Effective Teaching: A Workshop

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One of my favorite leisure-time activities is to walk down the hall and listen to classes in progress, hoping to get some teaching tips. I've got some time this morning—come along with me and let's see what we can pick up.

There's Professor Frobish—he's got the junior fluids course this semester.

**Frobish:** “...and on Monday we saw that if you write the coupled partial differential equations of change for this pseudoplastic fluid flowing in a cloverleaf-shaped channel and impose the usual singular perturbation theory boundary conditions you can easily prove that the liquid will emerge at the outlet as long as the pipe is tilted downward.”

**Student:** “Professor Frobish.”

**Frobish:** “That result by itself is of course only mildly interesting but Monday was the first day of class and I wanted to start slowly. Now today we'll see what happens if we relax some of those simplifying assumptions. Suppose, for example, we say that instead of a pseudoplastic fluid we have a virial gas moving at sonic velocity and the channel is made of expandable rubber and is mounted on a satellite in a decaying orbit. Now if we invoke a six-dimensional stress tensor we can easily see that...”

**Student:** “Professor Frobish!”

**Frobish:** “What is it already?”

**Student:** “You never finished the proof you were doing Monday and I didn't understand any of it as far as you got.”

**Frobish:** “Finishing it was an exercise for the class...the mathematics is completely straightforward...but if you need help you'll find something similar in that paper by Lundquist I cited.”

**Student (a trace of hysteria entering his voice):** “But I can't read Swedish.”

Oh well, that will probably go on for awhile so let's move on. Good man, Frobish, although some of the faculty feel that he's too applied—they want more fundamentals in the curriculum. Look in there now...see the guy with the mustache and the tee shirt that says”Chemical Engineers Do It in Fluidized Beds”? That's Greg Furze—he teaches kinetics and gets consistently high ratings. Seems to be some action in there—let's check it out.

**Furze:** “Ok, guys...get the chairs in a circle and let's get down to it. You people there are A molecules, got it, and you over there are B's. A's—put on your little hats so we'll all know which species you are. Good. Now, when I yell START UP you all get going, ok, and Angie there will keep count.”

**Student:** “Hey, Greg, I forget what we're supposed to do.”
Furze: “No sweat, Joe...this is tough stuff—I don't expect you to get it right away. When I yell you all start milling around inside the chairs...move in straight lines until you bump into someone else. If it's your species, you just bounce off and keep going. If it's the opposite species you roll a die, and if you throw a 1 then you yell out REACTION and sit down. Got it?”

Student: “Why are we doing this again?”

Furze: “Great question, Amy. We're demonstrating the kinetics of...what, gang? Right, a second-order reaction in a well-mixed batch reactor. Now, after this run, just for fun we're going to say that Pete over there is a catalyst and unknown to him there's a trace amount of sulfur in the reactor, which he's deathly allergic to. Pete, as the reaction proceeds you'll start gasping and clutching your throat, and the rest of you....”

* * * * *

Interesting fellow, Furze—students like him but for some reason I've never understood, Frobish doesn't...ah, we've got a treat coming up now. There's Professor Snavely—he's teaching the sophomores this semester and always keeps them laughing.

* * * * *

Snavely: “...and that's the flow chart. You people understand?...wonderful! Now, what do we do next...let's see what our old friend Miss Albright has to say. Miss Albright—give us the benefit of your wisdom.”

Student: “Um...I'm not sure what you're asking, Dr. Snavely.”

Snavely: “Oh, really? Well, I'll try again, more slowly. Miss Albright. What...do... we...do...next? Got it that time?”

Student: “Uh...I guess we need to find the amount of CO₂ in the product.”

Snavely: “The amount of CO₂ in the product. Miss Albright, have you ever had a chemistry course? Yes? Were you awake during the part of it when they talked about such esoteric concepts as mole fractions? You were. Amazing...hey, you there, the girl with the glasses. If you think you can teach this stuff better than I can why don't you come up and do that talking from up here. No? All right, then...suppose you tell Miss Albright here how she could determine the mole fraction of CO₂ once she learns what it's called.”

Student: “Uh...I don't know.”

Snavely: “You don't know? You don't know? Oh, I'm sorry—this is CHE 247...you must have been looking for the medieval history class down the hall and wandered in here by mistake. Why don't you just...”

* * * * *

Lot of fun, isn't he? He's on a fast track here—brought in two million dollars in grants last year and is a shoo-in for tenure. He has terrible luck, though—three or four times a year his car turns up with flat tires in the parking lot...you'd almost think someone was...say, there's lovable old Professor Wombat, teaching his course in process design. Believe it or not, he's taught that course since 1937 without missing a year.

* * * * *

Wombat: “...and that's the Chamber process, used to make most of the sulfuric acid we use today. Now I'm going to write a ten-year discounted cash flow rate of return on investment table for a typical plant...copy it carefully, since you will be responsible for it on the next test. After that I'll move on to the important reaction between steam and coke that gives us...watery coke...ha ha ha, a little humor there, class...actually it gives us water gas or blue gas, used as the fuel for many of the lights
R. M. Felder & R. Brent, *Effective Teaching*

*that illuminate our streets today. Now, the table...* pay special attention to the interesting way they treat depreciation in Row 18....*

* * * * * *

Look how the students are gently nodding their heads as they soak up the wealth of real-world information they're getting. Well, I think it's time to get back to...wait, there's Professor Buffo finishing up today's thermo lecture...looks like another 3-piece-of-chalk day from here.

