think partial credit***. Try to put something down for every part of every problem. If you don't have time to completely solve a problem, outline what you'd do if you had more time.
18. ***If you don't understand a question, ask the instructor/proctor for help***. You might get some, and it never hurts to try.

19. ***STAY IN MOTION, and budget your time***. Work on a problem until you get stuck. Think about it for a minute or two, and if nothing comes to you then drop it and go on to another problem. Don't spend 30 minutes sweating out an additional five points on a problem and run out of time, leaving a 40-point problem untouched. You may have time to return to the first one and you're much more likely to see how to do it then.

20. ***Don't panic***. If you feel yourself blanking out or hyperventilating, put down your pencil, close your eyes, take a few deep breaths, and consciously relax clenched muscles (jaw, neck, stomach) for 10–20 seconds. When you're calmer, go back to work.

21. ***If you have time at the end, check your solutions***. Did you answer every part of every question? Do your answers seem reasonable? Can you check them?

22. ***Hand in your paper when time is called***. Nothing irritates an instructor/proctor more than having to wrestle you to the floor to get your paper.

Good luck.
RF/JS

P.S. What if you do those things and still do poorly on the test? Try filling out the questionnaire at <*www.ncsu.edu/felder-public/Columns/memo.pdf*>.[*] If you check more than one or two "no" answers, you may get some insights into what you did wrong this time and avoid doing it next time.

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[*] See the next page of the notebook.

MEMO*
TO: Students who have been disappointed with their test grades
FROM: Richard M. Felder, North Carolina State University

Dear student,

Many of you have told your instructor that you understood the course material much better than your last test grade showed, and some of you asked what you should do to keep the same thing from happening on the next test.

Let me ask you some questions about how you prepared for the test. Answer them as honestly as you can. If you answer “No” to many of them, your disappointing test grade should not be too surprising. If there are still a lot of “No” responses after the next test, your disappointing grade on that test should be even less surprising. If your answer to most of these questions is "Yes" and you still got a poor grade, something else must be going on. It might be a good idea for you to meet with your instructor or a counselor to see if you can figure out what it is.

You'll notice that several of the questions presume that you're working with classmates on the homework—either comparing solutions you first obtained individually or actually getting together to work out the solutions. Either approach is fine. In fact, if you've been working entirely by yourself and your test grades are unsatisfactory, I would strongly encourage you to find one or two homework and study partners to work with before the next test. (Be careful about the second approach, however; if what you're doing is mainly watching others work out solutions you're probably doing yourself more harm than good.)

The question "How should I prepare for the test" becomes easy once you've filled out the checklist. The answer is...

Do whatever it takes to be able to answer “*Yes*” *to most of the questions.*

Good luck,
Richard Felder

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* *Chemical Engineering Education, 33*(2), 136-137 (1999).

Test Preparation Checklist

Answer "Yes" only if you *usually* did the things described (as opposed to occasionally or never).

Homework

__ Yes __ No 1 Did you make a serious effort to understand the text? (Just hunting for relevant worked-out examples doesn't count.)

__ Yes __ No 2 Did you work with classmates on homework problems, or at least check your solutions with others?

__ Yes __ No 3 Did you attempt to outline every homework problem solution before working with classmates?

__ Yes __ No 4 Did you participate actively in homework group discussions (contributing ideas, asking questions)?

__ Yes __ No 5 Did you consult with the instructor or teaching assistants when you were having trouble with something?

__ Yes __ No 6 Did you understand ALL of your homework problem solutions when they were handed in?

__ Yes __ No 7 Did you ask in class for explanations of homework problem solutions that weren't clear to you?

Test preparation

__ Yes __ No 8 If you had a study guide, did you carefully go through it before the test and convince yourself that you could do everything on it?

__ Yes __ No 9 Did you attempt to outline lots of problem solutions quickly, without spending time on the algebra and calculations?

__ Yes __ No 10 Did you go over the study guide and problems with classmates and quiz one another?

__ Yes __ No 11 If there was a review session before the test, did you attend it and ask questions about anything you weren't sure about?

__ Yes __ No 12 Did you get a reasonable night's sleep before the test? (If your answer is no, your answers to 1-11 may not matter.)

__ Yes __ No ***TOTAL***

The more "Yes" responses you recorded, the better your preparation for the test. If you recorded two or more "No" responses, think seriously about making some changes in how you prepare for the next test.

Grading Written and Oral Project Reports: Checklists and Rubrics[*]

- *Clearly formulate the criteria you will use to grade the reports, and put them in a* checklist (pp. C24 & C25) *or* rubric (p. C26). Using one of these instruments will make the grading both consistent and efficient. A good starting point designing a rubric to assess almost any written product or oral report is <*course1.winona.edu/shatfield/air/rubrics.htm*>.

  In what follows, we will use "rubric" to denote either a checklist or a rubric.

- *If possible, use at least two graders for all the reports*. The graders should independently mark all of the reports and then reconcile their ratings. If they cannot agree on a mark, they should average their individual marks. (If you can't get two graders, the rubric will still make the grading more consistent and efficient than it normally would be.)

- *Before they grade a large number of reports, the graders should get some training*. Give them several sample reports of varying qualities, and you and they should complete and reconcile rubrics for each sample. At that point, everyone should be on the same page regarding the meanings of the criteria.

- *Once you have a rubric, use it for teaching as well as grading*. Before the students begin working on their own reports, give them two sample reports or excerpts of reports of varying quality. Have them independently use your rubric to grade the samples, either in class or as homework. In class, have them get in pairs and reconcile their rubric for a report; then share the ratings you would have given and discuss your reasoning. Repeat for the other sample report. The students will then have a clear understanding of what you expect from them and what common mistakes to avoid, and their first efforts will be far better than what you would normally see if such training is not provided.

- *Be wary of giving detailed corrective feedback on final reports and essays.* It takes a huge amount of time for the grader, who frequently has to write the same corrections and suggestions over and over again, and students frequently just look at the grade and pay no attention to the detailed feedback. Instead, make brief comments on rubrics, and let students who want more detail come to you and ask for it. (Few will.)

- *Consider requiring and grading first drafts*. <u>Pro</u>: better products, greater learning. <u>Con</u>: more grading required. Providing detailed comments on drafts makes more sense than doing it on final versions.

- *Once the students have been trained in the use of the rubric, consider peer feedback*. In addition to or instead of you doing all the marking, have them grade one another's first drafts or final products. Especially if you collect and grade their rubrics the first one or two times, they will eventually be able to do your job for you, and you'll only need to spot-check their ratings.

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[*] R.M. Felder and R. Brent. (2010). "Hard Assessment of Soft Skills." *Chemical Engr. Education, 44*(1), 63–64, <*www.ncsu.edu/felder-public/Columns/SoftSkills.pdf*>.

Grading Checklist for Written Reports[*]

Team: ______________________________ **Project Phase:** ______________________

Date: ____________________ **Evaluator:** _________________________

	Possible Points	Score	Comments
Technical Content (60%)			
Topic mastery, including technical correctness	**20**		
All requested deliverables included	**15**		
Appropriate level of detail and thoroughness of documentation	**15**		
Completeness of analysis and interpretation of data	**10**		
Organization (15%)	**15**		
Clearly identified purpose & approach			
Content is clearly organized & supports purpose			
Good transition between topics			
Introduction and conclusion are tailored appropriately to the audience			
Presentation (15%)	**15**		
Easy to read			
Grammatically and stylistically correct			
Uniform writing style			
Layout/Visuals (10%)	**10**		
Quality of graphics			
Uniform document design and layout			
Total Score	**100**		

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[*] Courtesy of Dr. Lisa Bullard, Department of Chemical & Biomolecular Engineering, N.C. State University.

Grading Checklist for Oral Reports[*]

Team: ______________________________ Project Phase: _____________________

Date: ___________________ Evaluator: _________________________

	Possible Points	Score	Comments
Technical Content (60%)			
Topic mastery, including technical correctness	**20**		
All requested deliverables included	**15**		
Appropriate level of detail	**15**		
Completeness of data analysis and interpretation	**10**		
Organization (15%)	**15**		
Introduction clearly identifies purpose & approach, and previews main points of report			
Content is clearly organized & supports purpose			
Conclusion provides clear, memorable summary			
Introduction and conclusion are tailored appropriately to the audience			
Presenters respond to questions clearly, sufficiently, and succinctly			
Presentation includes logical transitions from one presenter to another			
Presentation (15%)	**15**		
Presenters are professional in dress, language, and style			
Movement, eye contact, and gestures enhance presentation			
Vocal quality is varied and illustrates interest in topic			
Presenters speak with appropriate pace and volume			
Presenters make reference to other parts of the presentation and connect their part to them			
Layout/Visuals (10%)	**10**		
Visuals are clear, consistent, readable and understandable			
Visuals accurately follow the oral presentation and provide a “visual map” of the presentation			

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[*] Courtesy of Dr. Lisa Bullard, Department of Chemical & Biomolecular Engineering, N.C. State University.

Grading Rubric for Oral Reports

Presenter: ________________________ **Project Phase:** ____________________

Date: __________________ **Evaluator:** _______________________

	1	2*	3	4*	5	R (1–5)	Wt**	R x Wt
Completeness	Many required parts missing or incomplete.		A few parts missing or incomplete.		Report complete.			
Organization	No logical sequencing of information.		Information presented in somewhat logical sequence.		Information presented in logical, interesting sequence.			
Delivery	Inaudible.		Moderately clear, somewhat animated.		Very clear, dynamic.			
Eye Contact	No eye contact.		Moderate eye contact with some of audience.		Good eye contact with entire audience.			
Graphics	Superfluous or no graphics.		Graphics that moderately support presentation.		Attractive graphics that consistently support presentation.			
Accuracy	Numerous serious errors.		Quite a few minor errors.		Very few or no errors			
Content Knowledge	Poor grasp of content.		Somewhat comfortable with content.		Full command of content.			
					Sum (S)	■	____	____
					Maximum (M) [5 x S(Wt)]	■	■	____
					Percentage (100 x S/M)	■	■	____

Homework

- Assign homework at least once a week.
- Provide repeated exercises in every technique you want students to learn and every skill you want them to acquire.
- Make most assigned problems drill-type exercises (routine practice problems). Make some more difficult, requiring analysis and/or synthesis. Make a few stretch the best students in the class.
- Assign particularly long or difficult problems for bonus credit.
- Count homework performance toward the final grade, even if by a token amount.
- Consider encouraging or requiring group homework sessions. If students can learn from one another (which they usually can) so much the better for everyone. Don't worry too much about some students getting free rides—they'll probably go down on the exams. For more suggestions on cooperative learning homework teams, see Section E of this notebook.
- **Be stingy about partial credit on homework and generous on tests.** Don't give them a free pass on homework, and then punish them for making the same errors on exams that they got by with on the homework. The homework is where they need to learn to be careful and check answers carefully. On time-limited tests where they may not have enough time to carefully check solutions, cut them some slack.
- Hand back graded homework quickly, preferably the period after it is collected.
- If you have a large class and few or no graders, it's legitimate to collect and grade only a subset of the assignments and/or to grade a subset of the problems in a given assignment.
- If you anticipate using problems in subsequent course offerings, try to outline solutions in class on the board as opposed to posting them.
- Accept late homework, but impose a penalty. (For example, if the assignment counts 10 points, give a maximum of 5 or 6 if it's late.) *If a student or homework team abuses this privilege, revoke it!*

Course Grading

- Should I grade on achievement? (Clearly!) Improvement? Attendance? Class participation? Effort? You decide, but make your decision known from Day 1 of the course.
- Should I curve grades or not?

  Answer: Do you want a grade "B" to mean (i) the student mastered the course material, or (ii) the student performed in the top 10-25% of the class, whatever he/she learned. If (i), don't curve. If (ii), curve.

  Recommendation: Don't curve (but make your tests reasonable).

  - Curving makes class competitive; not curving makes systematic cooperation possible.
  - It should be theoretically possible for every student to get an A (or an F).
- Possible grading scheme (see detailed example on p. B16)
  - Guaranteed floors for letter grades (e.g. $\geq$92 = A, $\geq$80 = B, etc.)
  - Gray area between each two letters (e.g. 89-91 = A/B or A–/B+, 76-79 = B/C or B–/C+,…), with challenge problems, upward or downward trend in test grades, class participation, attendance, etc., used to decide between higher and lower grade.
  - Consider a rule that the average exam grade must be above the passing grade level for the student to pass the course: a failing test grade cannot be raised to a passing course grade by averaging in homework grades, especially if students work together on homework.
  - State rules in writing on Day 1 of the course. *There should be no surprises in course grades.*
- Should I give incompletes? (*Recommendation*: Only for serious verified extenuating circumstances that kept students from completing the course requirements.)
- Should I fail seniors if my grade is all that stands between them and graduation? (*Recommendation*: Don't give an answer immediately, find out what university policy requires, and make sure their story is true. Beyond that, you're on your own.)

Additional Resources on Assessment of Learning

1. Angelo, T.A., Cross, K.P. (1993). *Classroom assessment techniques: A handbook for college teachers* (2nd Ed.) San Francisco: Jossey-Bass. Classroom assessment techniques (CAT's) have been adopted successfully by faculty across the country in diverse institutions and disciplines to help them monitor how students are learning. For an online tool that defines 12 of the most widely-used CAT's and gives examples in different fields, go to <*www.wcer.wisc.edu/nise/cl1/*>.
2. (a) Cohen, P.A. (1984). "College Grades and Adult Achievement: A Research Synthesis," *Res. in Higher Ed.*, *20*(3), 281–293; (b) G.E. Samson, M.E. Graue, T. Weinstein, & H.J. Walberg, "Academic and Occupational Performance: A Quantitative Synthesis," *Am. Educ. Res. Journal, 21*(2), 311–321 (1984). Two studies showing that grades in college courses have almost no correlation with professional success.
3. Diamond, R.M. (2008). *Designing & assessing courses & curricula: A practical guide*, 3rd Edn. San Francisco: Jossey-Bass. A classic reference that covers every aspect of its subject, from systematic curriculum design to writing specific learning objectives that address a broad range of desired learning outcomes.
4. Felder, R.M., and Brent, R. (2016). *Teaching and Learning STEM: A Practical Guide,* Ch. 8 (factual knowledge, quantitative problem-solving skills, conceptual understanding) and Ch. 10 (communication, creative thinking, critical thinking, and self-directed learning skills). San Francisco: Jossey-Bass.
5. Hattie, John (2009). *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. NY: Routledge. National Research Council. (2001). *Knowing what students know: The science and design of educational assessment.* Washington, DC: National Academy Press. A survey of the foundations, design, and practice of educational assessment.
6. Svinicki, M., & McKeachie, W.J. (2014). *McKeachie's teaching tips: Strategies, research, and theory for college and university teachers* (14th ed.), Ch. 7–10, Belmont, CA: Wadsworth. Practical ideas on assessing, testing, and evaluating student learning, preventing and handling cheating, and assigning course grades.
7. Walvoord, B.E., & Anderson, V.J. (1998). *Effective grading: A tool for learning and assessment.* San Francisco: Jossey-Bass. Suggestions for grading in the classroom and for broader assessment of faculty, departmental, and institutional assessment.