* * * * * *

**Buffo:** “...and the last problem is even more trivial. Look.” *(Writes on board)*

\[
dA = -P \, dV - S \, dT \quad \Rightarrow \quad dA = \left( \frac{dA}{dV} \right)_T \, dV + \left( \frac{dA}{dT} \right)_V \, dT \quad \& \quad dG = Y \, dP - S \, dT \quad \Rightarrow \quad dG = \left( \frac{dG}{dP} \right)_T \, dP + \left( \frac{dG}{dT} \right)_P \, dT
\]

* * * * * *

\[
\& \quad \hat{H} = \left( \frac{dH}{dS} \right)_P \, dS + \left( \frac{dH}{dP} \right)_S \, dP \quad \Rightarrow \quad \hat{H} = \left( \frac{dH}{dS} \right)_P \, dS + \left( \frac{dH}{dP} \right)_S \quad \Rightarrow \quad S = \left( \frac{dH}{dT} \right)_V \quad \& \quad \left( \frac{dP}{dT} \right)_S = \left( \frac{dS}{dT} \right)_P
\]

\[
\Rightarrow \left( \frac{dH}{dT} \right)_T = -\beta V = -\beta P
\]

**Buffo:** “...but only for an ideal gas, and the rest obviously follows. Is that clear? Good. Ok, next period we'll learn about some fascinating relationships between mu, f, phi, and if we have time for it, G and G_o. Class dismissed—don't forget the closed book exam on Friday.”
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Effective Teaching Workshop

Two Guiding Principles Of Effective Teaching

Practice & feedback

Balance
**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 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


- Wankat, P. C. (2002). *The effective, efficient professor*. Boston: Allyn and Bacon. Wankat is an engineer at Purdue who has written an excellent resource on teaching and all aspects of an academic career. Sections in the book are (1) time management techniques for academics, (2) efficient and effective teaching, (3) effective and efficient students, and (4) scholarship and service.
Electronic Resources on Learning and Teaching

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

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

http://www.ncsu.edu/felder-public

Articles and Handouts with Teaching Tips

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

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

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

http://www.howstuffworks.com/

- Narratives Supporting Excellent Teaching (NEXT) is a website developed at the University of Washington to assist engineering educators in dealing with common challenges such as time pressure, low student ratings, working with TAs, and teaching a class for the first time.

http://depts.washington.edu/next/

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

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

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

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

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

- **MERLOT**, Multimedia Educational Resource for Learning and Online Teaching, is an open resource designed primarily for faculty and students of higher education. Links to online learning materials are collected along with annotations such as peer reviews and assignments.
  
  ![http://www.merlot.org/merlot/index.htm](http://www.merlot.org/merlot/index.htm)

- **MIT OpenCourseWare** is an educational resource containing MIT course materials. There is no registration requirement or fee for use. Courses from almost every conceivable discipline are included. You can access lecture notes and in some cases tests, online textbooks, visuals and simulations.
  
  ![http://ocw.mit.edu](http://ocw.mit.edu)

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

- **National Science Digital Library (NSDL)** is a repository of resources and tools that support innovations in teaching and learning of science, technology, engineering, and mathematics education.
  
  ![http://nsdl.org/resources_for/university_faculty/](http://nsdl.org/resources_for/university_faculty/)

- **SMETE Digital Library** is an online community of digital collections for science, mathematics, engineering, and technology education.
  
  ![http://www.smete.org](http://www.smete.org)

- **World Lecture Hall** contains course materials in disciplines including engineering, sciences, mathematics, humanities, social sciences, business, and other professional schools.
  
  ![http://www.utexas.edu/world/lecture/index.html](http://www.utexas.edu/world/lecture/index.html)
Workshop Faculty Biographies

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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 over 100 universities in the United States and abroad, and he has authored or co-authored over 200 papers on chemical process engineering and engineering education. He has won the R.J. Reynolds Award for Excellence in Teaching, Research, and Extension, the Chemical Manufacturers Association National Catalyst Award, the University of North Carolina Board of Governors Award for Excellence in Teaching, the American Society for Engineering Education Chester F. Carlson Award for Innovation in Engineering Education, the American Institute of Chemical Engineers Warren K. Lewis Award for Contributions to Chemical Engineering Education, the ASEE Chemical Engineering Division Lifetime Achievement Award for Pedagogical Scholarship, and a number of national and regional awards for his publications on engineering education. At North Carolina State he has won the Sigma Xi faculty research award and has been designated a University Outstanding Teacher and Alumni Distinguished Professor.

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- The Index of Learning Styles (an on-line instrument students can use to determine their learning style)
- Information on teaching workshops given by Dr. Felder
- Handouts for students on a variety of topics
- Links to other web sites on engineering and science education
Workshop Faculty Biographies

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

Separately and together, Drs. Felder and Brent have presented over 300 workshops on effective teaching, course design, mentoring and supporting new faculty members, and faculty development on campuses throughout the United States and abroad. They co-direct the American Society for Engineering Education National Effective Teaching Institute.
A. How do students learn? How do I learn? What do I do to reach students whose learning styles are different from mine?
Learning Styles

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)

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*

<table>
<thead>
<tr>
<th>Sensing (S) Learners</th>
<th>Intuitive (N) Learners</th>
</tr>
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<tbody>
<tr>
<td>• Focus on external input (see, hear, taste, touch,</td>
<td>• Focus on internal input (thoughts, memories, images)</td>
</tr>
<tr>
<td>smell)</td>
<td>• Imaginative</td>
</tr>
<tr>
<td>• Practical</td>
<td>• Look for meanings (miss details)</td>
</tr>
<tr>
<td>• Observant (notice details of environment)</td>
<td>• Abstract thinking (theories, math models)</td>
</tr>
<tr>
<td>• Concrete thinking (facts, data, hands-on work)</td>
<td>• Like variety in learning experiences (bored with</td>
</tr>
<tr>
<td>• Learn through repetition (drills, numerous</td>
<td>repetition)</td>
</tr>
<tr>
<td>examples, replication of experiments)</td>
<td>• Quick</td>
</tr>
<tr>
<td>• Methodical</td>
<td>• Like working with concepts</td>
</tr>
<tr>
<td>• Like working with details</td>
<td>• Complaint about courses: “Plug &amp; Chug” (Lots of</td>
</tr>
<tr>
<td>• Complaint about courses: No apparent</td>
<td>memorization, repetitive formula substitution)</td>
</tr>
<tr>
<td>connection to real world</td>
<td>• Problem with exams: Careless mistakes</td>
</tr>
<tr>
<td>• Problem with exams: Run out of time</td>
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A-3
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.

<table>
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<th>Visual (Vs) Learners</th>
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<tbody>
<tr>
<td>“Show me.”</td>
</tr>
<tr>
<td>− pictures</td>
</tr>
<tr>
<td>− diagrams</td>
</tr>
<tr>
<td>− sketches</td>
</tr>
<tr>
<td>− schematics</td>
</tr>
<tr>
<td>− flow charts</td>
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<tr>
<td>− plots</td>
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<table>
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<tr>
<th>Verbal (Vb) Learners</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Explain it to me.”</td>
</tr>
<tr>
<td>− spoken words</td>
</tr>
<tr>
<td>− written words, symbols</td>
</tr>
<tr>
<td>(seen, but translated by brain into their oral equivalents)</td>
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Bias dominance. Visual and verbal information are processed differently by the brain. 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!

<table>
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<th>Active (A) Learners</th>
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<tbody>
<tr>
<td>Tend to process actively (doing something physical with presented material, then reflecting on it)</td>
</tr>
<tr>
<td>Think out loud</td>
</tr>
<tr>
<td>“Let’s try it out and see how it goes.”</td>
</tr>
<tr>
<td>Tend to jump in prematurely</td>
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<tr>
<td>Like group work</td>
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<th>Reflective (R) Learners</th>
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<tr>
<td>Tend to process reflectively (thinking about presented material, then doing something with it)</td>
</tr>
<tr>
<td>Work introspectively</td>
</tr>
<tr>
<td>“Let’s think it through and then try it.”</td>
</tr>
<tr>
<td>Tend to delay starting</td>
</tr>
<tr>
<td>Like solo or pair work</td>
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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!
Exercise: Who’s Talking?

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 go crazy when I have to sit still through a class—I need to do stuff and talk about it to learn it.

3. I can’t do the homework unless I see how it all fits together.

4. I hate all this plug and chug—it’s boring!

5. Lectures don’t do a thing for me. You want me to understand something, show me a picture.

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

7. 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.

8. 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, dropouts—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).

Derive the velocity profile and pressure drop of a newtonian fluid in a circular pipe. (Takes about two weeks at the beginning of the course.)

**Plan 1. Conventional approach.**

- Derive the differential mass and momentum balance equations for a fluid flowing in a pipe—coupled partial differential equations in cylindrical coordinates. [*Intuitive, verbal, sequential*]
- Express the shear stress in terms of velocity using Newton’s law. [*Intuitive, verbal, sequential*]
- Solve the equations for velocity \([u(r)]\) and pressure \([P(z)]\) in the pipe. [*Intuitive, verbal, sequential*]
- Show plots of the solutions. [*Visual, sequential*]

![Diagram](image)

- Homework: Have students calculate velocities, pressure drops, stresses at the pipe wall, and derive comparable formulas for a rectangular flow channel. [*Intuitive, active, reflective, sequential*]

Two weeks have just gone by, in a manner that is almost entirely

1. *Intuitive:* Concepts, variables, formulas, words
2. *Verbal:* Spoken and written words, formulas (except for two plots)
3. *Passive:* The only meaningful student activity is homework
4. *Sequential:* Step-by-step, no effort to make the material relevant to other subjects and personal experiences.

The sensing, visual, active, and global learners might as well stay home and copy someone else’s lecture notes for all they will get out of attending class during this two-week period.
Plan 2: Approach designed to address the full spectrum of learning style

- Divide the class into groups of two and three at their seats. 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]

- Ask groups for everyday situations that involve fluid flow in channels. [Sensing, intuitive, verbal, active, global]

- Sketch and describe devices to measure $u(r)$ and $P(z)$. Sketch plots of $u$ vs. $r$ and $P$ vs. $z$. [Sensing, visual, verbal]

- Reconsider the circular pipe. Write a force balance on a cylindrical fluid element, derive formulas for $u(r)$ and $P(z)$. Compare them with the results obtained experimentally. [Intuitive]

- 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, violation of assumptions in derivation,…) [Sensing, intuitive, verbal, active, global]

- Derive the differential balances with which Plan 1 began, solve them to confirm the results obtained with the force balances. [Intuitive]
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 (2²) 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.

![Diagram of 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.

![Diagram of strong in preferred category, weak in less preferred one]

- **Solution:** Teach to both sides of each dimension.