D. How can I be an effective lecturer and get students actively involved in class?

An education which is an active discovery of reality is superior to one that consists merely in providing the young with ready-made truths.
(Jean Piaget)

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 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.
- Have students write 1-2 page autobiographies as part of the first assignment. Try to tie course content to their goals and interests.
- 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 second week***. On Day 1, hand out a summary of key learning objectives covering the prerequisites to be used as a study guide, hold a review session (optional), and give the test. Count it toward the final grade. (This is an alternative to spending weeks re-teaching things they should have previously learned.)

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.
- 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.

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.
- ***Get students to brainstorm (or you survey) real-world applications of the course topics.***
- ***Inquiry-based strategy*****:** Present an open-ended problem that will require course material to solve. Have students briefly work in groups to outline how they would approach it. Subsequently use the problem to provide motivation and context for each new topic. Repeat the opening exercise at the end of the course to give students a sense of how much they have learned.

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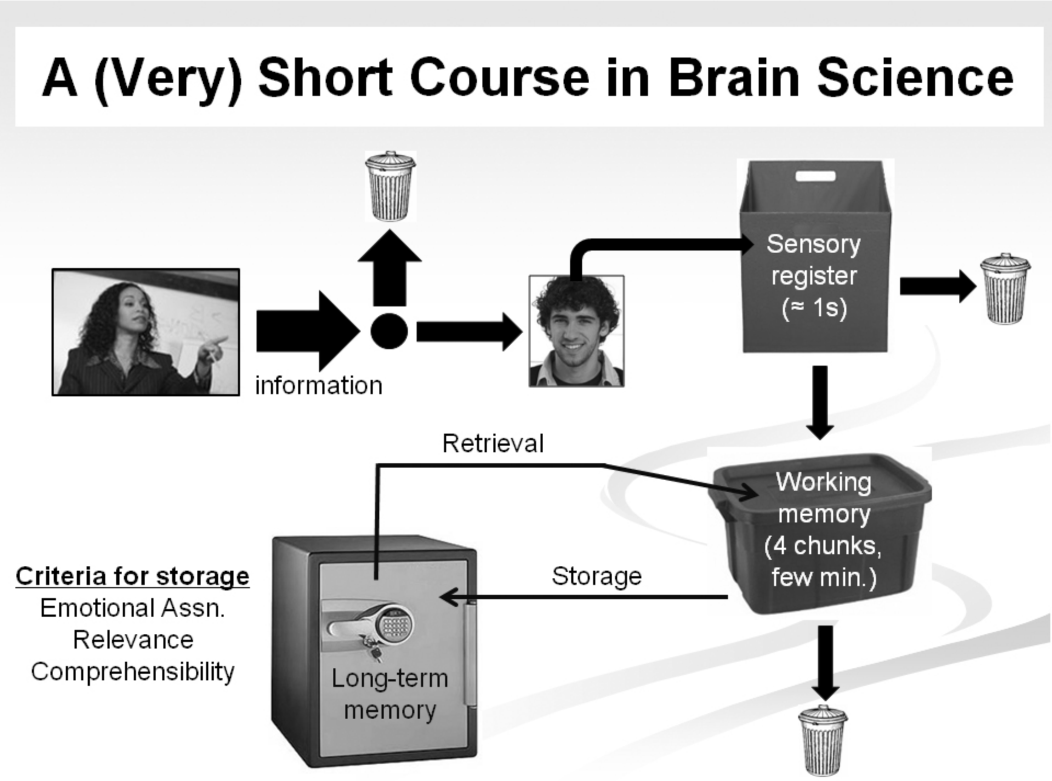
[*] R.M. Felder & R. Brent, *Teaching and Learning STEM: A Practical Guide,* Sect. 3.6. San Francisco: Jossey-Bass.



"Learning" is shorthand for encoding and storing information in long-term memory, from which it can later be retrieved and used. According to a widely used model of this process, new information comes in through the senses, is held for a fraction of a second in the *sensory register,* and is then either passed on to *working memory* or judged as unimportant and lost. Information that gets into working memory remains there for a few minutes or less (longer if the information is repeated), during which it is evaluated by an executive controller, and if it meets one or more of several criteria, is stored in *long-term memory*. If it isn't stored, it is permanently lost to the individual. The inputs to working memory most likely to be stored relate to (1) *threats* to the learner's survival or well-being. In descending order, the next most likely inputs are those with (2) *strong emotional associations* for the learner, (3) *relevance* (relationship to the learner's interests, goals, and existing stored knowledge), and (4) *sense* (comprehensibility).

It follows that if teachers present information irrelevant to anything students know and care about and it makes little sense to them, there should be no surprise if the students later act like they never heard it. It never made it into their long-term memory, so from their point of view they *didn't* hear it. Even if information makes it into long-term memory, unless it is reinforced by rehearsal (conscious repetition), the memory traces that contain it are weakly connected and the information may not be easily retrieved.

Another important thing to know is that working memory has a very limited capacity—roughly four "chunks" of information. When new information comes in from the sensory register, the controller judges whether it is more important than anything currently in working memory, and depending on the decision, either the new information or one of the old chunks is lost. An implication is that if learners are flooded with new information in a lecture at a rate much faster than the brain has time to process, the instructor can be sure that most of the lecture content (including the most important parts) won't be absorbed.

In short, *the more new information has relevance and comprehensibility to students and the more opportunities the students are given to process the most important parts of it, the more likely those parts are to be stored in long-term memory (learned). Once stored, the more often the information is retrieved and rehearsed, the more effective the learning is likely to be.* [See most references on modern cognitive science, such as Sousa, D.A. (2011). *How the brain learns* (4th ed.)].

Lecturing Tips[1]

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 online materials.
- *If it isn't written down, it will be ignored.* Plan what you will write on the board, tablet or document camera with an eye toward what you want students to have in their notes.
- ***Give out handouts with gaps***.[2] 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.[3]
  - 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. D6.

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[1] R.M. Felder and R. Brent, *Teaching and Learning STEM: A Practical Guide,* Ch. 4–5. San Francisco: Jossey-Bass.

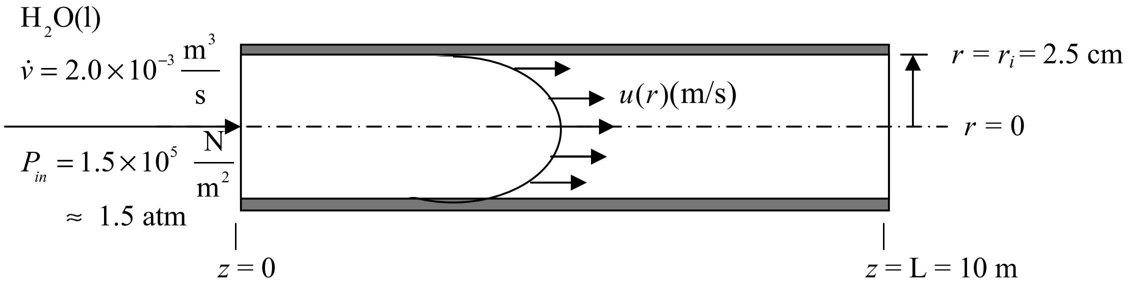
[2] R.M. Felder and R. Brent. (2015). Handouts with gaps. *Chem. Engr. Education, 49*(4), 239–240. <*www.ncsu.edu/felder-public/Columns/HandoutsWithGaps.pdf*>.

[3] 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.

Excerpt from a Handout with Gaps

Steady-state laminar flow: Incompressible Newtonian fluid in a horizontal circular pipe

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

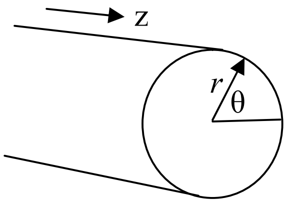


Water enters a 5.0-cm ID x 10.0 m long pipe at a volumetric flow rate $\dot{v}=2.0\times10^{-3}$ m^3/s and a pressure $P = 1.5\times10^5$ N/m^2 (150 kPa ~ 1.5 atm). Our goal is to find out as much as we can about relations among system variables at steady state.