![Diagram of 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 pictures, schematics, graphs, and simple sketches before, during, and after presenting verbal material. Use *Google Images* 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. 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) or learning logs. (*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 it (*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. D28–D30).
- **Tell students about their learning styles or let them assess their own style.** Click on the link to *Index of Learning Styles* at <http://www.ncsu.edu/felder-public>.
- **Make changes gradually.** If you decide 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.
MEET YOUR STUDENTS. 1. STAN AND NATHAN

Richard M. Felder

Stan and Nathan are juniors in chemical engineering and roommates at a large midwestern university. They are similar in many ways. Both enjoy partying, midnight pizza runs, listening to rock and watching TV. 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 agree the text was superb), thermodynamics incomprehensible, English boring, and other humanities courses useless. Both have girl friends who occasionally accuse them of being "too logical."

For all their similarities, however, they are fundamentally different. If single words were chosen to describe each of them, Stan's would be "practical" and Nathan's would be "scholarly" (or "spacy," depending on whom you ask). Stan is a mechanical wizard and is constantly sought after by friends with ailing cars and computers, while changing a light bulb is at the outer limits of Nathan's mechanical ability. Stan notices his surroundings, tends to know where he put things, 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. Nathan subscribes to *Scientific American* and reads science fiction and mystery novels voraciously; Stan only reads when he has to. Stan has trouble following lectures; Nathan follows them easily, but when instructors spend a lot of class time going through detailed derivations or homework assignments he already understands he gets bored and his attention wanders.

When Stan takes a test he reads the first problem, reads it again, and if the test is open-book tries to find an identical worked-out problem and copy the solution. If he can't find one, he searches for suitable formulas to plug into. He frequently rereads the problem while working on it and repeats each numerical calculation just to be on the safe side. When he has gone as far as he can go he repeats the process on the second problem. He usually runs out of time and gets class average or lower on the test. Nathan reads test problems only up to the point where he thinks he knows how to proceed and then plunges in. He works quickly and usually finishes early and gets high grades. However, he sometimes blows tests because he makes careless errors and lacks the patience to check his calculations, or he fails to read a question thoroughly enough and misses important data or answers a different question than was asked.

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 did well in only one non-laboratory engineering course. The instructor used a lot of visual demonstrations—transparencies, pictures and diagrams, and actual equipment; provided clear outlines of problem solution procedures; and gave practical applications of all theories and formulas the students were required to learn. Stan claimed that it was the first course he had taken that seemed to have anything to do with the real world. Nathan thought the course was okay but he could have done with a bit less plug-and-chug on the homework.

*Stan is a sensor; Nathan is an intuitor.*¹ Sensors favor information that comes in through their senses and intuitors favor internally-generated information (memory, conjecture, interpretation). Sensors are attentive

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to details and don't like abstract concepts; intuitors can handle abstraction and are bored by details. A student who complains about things having nothing to do with the real world is almost certainly a sensor. Sensors like well-defined problems that can be solved by standard methods; intuitors prefer problems that call for innovation. Individuals of both types may be excellent engineers: the observant and methodical sensors tend to be good experimentalists and plant engineers, and the insightful and innovative intuitors tend to be good theoreticians, designers, and inventors.

The degree to which someone favors sensing or intuition can be determined with the Myers-Briggs Type Indicator, a personality inventory that has been administered to hundreds of thousands of people including many engineering students and faculty members. Most undergraduate engineering students have been found to be sensors and most engineering professors are intuitors. A mismatch thus exists between the teaching styles of most professors, who emphasize basic principles, mathematical models and thought problems, and the learning styles of most undergraduates, who favor observable phenomena, hard facts, and problems with well-defined solution methods. Intuitive students would consequently be expected to enjoy a clear advantage in school, and indeed intuitors have been found to get consistently higher grades except in courses that emphasize facts, experimentation, and repetitive calculations.

For many sensing students, the disparity between the way they learn best and the way they are generally taught is too great: they get poor grades no matter how hard they work, become disillusioned, and drop out. Felder and Silverman\(^1\) give several ways instructors can accommodate the learning styles of these students without compromising their own teaching styles or their ability to get through the syllabus. The accommodation is well worth attempting: sensors are sorely needed in industry and may do exceptionally well there if they manage to survive school.

Postscript: 15 years later. Nathan graduated magna cum laude, went to graduate school and got a Ph.D., worked for several years in the research and development division of a major chemical company, got several important patents, moved to manufacturing, and ended up as a group leader supervising a team of designers and systems analysts. Stan struggled through the curriculum, graduated in the bottom third of his class, and got a production engineering job in the same company Nathan went to work for. His mechanical talents soon became apparent and he was put in charge of a trouble-shooting team that came to be in great demand throughout the plant. His managerial skills then led to a rapid series of promotions culminating in his becoming the youngest corporate vice president in company history. Among the thousands of employees in the branch he heads is Nathan, with whom he gets together occasionally to talk over old times. Stan thoroughly enjoys these meetings; Nathan also enjoys them but perhaps not as much.

representative sensor and Nathan a representative intuitor, but not all sensors are just like Stan and not all intuitors are just like Nathan. Sensation and intuition are preferences, not clear-cut categories, and all human beings exhibit characteristics of both types to different degrees.
MEET YOUR STUDENTS. 2. SUSAN AND GLENDA

Richard M. Felder

Susan and Glenda are seniors in chemical engineering at a private northeastern university. They are both bright and personable. They like to study with friends and enjoy the lengthy bull sessions that the study sessions sometimes turn into. They both have a hard time saying no to requests for help with classwork, even if they don't have the time for it. Neither one cares for laboratory courses. They have almost identical grade point averages—about 3.2/4.0.

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.

² See R.M. Felder and L.K. Silverman, "Learning and Teaching Styles in Engineering Education," Engineering Education 78(7), 674(1988) (<http://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.
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 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.
Additional Resources on Learning Styles

A survey of models of learning styles, approaches to learning, and levels of intellectual development.

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 on-line paper is preceded by a 2002 preface that states and explains changes in the model that have been made since 1988.

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.

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? How can I get it off to a good start?
Learning Objectives

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

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

Examples grouped according to their levels on Bloom’s Taxonomy (p. B4):

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 conduction and convection]

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

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

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

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

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

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

- **Complete course.** Few, general—suitable to include on course syllabus. (See p. B10).
- **Section of course.** 1–2 pages, specific—suitable as study guide for an exam. (See p. B7).
- **Individual lesson.** 1–3 (maximum), very specific—put on board at the beginning of a lecture.

Taxonomies of Educational Objectives

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

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

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

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

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

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


Bloom’s Taxonomy of Learning
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).

Illustrative Detailed Objectives

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

Unacceptable: …learn how to design and conduct experiments.
Weak: …be able to design an experiment to measure *** and analyze the results
Good: …be able to
(a) design an experiment to measure *** as a function of *** (Creating) and perform an error analysis (Applying or analyzing)
(b) explain in terms a bright high school senior could understand the meaning of the results (Understanding).
(c) rate the applicability of different empirical correlations for *** vs. ***. (Evaluating)

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

Unacceptable: …understand the requirements of multidisciplinary teamwork.
Weak: …be able to function effectively on a multidisciplinary project team.
Good: …be able to
(a) function effectively as a team member on a multidisciplinary project team, with effectiveness being determined by peer ratings and self-assessment (Applying & affective)
(b) judge the relative importance of the different disciplines in the project (Evaluating)

Reasons for Writing Objectives

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

- Make lectures, in-class activities, assignments, and exams coherent. When objectives are used as the basis for designing all of them, it helps avoid the common disaster of teaching one thing and testing on something else. It also helps assure that adequate practice and feedback is provided on high-level skills before the skills are assessed.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

13. Use a \( Txy \) 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.

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

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

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

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

General

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

Technical

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

Course Syllabus

What should be included?

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

What may be included?

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

NCSU Department of Chemical Engineering
CHE 205: Chemical Process Principles

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

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

Teaching Assistants: ...
Graders: ...


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

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

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

- **Basic engineering calculations.** Convert quantities from one set of units to another quickly and accurately; define, calculate, and estimate properties of process materials including fluid density, flow rate, chemical composition variables (mass and mole fractions, concentrations), fluid pressure, and temperature.

- **Material and energy balance calculations.** Draw and label process flowcharts from verbal process descriptions; carry out degree-of-freedom analyses; write and solve material and energy balance equations for single-unit and multiple-unit processes, processes with recycle and bypass, and reactive processes.

- **Applied physical chemistry.** Perform pressure-volume-temperature calculations for ideal and non-ideal gases. Perform vapor-liquid equilibrium calculations for systems containing one condensable component and for ideal multi-component solutions. Calculate internal energy and enthalpy changes for process fluids undergoing specified changes in temperature, pressure, phase, and chemical composition. Incorporate the results of these calculations into process material and energy calculations.

- **Computation.** Use spreadsheets (EXCEL) and an equation-solving program (EZ-Solve) to solve material and energy balance problems.

- **Teamwork.** Work effectively in problem-solving teams and carry out meaningful performance assessments of individual team members.
CHE 205: Chemical Process Principles
POLICIES AND PROCEDURES

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

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

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

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

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

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

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

- **Test and homework grading.** If you believe that an error was made in grading the homework, you should write a short justification of your claim and attach it to the original homework assignment in question. Put the
justification and homework paper (stapled together) in Dr. Bullard’s mailbox in 2009 EB1 or in the red homework box. Put the name(s) of the TA(s) who graded the problem(s) in question as well as your contact email. The TA or one of the instructors will review your concern and respond to you directly. The “statute of limitations” for submitting such claims is one week after the homework is returned. For exams, the instructor will respond to re-grading requests – but note that the entire exam will be re-graded, not just the problem in question, in order to ensure consistency and fairness.

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

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

- **Attendance.** Students who miss class due to an excused absence should work with the instructor or problem session TA to make up any missed work or tests. Documented medical excuses should be presented to the instructor. For a full statement of the university attendance policy see <www.ncsu.edu/provost/academic_regulations/attend/reg.htm>.

Examples of anticipated situations where a student would qualify for an excused absence are:

a. The student is away from campus representing an official university function, e.g., participating in a professional meeting, as part of a judging team, or athletic team. These students would typically be accompanied by a University faculty or staff member.

b. Required court attendance as certified by the Clerk of Court.

c. Religious observances as verified by Parents & Constituent Services (515-2441). For more information about a variety of religious observances, visit the Diversity Calendar.

d. Required military duty as certified by the student's commanding officer

- **Calculation of course grade.** A weighted average grade will be calculated as follows:

  - Exams (3) = 40%
  - Final examination = 30%
  - Homework = 20%
  - Problem session quizzes and in-class exercises = 10%.