$u(r,z)-$ local velocity profile

$\dot{v}(z)-$ volumetric flow rate

$P(r,z)-$ local fluid pressure



- Derive an expression for the mass flow rate, $\dot{m}$(kg/s), at the inlet, in terms of the velocity profile, *u(r)*. (Hint: first derive an expression for the volumetric flow rate.)

- 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. D9 for more ideas.)
- ***Avoid calling on individual students cold (giving them 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, course message boards and Facebook and Twitter accounts and anything else that actively engages students can greatly enhance learning; on the other hand, *don't turn your lectures into PowerPoint shows* (see p. D15).
- *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

- ***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*, <*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.
- *Do formative assessment in your class.* Carry out some of the formative techniques mentioned on p. C3 (midterm evaluations, minute papers and other classroom assessment techniques, ConcepTests, online quizzes, etc.). Use the results and whatever your summative assessments (exams, assignments, project reports) tell you about what's not working well to guide changes in your teaching.
- *Read about teaching.* The paper and electronic reference lists in this notebook offer good places to start learning about teaching. Check out publications (*College Teaching, J. Coll. Sci. Teaching, J. Engr. Education, J. Chem. Education, The Physics Teacher,...*), conferences and web sites for relevant professional organizations. Look back through this notebook for ideas or articles that interest you.
- *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.

ANY QUESTIONS?[4]

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

1. *"If a first-order reaction* A→B *with specific reaction rate* 3.76 (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 (an engineering freshman, a biology major, your non-scientist grandparents) could understand, briefly explain the concept of vapor pressure (viscosity, heat transfer coefficient, ideal solution).*[2]

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 gone. Sketch plots of T and h vs. time, labeling the temperatures at which abrupt changes in system behavior occur.*[3]

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[4] Adapted from *Chem. Engr. Education, 28*(3), 174-175 (1994).

[2] Warning: Don't ask your students to give a comprehensible definition of something like τ_{xx} or entropy or temperature or mass unless you're sure *you* can do it

[3] 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°C and then the liquid boils.

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?*[4]
- *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→B with specific reaction rate 3.76 (min^{-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.*

We 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. The usual approaches often don't work that well. If you ask the whole class a question and wait for someone to volunteer an answer, the students are likely to remain silent and nervously avoid eye contact with you until one of them (usually the same one) pipes up with an answer. On the other hand, if you call on individual students with questions, you are likely to provoke more fear than thought. No matter how kindly your manner and how many eloquent speeches you make about the value of wrong answers, most students consider being questioned in class as a setup for them to look ignorant in public—and if the questions require real thought, their fear may be justified.

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. Vary the procedure occasionally by having the students formulate answers individually, then work in pairs to reach

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[4] 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.

consensus. For more complex problems, you 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.[5]

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[5] For more information on helping students develop creative problem-solving abilities, see R.M. Felder and R. Brent, *Teaching and Learning STEM: A Practical Guide,* Section 10.3. San Francisco: Jossey-Bass (2016).

IS TECHNOLOGY A FRIEND OR FOE OF LEARNING?[1]

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 short video clip of her instructor discussing 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

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[1] Adapted from R.M. Felder and R. Brent, *Teaching and Learning STEM: A Practical Guide,* Ch. 7. San Francisco: Jossey-Bass (2016).

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.[5] 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 campus-based and online universities, 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.

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[5] Means, B, Toyama, Y., Murphy, R., Bakia, M., and Jones, K. (2010). *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies*. Washington, DC: U.S. Department of Education. Retrieved from <*www2.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf*>.

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 PowerPoint slides. 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 PowerPoint slides extensively, about 15 per class. He also handed out hard copies of the slides 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 slides 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 slides. 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 slides (usually about 8 -10 per class), and I handed out hard copies of the slides 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 slides 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 slides, 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 slides and used the chalkboard instead. Both said `yes.' For the rest of the semester, I went back to the chalkboard (no slides 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 PowerPoint.*"

* * *

The point of this column is not to trash PowerPoint. We use it 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 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

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[*] Adapted from *Chem. Engr. Education, 39*(1), 28-29 (2005).

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. The term "Death by PowerPoint" has been 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, 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 using resources like Google Images and YouTube.
- *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.

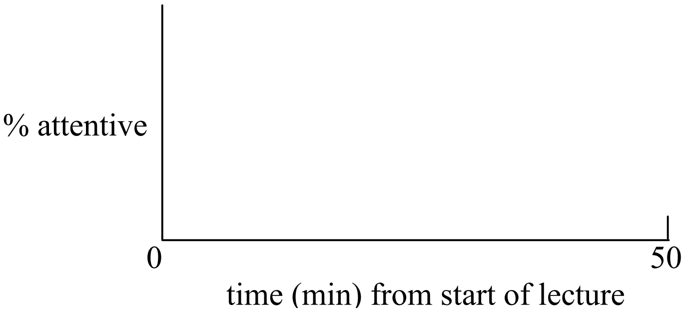
If there's an overriding message here, it is that doing too much of *anything* in a class is probably a mistake, whether it's non-stop lectures, non-stop slide shows, non-stop activities, or anything else that falls into a predictable pattern. If a teacher lectures for ten minutes, does a two-minute 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 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.

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, average number of students paying attention to the lecturer was monitored as a function of time.



Similar results reported in several studies:

- Bligh, D.A. (1998). *What's the use of lectures?* San Francisco: Jossey-Bass, Ch. 2.
- Bunce, D.M., Flens, E.A., & Neiles, K.Y. (2010). How long can students pay attention in class? A study of student attention decline using clickers. *J. Chem. Education, 87* (12), 1438–1443.
- Middendorf, J., & Kalish, A. (1996). The "change-up" in lectures. *National Teaching and Learning Forum, 5* (2), 1-5.
- Penner, J. (1984). *Why many college teachers cannot lecture*. Springfield, IL: Charles C. Thomas. See in particular a reference to a study conducted by J. McLeish.
- Stuart, J., & Rutherford, R. (1978). Medical student concentration during lectures. *The Lancet, 2*, 514–516.

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

- Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H., and Wenderoth, M.P. (2014). "Active learning increases student performance in science, engineering, and mathematics." *Proceedings of the National Academy of Sciences, 111*(23), 8410–8415. < *http://www.pnas.org/content/111/23/8410*>.
- Prince, M. (2004). "Does active learning work? A review of the research." *J. Engr. Education, 93*(3), 223-231, <*www.ncsu.edu/felder-public/Papers/Prince_AL.pdf*>.

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[*] Felder, R.M., & Brent, R. (2016). *Teaching and Learning STEM: A Practical Guide,* Ch. 6. San Francisco: Jossey-Bass .

Active learning structures

- **In-class teams.** Get class to form teams of 2-4 and choose team recorders. Give teams 10 seconds-3 minutes to
  - Recall prior material
  - Answer or generate a question
  - Start or work out the next step in a problem solution, derivation, or case study analysis
  - Think of an example or application
  - Explain a concept
  - Figure out why a predicted outcome turned out to be wrong (troubleshoot)
  - 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 discuss answers with other pairs before sharing.
- **Flipped classroom.** Students watch commercial or instructor-prepared screencasts or online tutorials before class sessions, then spend the sessions on active learning exercises that build on the online lessons. This technique, which is becoming popular in both K-12 and higher education, is powerful, *but it is only as good as the online materials provided to the students*. Complete screen-captured lectures, readings, and slide shows are not effective: 3–10-minute screencasts (e.g., <*www.khanacademy.org*>), demonstrations, and interactive tutorials are.
- **ConcepTests.** Ask class challenging multiple-choice conceptual questions, with distracters that reflect common misconceptions. Students vote individually, then pair and discuss, then vote again. Discuss why wrong answers were wrong. Initially "clickers" were used to do the polling and sometimes still are, but currently systems (such as Poll Everywhere, <*www.polleverywhere.com*>) are more often used that allow students to enter their votes using their own mobile phones or personal computers. Libraries of ConcepTests can be found online by entering "ConcepTests ____" into a browser, where ____ is the subject being taught.
- **Guided reciprocal peer questioning.**[6] 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.
- **Cooperative note-taking pairs.**[7] 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 and note-taking skills.

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[6] King, A. (1993). From sage on the stage to guide on the side. *College Teaching, 41* (1), 30-35.

[7] Johnson, D.W., Johnson, R.T., & Smith, K.A. (1998). *Active learning: Cooperation in the college classroom* (2nd ed.). Edina, MN: Interaction Book Co.

- **Pair programming.**[8] 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**[9,10] 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.
- **TAPPS**[11] (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.
  - Get students in pairs & have them identify one problem-solver (or explainer, if the solution is available) and one listener (or questioner).
  - Define the first activity (e.g., read and explain the problem statement) and give pairs a short time to do it. Problem solver works though first step of solution or explains first passage of text. Listener questions, gives hints when necessary, and keeps the problem solver talking.
  - After several minutes, stop the activity, call on several randomly chosen students to explain it to you. When explanation is complete, elaborate on it if appropriate, have pairs reverse roles and continue.

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[8] Williams, L., and Kessler, R. (2002). *Pair programming illuminated*. Boston: Addison-Wesley. See also <*openseminar.org/se/modules/3/index/screen.do* >.

[9] Brent, R., & Felder, R. M. (1992). Writing assignments—Pathways to connections, clarity, creativity. *College Teaching, 40* (2), 43–47. < *www.ncsu.edu/felder-public/Papers/Writing_Paper.pdf* >

[10] Young, A. (1999). *Teaching writing across the curriculum* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

[11] Lochhead, J., & Whimbey, A. (1987). Teaching analytical reasoning through thinking aloud pair problem solving. In J. E. Stice (Ed.), *Developing critical thinking and problem-solving abilities: New directions for teaching and learning, No. 30.* San Francisco: Jossey-Bass.

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.*
- ***Avoid the three fatal mistakes of active learning.***[*]

  Mistake 1: Making activities trivial. If you ask a question with an obvious answer and tell students to get into groups to answer it, you're wasting their time and many will resent it. **Rule: Make activities challenging enough to justify the time it takes to conduct them.**

  Mistake 2: Making activities too long. If too much time is allowed for activities, faster students will finish early and wander off-task, and slower students will be frustrated by having to struggle for a long time, much of which is likely to be wasted. **Rule: Keep activities short and focused.** A good rule of thumb is to keep them between ten seconds and three minutes. If you are working on a problem that takes more than three minutes to solve, break it into shorter chunks.

  Mistake 3: Call on volunteers at the end of every activity. If you do that, some students will realize that they can simply ignore the activity and eventually someone else (such as you) will provide the correct response. **Rule: After stopping some activities, call randomly on individuals or groups to respond**. If students know they could be called on after every activity, fear of embarrassment will motivate most of them to do what the activity calls for.
- *For longer exercises, circulate around the classroom and assist when called upon.*
- *Mix things up.* Don't get into a pattern with in-class exercises of always doing the same thing (lecture 10 minutes, 2-minute exercise,…). Vary it 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

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[*] For more details on common mistakes and how to avoid them, and information about common concerns about using active learning and how to lay them to rest, see Felder, R.M., and Brent, R. (2016). *Teaching and Learning STEM: A Practical Guide,* pp. 122–128. San Francisco: Jossey-Bass.

SERMONS FOR GRUMPY CAMPERS[*]

In workshops, we 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] We 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. We've developed several mini-sermons to help with this process. If any look useful, feel free to appropriate them.

* * *

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.)"

* * *

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.*'

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[*] Adapted from R.M. Felder and R. Brent, *Teaching and Learning STEM: A Practical Guide,* pp. 243–244. San Francisco: Jossey-Bass (2016).

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.[4] 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."

* * *

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."

* * *

And that's that. Our suggestion is to put your own spin on those sermonettes and trot them out when the right occasion presents itself. While we don't guarantee that they will immediately convert all students into believers—in fact, we guarantee they won't—our 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 us give you one more encouraging word about student resistance to learner-centered teaching methods. Our colleague Lisa Bullard uses cooperative learning in both an introductory sophomore chemical engineering course and the capstone senior design course. She once told us 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.

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2. K.A. Smith, S.D. Sheppard, D.W. Johnson, & R.T. Johnson, "Pedagogies of Engagement: Classroom-Based Practices," *J. Engr. Education, 94*(1), 87–101 (2005).
3. R.M. Felder and R. Brent, "Navigating the Bumpy Road to Student–Centered Instruction," *College Teaching, 44* (2), 43–47 (1996), <*www.ncsu.edu/felder-public/Papers/Resist.html*>.
4. R.M. Felder, "The Alumni Speak," *Chem. Engr. Education, 34*(3), 238-239 (2000), <*www.ncsu.edu/felder-public/Columns/alumni.html*>.

LEARNING BY SOLVING SOLVED PROBLEMS[*]

See if this one sounds familiar. You work through an example in a lecture or tell the students to read it in their textbook, then assign a similar but not identical problem for homework. Many students act as though they never saw anything like it in their lives, and if pressed they will claim they never did. It is easy to conclude—as many faculty members do—that the students must be incompetent, lazy, or incapable of reading.

A few of our students may be guilty of those things, but something else is behind their apparent inability to do more than rote memorization of material in lectures and readings. The problem with lectures is that it's impossible for most people to learn much from a bad one, while if the lecturer is meticulous and communicates well, everything seems clear: the hard parts and easy parts look the same; each step seems to follow logically and inevitably from the previous one; and the students have no clue about the hard thinking required to work out the flawless derivation or solution going up on the board or projection screen. Only when they confront the need to do something similar on an assignment do they realize how much of what they saw in class they completely missed.

It's even worse when an instructor tells students to read the text, fantasizing that they will somehow understand all they read. There are two flaws in this scenario. Many technical texts were not written to make things clear to students as much as to impress potential faculty adopters with their rigor, so they are largely incomprehensible to the average student and are generally ignored. On the other hand, if a text was written with students in mind and presents things clearly and logically, we are back to the first scenario—the students read it like a novel, everything looks clear, and they fail to engage in the intellectual activity required for real understanding to occur.

A powerful alternative to traditional lectures and readings is to have students go through complete or partially worked-out derivations and examples in class, explaining them step-by-step to one another. One format for this technique is an active-learning structure called *Thinking-Aloud Pair Problem Solving*, or TAPPS [Felder & Brent, 2009; Lochhead & Whimbey, 1987]. It goes like this.

1. Prepare a handout containing the derivation or solved problem to be analyzed and have the students pick up a copy when they come in to class. Tell them to form into pairs (if the class has an odd number of students, have one team of three) and designate one member of each pair as *A* and one as *B* (plus one as *C* in the trio).
2. When they've done that, tell them that initially *A* will be the *explainer* and *B* (and *C*) will be the *questioner(s).* The explainers will explain a portion of the handout to the questioners, line-by-line, step-by-step, and the questioners will (a) *ask questions* (if the explainers say anything incorrect or confusing), (b) *prompt the explainers to keep talking* (if they fall silent), and (c) *give hints* (if the explainers are stuck). If both members of a pair are stuck, they raise their hands and the instructor comes over and helps. The second function is based on the fact that vocalizing one's thinking about a problem sometimes leads to the solution.
3. The students first individually read the description of the formula or model to be derived or the statement of the problem to be solved; then the explainers explain it in detail to the

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[*] *Chem. Engr. Education, 46*(1), 29–30, (2012). <*www.ncsu.edu/felder-public/Columns/WorkedSolutions.pdf*>.

questioners and the questioners ask questions, keep the explainers talking, and offer hints when necessary. Give the class 2–3 minutes for this activity.