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

The course grades will be determined as follows:

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;97</td>
<td>A+</td>
</tr>
<tr>
<td>93 –</td>
<td>A</td>
</tr>
<tr>
<td>92.9</td>
<td>A-</td>
</tr>
<tr>
<td>90 –</td>
<td>B+</td>
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<tr>
<td>89.9</td>
<td>B</td>
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<td>83 –</td>
<td>B-</td>
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<td>86.9</td>
<td>C+</td>
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<td>82.9</td>
<td>C</td>
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<td>80 –</td>
<td>C-</td>
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<td>79.9</td>
<td>D+</td>
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<td>77 –</td>
<td>D</td>
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<tr>
<td>76.9</td>
<td>D-</td>
</tr>
<tr>
<td>72.9</td>
<td>F</td>
</tr>
</tbody>
</table>

*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, while acting within the bounds of the stated 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.
What to Do During the First Week

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

Introduce yourself

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

Establish expectations (yours and the students’)

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

Establish student-instructor and student-student communication mechanisms

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

Find out what students know and want to know

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

Motivate the students’ interest in the course.

• Show a graphic organizer for the course.
• Do a demonstration. Get the students to predict the outcome first.
• Survey (or get students to brainstorm) real-world applications of the course topics.
• Use the integrated inquiry-based learning strategy described in the middle of page B-15.

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INDUCTIVE TEACHING AND LEARNING*

Course topics and entire courses can be taught


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

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

Features of common inductive instructional methods

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

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

Inquiry-Based Learning

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

- To teach with an inquiry-based approach
  - introduce each major course topic with a challenge (a question to be answered, a problem to be solved, a set of observations or experimental data to be explained, or a case study or dilemma to be worked through);
  - to the greatest possible extent, get the students to speculate on or predict outcomes before they do any of the required work and to identify the need for information before you provide it;
  - get them to outline solution procedures for complex problems before they undertake the procedures and to identify possible applications of formulas and algorithms before they work through detailed derivations;
  - anticipate that not all students will welcome this approach and some may resist it vigorously, and be prepared with strategies to eliminate or at least minimize the resistance. For some ideas, see “Navigating the Bumpy Road to Student-Centered Instruction” (reference on p. B16).

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

Problem-Based Learning (PBL)

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

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

- University of Delaware Problem-Based Learning Web Site, <http://www.udel.edu/pbl/>.
HOW TO PREPARE NEW COURSES WHILE KEEPING YOUR SANITY*

Richard M. Felder
North Carolina State University

Rebecca Brent
Education Designs, Inc.

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

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

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

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

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

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

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

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

altogether. Your policies regarding late homework, absences, missed tests, grading, and cheating will be fuzzy and inconsistent. Without learning objectives to guide the preparation, the course will be incoherent, with lectures covering one body of material, assignments another, and tests yet another. The students’ frustration and complaints will mount, and the final course evaluations will look like nothing you’d want to post on your blog.

There’s a better way.

A rational approach to new course preparation.

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

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

2. **Don’t reinvent the wheel.**

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

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

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

   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) and assignments that provide instruction and practice in the tasks specified in the objectives. As you get new ideas for things you want to teach, add them to the study guide. One to two weeks before the test,

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

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

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

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

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

Course design


- Fink, L.D. (2003). *Creating significant learning experiences*. San Francisco: Jossey-Bass. An integrated approach to developing learning experiences for students. Check out Chapter 2 (pp. 27-59) for an alternative to Bloom’s Taxonomy that includes foundational knowledge, application, integration, the human dimension, caring, and learning how to learn. Chapter 3 (pp. 60-101) has a detailed approach to course design.


Developing higher level thinking skills:


C. How can I create tests and assignments that are both fair and meaningful? How can I be both rigorous and fair in grading?
Model Exam

Given below is the first test in an introductory sophomore engineering course. 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 on the two pages that follow. In your group, critique the test.

CHE 203

Exam #1. 50 minutes—closed book.

A solid inverted cone floating in an 8 ft³ cubical tank filled to a depth of 1 ft with a height of 20 cm and a diameter of 25 cm has a 10 in³ copper block on it. The cone is 15 cm deep. At a certain time the block which has a specific gravity of 8.92 is carefully removed and dropped in the tank. What does the cone, which has a specific gravity of 0.75, do? Note that 1 in = 2.54 cm.
Problem: Determine the position of the cone relative to its initial position.

- Mass of cone: \( M_c = V_c \rho_c = \frac{\pi}{3} (12.5 \text{ cm})^2 (30 \text{ cm}) (0.75 \text{ g/cm}^3) = 2954 \text{ g} \)

- Mass of block: \( M_b = V_b \rho_b = (10 \text{ in}^3) \left( \frac{2.54 \text{ cm}^3}{1 \text{ in}^3} \right) (8.93 \text{ g/cm}^3) = 1462 \text{ g} \)

- Immersed volume:
  \[
  V_e = \frac{\pi}{3} (9.375 \text{ cm})^3 (15) = 1381 \text{ cm}^3
  \]

- Mass of displaced liquid: \( M_d = 1381 \text{ fl oz (g)} \)

- Archimedes' Principle: \( M_c + M_b = M_d \Rightarrow (2954 + 1462) = 1381 \text{ fl oz} \Rightarrow \text{fl oz} = 3.836 \text{ cm}^3 \)

Now remove the block.

- Immersed volume of cone
  \[
  V_e = \frac{\pi}{3} \left( \frac{5h}{4} \right)^2 h = 0.4091 h^3 \text{ (cm}^3\text{)}
  \]

- Mass of displaced liquid: \( M_d = 0.4091 h^3 \text{ (cm}^3\text{)} \times 2.836 \text{ g/cm}^3 = 1.16 h^3 \text{ (g)} \)

- Archimedes Principle: \( M_c + M_b = 3.836 \Rightarrow h = 12.84 \text{ cm} \)

The cone base is now 20 - 12.84 = 7.16 cm above the liquid surface.

However, the liquid level also changes.

- Original liquid height = \( (1 \text{ ft}) (12 \text{ in/ft}) (2.54 \text{ cm/in}) = 30.48 \text{ cm} \)

Tank cross section = \( (3 \times 2) \text{ ft}^2 \times \frac{144 \text{ in}^2}{1 \text{ ft}^2} \times \frac{2.54 \text{ cm}^2}{1 \text{ in}^2} = 3.716 \text{ cm}^2 \)

Do a liquid balance: \( \text{Liquid in tank} = \text{Liquid in tank} \times \) (Continue on next page)
Solution

\[
\frac{1381 \text{ cm}^3}{3.716 \text{ cm}^2} = \frac{(3.716 \times H - 866 - 164) \text{ cm}^3}{1.19} = \frac{30.39 \text{ cm}}{1.19} = 30.39 \text{ cm}
\]

The level dropped by \( 30.48 - 30.39 = 0.09 \text{ cm} \)

The cone rose \( 7.16 - 5.00 = 2.16 \) above the liquid

\( \text{The cone rose} \ 2.16 - 0.04 = 2.07 \text{ cm} \)

(Solution time = 35 min.)
CHE 203

Exam #1. 50 minutes—Open Book.

A solid cone of base diameter 25.0 cm, height 20.0 cm, and specific gravity of 0.750, floats point downward in a liquid of unknown density. A copper block with a volume of 164 cm$^3$ and a specific gravity of 8.92 rests on the base of the cone. The cone is immersed to a depth of 15.0 cm. The tank is a cube 2.00 ft on each side. The liquid level is half the height of the tank. At a certain time the copper block is lifted off the cone and gently immersed in the tank.

![Diagram of cone and liquid](image)

a) (20 pts) Calculate the masses of the cone and of the copper block. Recall that $V_{cone} = \pi r^2 h/3$, where $r$ and $h$ are the base radius and height, respectively.

b) (30 pts) Use Archimedes’ Principle to determine the density of the liquid (g/cm$^3$).

c) (30 pts) Assume the solution to Part b) for the liquid density is 2.700 g/cm$^3$. (It might not be.) Calculate the vertical distance (cm) from the liquid surface to the base of the cone after the block is immersed in the liquid.

d) (20 pts) Assume the solution to part c) is 6.00 cm. (It might not be.) 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."
(a) \[M_c = V_c \rho_c = \frac{\pi}{3} (12.5 \text{ cm})^2 (20 \text{ cm}) 0.75 \frac{\text{g}}{\text{cm}^3} = 2459 \text{ g}\]
\[M_o = (16.4 \text{ cm}^3) (8.92 \frac{\text{g}}{\text{cm}^3}) = 1463 \text{ g}\]
\[D_c = \frac{25}{10} \Rightarrow D_c = \frac{25 \times 10}{20} = 12.5 \text{ cm}\]
\[V_c = \frac{\pi}{3} (2.575)^2 (14.7) = 1381 \text{ cm}^3\]

Mass of displaced liquid : \[M_0 = 1381 \text{ g}\]
Archimedes' Principle : \[M_c + M_o = M_0 \Rightarrow (2459 + 1463) - 1381 \Rightarrow \rho_c = 2.88 \frac{\text{g}}{\text{cm}^3}\]

(b) Immersed volume \[V_c = \frac{\pi}{3} \left(\frac{5h}{8}\right)^2 h = 0.4091 \frac{\text{m}^3}{\text{cm}^3}\]

Mass of displaced liquid (cone only) \[M_0 = 0.4091 \text{ cm}^3 \times 2.700 \frac{\text{g}}{\text{cm}^3} = 1.125 \text{ g}\]
Archimedes Principle : \[M_c + M_0 \Rightarrow 2454 = 1.125 h \Rightarrow h = 13.05 \text{ cm}\]
The cone is now \[30 - 13.05 = 16.95 \text{ cm} above the liquid surface\]

(c) \[V_{immersed} = 1381 \text{ cm}^3 - 1043 \text{ cm}^3 = 338 \text{ cm}^3\]
\[30.48 \times 3.776 - 1381 = \left[376.4 - 193 - 164\right] \text{ cm}^3\]
\[H = \frac{31.99 - 193 + 164}{3.776} = 30.45 \text{ cm}\]
Base of cone is \[30.45 + 6.00 = 36.45 \text{ cm}\] (Solution time = 25 min)

36.4 cm above the tank bottom
Tips on Tests

- Tests perceived by students as unfair (too long, too “tricky,” too much on untaught material) may be the leading cause of poor student evaluations of teaching.
- Review your learning objectives before and after writing each test.
- Consider handing out a study guide a week before each test. Make it thorough.
- **No surprises on tests!** The students should never see a type of question or problem that they have not had adequate practice on in classes and assignments.
- **Test understanding, not speed.** 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. (Who would you rather have design the bridges you drive across or the planes you fly in?)
- Design 10–15% of the test to discriminate between A-level and B-level performance. (No more, no less.)
- Announce point values for each item.
- Always work out a test from scratch when you have the final version. 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.
- If the grades are much lower than you anticipated, you may want to consider *shifting* the grades by adding enough points to bring the top grade up to 100 or the average to a desired level.
- If almost all students miss one problem, consider giving a short quiz on the same type of problem and using the results to add points to the test grades.
- Return graded tests promptly to maximize learning.
- **Consider a time limit for requesting re-grading (e.g., one week). Have students make all requests in writing explaining their case.**
- 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.