4. Stop the students when the allotted time has elapsed, randomly call on several of them to answer questions about the description or problem statement they just went through, and call for volunteers if additional responses are desired. Add your own explanations and elaborations (you're still teaching here). Then have the pairs reverse roles and work through the first part of the derivation or problem solution in the same manner. When results are obtained that are not in the handout, write them on the board so everyone can see and copy them. Proceed in this alternating manner through the entire derivation or solution.

After going through this exercise, the students *really* understand what they worked through because they explained it to each other, and if they had trouble with a tricky or conceptually difficult step they got clarification in minutes. Now when they tackle the homework they will have had practice and feedback on the hard parts, and the homework will go much more smoothly for most of them than it ever does after a traditional lecture.

Cognitive science provides an explanation for the effectiveness of this technique [Ambrose *et al.*, 2010; Sweller & Cooper, 1985]. Experts have developed cognitive structures that enable them to classify problems in terms of the basic principles they involve and to quickly retrieve appropriate solution strategies, much the way expert chess players can quickly plan a sequence of moves when they encounter a particular type of position. Novices—like most of our students—don't have those structures, and so they have the heavy *cognitive load* of having to figure out how and where to start and what to do next after every single step. Faced with this burden, they frantically scour their lecture notes and texts for examples resembling the assigned problems and focus on superficial details of the solutions rather than trying to really understand them. They may learn how to solve nearly identical problems that way, but even moderate changes can stop them cold.

Ambrose *et al.* and Sweller and Cooper report studies showing that students are indeed better at solving new problems when they have first gone through worked-out examples in the manner described. When they have to explain a solution to a classmate, their cognitive load is dramatically reduced because they don't have to figure out every trivial detail in every step—most of the details are right there in front of them. Instead, they have to figure out *why* the steps are executed the way they are, which helps them understand the key features of the problem and the underlying principles. The effect is even greater if they are given contrasting problems that look similar but have underlying structural differences, such as a mechanics problem easily solved using Newton's laws and a similar one better approached using conservation of energy. Having to explain why the two problems were solved in different ways helps equip the students to transfer their learning to new problems.

Give it a try. Pick a tough worked-out derivation or solved problem, and instead of droning through it on PowerPoint slides, put it on a handout—perhaps leaving some gaps to be filled in by the students—and work through it as a TAPPS exercise. Before you do it for the first time, read Reference 2, note the common mistakes that reduce the effectiveness of active learning (such as making activities too long or calling for volunteers after each one), and avoid making them. After several such exercises, watch for positive changes in your students' performance on homework and tests and in their attitudes toward the class. Unless a whole lot of research is wrong, you will see them.

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Additional Resources on Lecturing and Active Learning

Lecturing

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- Svinicki, M., & McKeachie, W.J. (2014). *McKeachie's teaching tips: Strategies, research, and theory for college and university teachers* (14th ed.), Ch. 5, 6, 18. Belmont, CA: Wadsworth.
- Wankat, P.C. (2002). *The effective, efficient professor.* Boston: Allyn & Bacon. Chapter 5: Lecture-style classes.

Active Learning

- Two videos available on YouTube:
  (1) Creating partnerships: Active learning in an engineering class, with Richard Felder and Rebecca Brent. < *https://www.youtube.com/watch?v=0p7gNXGvcww*>
  (2) Active learning, with Richard Felder. <*https://www.youtube.com/watch?v=1J1URbdisYE*>
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Additional Resources on Technology

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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 dysfunctionalities 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.

CATME
SMARTER Teamwork

- Prepares students to function effectively in teams
- Supports faculty in managing student teams’ experiences
- Web-based & free for use in higher education

www.CATME.org

Team-Maker	Assigns students to teams using instructor-specified criteria selected from a list of questions or written by the instructor.
Peer Evaluation	Collects and summarizes student self- and peer evaluations. Provides feedback to students and data to the instructor.
Rater Calibration	Teaches students to rate accurately and increases their understanding of how to be an effective team member.
Meeting Support	Provides templates for team charters, meeting agendas, and meeting minutes.
Teamwork Training	Trains students to work in teams by providing information, demonstration, practice, and feedback (in development).

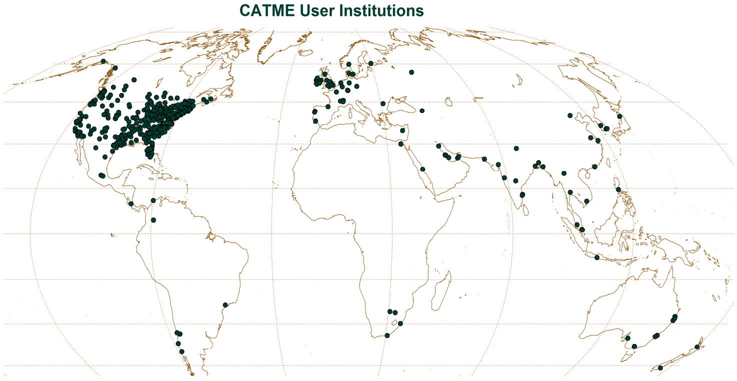
The CATME model of teamwork has five dimensions, shown above.

CATME helps instructors to:

- Gather information from students and provide feedback to students.
- Understand their student teams’ processes, team-members’ contributions, and students’ perspectives on their experience.
- Be aware of problems occurring in their students’ teams
- Hold students accountable for contributing to their teams.
- Use best practices when managing student team experiences.

CATME users

CATME has been free for academic use since 2003. The system is used by over 3,200 faculty at more than 600 institutions in 48 countries. More than 150,000 students have used the system.



Learn about the project history, publications, presentations, meeting support templates, contact information, and how to start using CATME Team Tools at www.CATME.org.

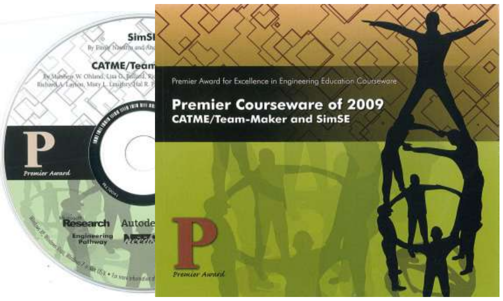
Awards recognizing CATME and related scholarship

The Maryellen Weimer Scholarly Work on Teaching and Learning Award (2013) recognizes outstanding scholarly contributions with the potential to advance college-level teaching and learning practices. The award recognized the paper "The Comprehensive Assessment of Team Member Effectiveness: Development of a Behaviorally Anchored Rating Scale for Self and Peer Evaluation" published in *Academy of Management Learning & Education* in December 2012 and awarded at The Teaching Professor Conference, New Orleans, May 31–June 2, 2013.

The Comprehensive Assessment of Team Member Effectiveness: Development of a Behaviorally Anchored Rating Scale for Self- and Peer Evaluation

The MED Best Symposium in Management Education and Development Award (2011) is sponsored by McGraw Hill/Irwin for the symposium at the Annual Meeting of the Academy of Management that offers the most significant contribution to advance management education and development. It was awarded to Misty L. Loughry, Matthew W. Ohland, David J. Woehr, Eric Lamm, Antoaneta Petkova, Timothy M. Madden, and Mark E. Collins for "Team-Based Learning and Peer Evaluation in Management Education: Issues, Challenges, and Solutions" in Antonio, TX, August 12–16, 2011.

The Premier Award for Engineering Education Courseware (2009) is an international award for non-commercial courseware that enhances engineering education. It was awarded by NEEDS & Engineering Pathway to the development team of Comprehensive Assessment of Team Member Effectiveness (CATME) and Team-Maker at the 2009 Frontiers in Education Conference in San Antonio, TX, October 18–21, 2009.



Citations for CATME Peer Evaluation

Ohland, M.W., Loughry, M.L., Woehr, D.J., Finelli, C.J., Bullard, L.G., Felder, R.M., Layton, R.A., Pomeranz, H.R., & Schmucker, D.G. (2012). The Comprehensive Assessment of Team Member Effectiveness: Development of a Behaviorally Anchored Rating Scale for Self and Peer Evaluation. *Academy of Management Learning & Education*, 11 (4), 609–630.

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Citation for CATME Team-Maker

Layton, R.A., Loughry, M.L., Ohland, M.W., & Ricco, G.D. (2010). Design and validation of a web-based system for assigning members to teams using instructor-specified criteria. *Advances in Engineering Education*, 2 (1), 1–28.

Resources for Cooperative Learning

To get an overview of CL:

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2. Michaelson, L.K., Knight, A.B., and Fink, L.D. (2004). *Team-Based Learning: A Transformative Use of Small Groups in College Teaching.* Sterling, VA: Stylus.
3. Millis, B.J., ed. (2010). *Cooperative Learning in Higher Education: Across the Disciplines, Across the Academy.* Sterling, VA: Stylus.
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To find practical suggestions for CL structures and troubleshooting:

5. Felder, R.M., & Brent, R. (1996). Navigating the bumpy road to student-centered instruction. *College Teaching, 44*(2), 43–47, <*www.ncsu.edu/felder-public/Papers/Resist.html*>.
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11. Svinicki, M., & McKeachie, W.J. (2014). *McKeachie's Teaching Tips: Strategies, Research, and Theory for College and University Teachers* (14th ed.), Ch. 14. Florence, KY: Cengage Learning.

To assess the performance of individual members of project teams

12. *CATME Smarter Teamwork*, <*www.catme.org*>. A set of online resources to use with teams including a powerful and extensively validated Web-based peer rating tool and an online tool (Team-Maker) that can be used for forming teams using criteria specified by the instructor. See pp. D32–D33 for more information.
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24. *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. <*www.ncsu.edu/felder-public/CL_forms.doc*>
25. *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. <*www.iasce.net/*>

E. What student problems am I likely to face? What problem students am I likely to face? What can I do about them?

There is no decent, adequate, respectable education, in the proper sense of that much-abused word, without personal involvement by a teacher with the needs, concerns, academic and personal, of his/her students. All the rest is "instruction" or "information transferral," "communication technique," or some other impersonal and antiseptic phrase, but it is not teaching and the student is not truly learning.

Page Smith, *Killing the Spirit*

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? *

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* To see our recommendations, go to <*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 <*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?

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!

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* R.M. Felder & R. Brent, *Teaching and Learning STEM: A Practical Guide,* Sect. 3.6.4. San Francisco: Jossey-Bass (2016).

Suggestions for Addressing Academic Integrity Issues*

1. **Integrate the concept of academic integrity into 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. **Establish clear expectations about what will and will not be considered cheating**
   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.
3. **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.
4. **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.
5. **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.
6. **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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* See L.G. Bullard & A.T. Melvin, "Using a role-play video to convey expectations about academic integrity," *Advances in Engineering Education, 2*(3), Winter 2011, <*advances.asee.org/vol02/issue03/02.cfm*>.

Examples of syllabus language that addresses academic integrity

Example 1:

Academic integrity. Students should refer to the University policy on academic integrity found at <*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, <*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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[*] *Chemical Engineering Education, 45*(1), 37–38 (2011).

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.[2] 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 online 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.[22][*]

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.
- *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

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[*] <*www.che.ncsu.edu/bullard/Academic_integrity.htm*> contains links to clips from the video and the policy statements and reflection assignment.

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

1. Carpenter, D.D., Harding, T.S., and Finelli, C.J. (2010). Using research to identify academic dishonesty deterrents among engineering undergraduates. *Intl. J. Engineering Education, 26*(5), 1156–1165. See also Carpenter *et al.*, (2006). Engineering students' perceptions of and attitudes toward cheating. *J. Engr. Education, 23*(4), 181–194.
2. Bullard, L.G., and Melvin, A.T. (2011). Using a role-play video to convey expectations about academic integrity. *Advances in Eng. Education*, *2*(3), 1–12.
3. Felder, R.M. (2009). The ten worst teaching mistakes. II. Mistakes 1–4. *Chem. Engr. Education, 43*(1), 15–16.

IMPOSTORS EVERYWHERE[*]

Richard M. Felder
North Carolina State University

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: 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.

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[*] *Chem. Engr. Education, 22*(4), 168–169 (Fall 1988). Access at *www.ncsu.edu/felder-public/Columns/Impostor.html.*

[**] Pauline R. Clance. (1985). *Impostor Phenomenon: Overcoming the Fear that Haunts Your Success*. Atlanta: Peachtree Pubs.

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.

Chem. Engr. Education, 35(4), 266-267 (2001)

FAQs. IV. DEALING WITH STUDENT BACKGROUND DEFICIENCIES AND LOW STUDENT MOTIVATION

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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.[2] 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[3] 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,[3] 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[4] 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[4] 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.

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3. R. Brent and R.M. Felder, "Objectively Speaking," *Chem. Engr. Education, 31*(3), 178–179 (1997). Available online at the URL in Reference 1.

Additional Resources on Classroom Management, Advising, and Academic Misconduct

Classroom Management

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Advising

- Felder, R.M. (1988) "Impostors everywhere." *Chem. Engr. Education*, *22*(4), 168-169.
  The Impostor Phenomenon ("Everyone around me really belongs here but I really don't").
  Access at *www.ncsu.edu/felder-public/Columns/Impostor.html.*
- Felder, R.M., & Stice, J.E. "Tips on test-taking." Good practices in preparing for tests and taking them. Access at *www.ncsu.edu/felder-public/Papers/testtaking.htm*
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Academic Misconduct (Cheating)

- Bullard, L.G., & Melvin, A.T. (2011). Using a role-play video to convey expectations about academic integrity. *Advances in Engineering Education, 2*(3). Access at *advances.asee.org/vol02/issue03/02.cfm*.
- *Center for Academic Integrity*, <*www.academicintegrity.org/index.asp*>. A Duke University facility that provides numerous resources for addressing misconduct problems at institutional levels and in individual classrooms.
- Felder, R.M. (2011). How to stop cheating (or at least slow it down). *Chem. Engr. Education, 45*(1), 37–38.
- Svinicki, M., & McKeachie, W.J. (2014). *McKeachie's teaching tips: Strategies, research, and theory for college and university teachers* (14th ed.), Ch. 8. Belmont, CA: Wadsworth.
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F. How can new faculty members get off to a good start?

One fact stands out in my 20 years of studying new faculty. Almost all the failures and miseries of these new hires owed to misunderstandings about effective ways of working and socializing. Never, in my close observations of over a thousand novice professors, did I see someone falter for reasons of inexpertise in his or her area of scholarship. Or from lack of desire. Instead, the most telling mistakes were easily correctable problems such as not understanding how to moderate student incivilities in classrooms, not knowing how to manage enough writing for publication in modest amounts of time, and not learning how to elicit effective collegial support.

(Robert Boice)

Success Strategies for New Faculty

New faculty members are stressed by several things:

- Too much to do and too little time to do it in;
- Inadequate feedback and recognition (so that they don't know how well they are progressing toward promotion and tenure)
- Unrealistic expectations (imposed on them by their department head, and imposed by them on themselves)
- Lack of collegiality in their department
- The challenging of balancing demands of work and personal life

Under-represented minority faculty members (including women in engineering) are subjected to additional stressors:

- A chilly climate toward minorities from administrators and faculty colleagues
- Excessive student demands (minority students seek guidance from minority faculty members, men and women alike look to women faculty members for counseling)
- Excessive committee assignments (stemming from a well-meaning desire to have diversity on committees)

Robert Boice[23] studied career trajectories of hundreds of new faculty members. He found that roughly 95% of them took 4–5 years to meet their institutions' expectations for research productivity and teaching effectiveness, and the other 5%—the *quick starters*—met or exceeded research expectations and scored in the top quartile of teaching evaluations within their first 1–2 years. Boice identified mistakes the 95% routinely made that limited their productivity and effectiveness and strategies the quick starters used to avoid the mistakes, and he also found that new faculty members could be taught to use the same strategies.

Mistake #1: Giving proposal and paper writing the highest verbal priority while spending relatively little time on them and producing relatively little. Concentrating on the most pressing tasks (e.g., preparing for tomorrow's class) and waiting for "blocks of uninterrupted time" to do the "real writing."

- *Consequences:* Lack of productivity, and anxiety about it. Long warm-up time when and if the blocks of time appear.
- *Success Strategy #1.* Schedule regular time—30–45 min/day, or 2–3 longer blocks weekly—for scholarly writing (proposals, papers, reports)
  - Make appointment with yourself
  - Work away from office
  - Freewrite first, then revise[24]
  - Keep time log for a week (see how much time is spent on nonessential activities)

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[23] Boice, R. (1992). *The New Faculty Member.* San Francisco, CA: Jossey-Bass, and Boice, R. (2000). *Advice for New Faculty Members.* Needham Heights, MA: Allyn & Bacon.

[24] Felder, R.M., and Brent, R. (2008). How to write anything. *Chem. Engr. Education, 42*(3), 139–140. <*www.ncsu.edu/felder-public/Columns/WriteAnything.pdf*>. Reprinted on p. F7.

- *Results.*
  - Regular sessions → maintain momentum, less warm-up time
  - Steady progress → less anxiety

Mistake #2: Overpreparing for classes. Spending nine hours or more preparing for each lecture hour. Equating good teaching with complete & accurate notes. Attempting to be ready for any question.

- *Consequences:* Too much material. Rush to cover syllabus, little time for questions or activities in class. Little time for anything else, including scholarship & personal life.
- *Success Strategy #2.* Limit preparation time for class, especially after first offering. Shoot for 2 hours preparation per lecture hour. Often won't make it, but if it's 8–10, it's a problem.
- *Results.*
  - Less material to cover → more time to cover it well, better learning.
  - Less preparation time → more time for scholarship & personal life.

Mistake #3: Working non-stop and alone. Waiting for colleagues to come to them.

- *Consequences:* Failure to get available support. Failure to learn faculty culture. Sense of isolation, depression.
- *Success Strategy #3.* 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,…), figure out which colleagues are likely to be helpful and seek them out.[25]
- *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 don't help achieve long-term goals, and failing to take steps that *would* help.

- *Consequences:* Becoming spread too thin. Falling behind in tenure quest. Anxiety, depression.
- *Success Strategy #4.* Develop clear goals and specific milestones for reaching them (proposals, papers, conference presentations, new course preps,...). Get periodic feedback from department head and senior colleagues.
- *Results.* Make commitments wisely. Maximize chances of reaching goals.

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[25] Rockquemore, K.A. (2011). Will you be my mentor? *Inside Higher Education,* November 14, 2011. <*www.insidehighered.com/advice/2011/11/14/essay-mentoring-and-minority-faculty-members*>.

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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, 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 and let their voice mail take their calls. If you're not one of them, your only alternative is to get out of the office. Do it and watch your productivity rise.
- *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.

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[*] However, if your department head or dean is the one doing the asking, it's advisable to have a good reason for saying no.

HOW TO WRITE ANYTHING*

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> *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 come as a surprise. If there is no firm due date, the project simply never gets done: the book

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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.

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.[26]

Richard M. Felder and Rebecca Brent
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- 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[27]:

  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 or dissertation, 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.[28]

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[26] P.C. Wankat & F. S. Oreovicz, *Teaching Engineering,* New York: McGraw-Hill, 1993. Chapter 2 contains excellent ideas on efficiency, some of which are included in this list.

[27] S.P. Covey, A.R. Merrill, and R.R. Merrill, *First Things First*, New York: Simon & Schuster, 1994.

[28] R. Boice, *Advice for New Faculty Members,* Boston: Allyn and Bacon, 2000. This book is filled with terrific suggestions especially designed to help new faculty develop balanced work habits.

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.
- 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. Good enough is good enough.
- 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 on Mentoring and Starting Academic Careers

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

- Boice, R. (1992). *The new faculty member.* San Francisco, CA: Jossey-Bass.
  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.
- Leaming, D.R. (2006). *Academic leadership: A practical guide to chairing the department (*2nd ed). San Francisco: Jossey-Bass. Developing a vision, working with constituents, retaining students, conflict management, mentoring faculty, and post-tenure review.
- Rice, R.E., Sorcinelli, M. D., & Austin, A. (2000). *Heeding new voices: Academic careers for a new generation.* Washington, DC: American Association for Higher Education. 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 <styluspub.com>.
- Zachary, L.J. (2012). *The mentor's guide: Facilitating effective learning relationship (*2nd ed.). San Francisco, CA: Jossey-Bass. 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, R. (2000). *Advice for new faculty members.* Needham Heights, MA: Allyn & Bacon. A practical book for new faculty members and their mentors based on Boice's 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.
- *Chronicle of Higher Education* advice columns*,* *<http://www.chronicle.com/section/Advice/66/?cid=UCHETOPNAV>.*
- Lucas, C.J., & Murry, J.W. (2011). *New faculty: A practical guide for academic beginner,*(3rd ed.). New York: Palgrave Macmillan. Advice on teaching methods, advising, getting published, grantsmanship, service, and legal issues.

G. Epilogue

Checklist for Preparing a Course

Learning (Instructional) Objectives

1. Have you clearly identified what students should be able to do after each section of material? (Use the objectives in Section B of this workshop notebook as examples.)
2. Do some of the objectives cover higher levels in Bloom's Taxonomy?
3. Are your objectives reasonable given the amount of time you have for the course?

Learning Styles

1. Do you have a balance of concrete, real world examples (sensing learners) and unifying principles or research support (intuitive learners)?
2. Have you included visuals (visual learners) in addition to words and explanations (verbal learners) for all important concepts?
3. Have you provided opportunities for active participation (active learners) and time for individual thinking (reflective learners)?
4. Have you included a big picture overview and connections to related material (global learners) and a logical presentation sequence (sequential learners)?

Active Involvement

1. Have you planned an opening exercise to motivate the students? (See "What to do in the first week" in Section D.)
2. Have you included a mixture of individual, pairs, small group, and whole group activities? (Look at the suggestions for active learning in Section D for possibilities.)
3. Have you built in breaks at appropriate intervals for long class periods?

Assessment and Evaluation

1. Have you clearly explained in writing and orally in class how students will be evaluated?
2. Do your in-class and out-of-class activities give students opportunities to practice what you have said you want them to be able to do? In other words, do the activities match your objectives?
3. Have you provided students with objectives for each section of the course and study guides before each test?
4. Do your tests reflect the objectives for the course? (Remember that students should not be asked to do any type of complex thinking or deal with new question types that they have not had a chance to practice on before the test.)

WHAT TO DO AFTER THE WORKSHOP

Richard M. Felder
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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.
- *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.

- *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.
- *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.)
- *Give tests based on your learning objectives. Follow the test construction guidelines in the workshop notebook, especially those that keep the test from being too long.* Make 10-15% of each test require conceptual understanding and include at least one of the gaps in the handouts.
- *Use a checklist or rubric to grade written or oral project reports and essays, and also use it to teach students the skills the project is designed to teach.*
- *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.
- *Make sure you're meeting the needs of students with all the different learning style preferences* (Section A).

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 learning 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.
- *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 slides.

- *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.*
- *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.
- *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.
- *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.*
- *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. viii 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.