Tips for Quantitative Problem-Solving Tests

- You should be able to work out the test in 1/3 the time students will have to do it (or 1/4 or 1/5 if the test is very difficult or requires a lot of calculations). If you can’t, cut it down:
  - Eliminate questions
  - Present some formulas instead of requiring derivations
  - Ask for solution outlines rather than complete calculations. “Write in order the equations you would use to solve the problem. For each, circle the variable(s) for which you would solve.”
- 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 (and incorrect) answer to Part (a), regardless of what they actually got. (Give practice on this type of problem in class and homework before doing it on a test.)
Closed-book exams test primarily memory; open-book exams test primarily understanding. Give the type of exam that tests what you want the students to emphasize. (Allowing summary sheets prepared by you or the students is a good compromise.)

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. Give it to whoever proctors the exam and whoever grades it. Consider posting after the test is collected.

Be generous with partial credit on time-limited tests.

One possible scoring scheme for tests (and homework, for that matter) was developed by Jim Stice at University of Texas-Austin:

- 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%
- We have no idea what you’re trying to do: –100%

Even if you scale or curve, if the average is 35, think about the possibility that it’s a lousy test.

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.)

Consider opportunities to rework the test (individually or in groups) for additional credit.

Tips for 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 using short paragraph, chart, or graph followed by several test items. (Leads to questions at a higher level of thinking)
- When checking the test length, allow about 1 minute for each multiple-choice item. (McKeachie, 2002, pp. 80)
- Encourage students to explain answers to questions that seem tricky or confusing. (Reduces test anxiety, helps you locate unfair or poorly worded questions)
- Tally incorrect responses. (Helps locate weak options and common student errors)
- For suggestions on constructing multiple-choice items, refer to pages 78-80 in McKeachie’s book (full citation in reference list at the beginning of this notebook) or check out FYC 8: Improving Multiple-Choice Questions, a short monograph from the University of North Carolina-Chapel Hill, available online at [http://cfe.unc.edu/pdfs/FYC8.pdf](http://cfe.unc.edu/pdfs/FYC8.pdf)
Tips for 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 (For ideas and model rubrics, go to rubistar.org) or develop model answers with point values
  - 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. (McKeachie, 2002, p.80)

- Some useful tips on grading essay questions can be found on pages 84-86 in McKeachie’s book found on the reference list at the beginning of this notebook. For more information on all aspects of using essay tests, check out FYC 7: *Writing and Grading Essay Questions*, a short monograph from the University of North Carolina–Chapel Hill, available on-line at http://cfe.unc.edu/pdfs/FYC7.pdf
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.

- **Test on what you teach.** 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 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 instructional objectives for courses. 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).

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 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,* 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.

References


Assessing Learning Objectives

To assess objectives in a course, use a subset of the following:

1. *Performance on test items clearly linked to objectives* (content knowledge, problem-solving, analysis, synthesis, evaluation)
2. *Performance on standardized tests or concept inventories*—e.g., GRE, Hestenes test in physics (content knowledge, analysis, evaluation)
3. *Project reports* (content knowledge, analysis, synthesis, evaluation, integrative thinking, creativity, writing)
4. *Videotapes of oral presentations* (content knowledge, analysis, public speaking)
5. *Research proposals and papers* (content knowledge, problem identification, analysis, synthesis, writing)
6. *Resumes, letters, memos* (writing in a professional context)
7. *Written critiques of technical reports or papers* (content knowledge, analysis, evaluation, writing)
8. *Peer evaluations, self-evaluations* (teamwork, communication skills)
9. *Surveys* (attitudes, self-confidence levels)
10. *Learning logs, journals* (content knowledge, comprehension, attitudes)
Grading Checklist for Written Reports*

Team: _____________________________                Project Phase: _____________________
Date: ___________________                                     Evaluator: ________________________

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<tr>
<th></th>
<th>Possible Points</th>
<th>Score</th>
<th>Comments</th>
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<tr>
<td><strong>Technical Content (60%)</strong></td>
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<td>Topic mastery, including technical correctness</td>
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<td>All requested deliverables included</td>
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<tr>
<td>Appropriate level of detail and thoroughness of documentation</td>
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<td>Completeness of analysis and interpretation of data</td>
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<td><strong>Organization (15%)</strong></td>
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<td>Clearly identified purpose &amp; approach</td>
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<td>Content is clearly organized &amp; supports purpose</td>
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<td>Good transition between topics</td>
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<td>Introduction and conclusion are tailored appropriately to the audience</td>
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<td><strong>Presentation (15%)</strong></td>
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<td>Easy to read</td>
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<td>Uniform writing style</td>
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<td><strong>Layout/Visuals (10%)</strong></td>
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<td>Quality of graphics</td>
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<tr>
<td><strong>Total Score</strong></td>
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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: ________________________

<table>
<thead>
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<th>Possible Points</th>
<th>Score</th>
<th>Comments</th>
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</table>

**Technical Content (60%)**

- Topic mastery, including technical correctness: 20
- All requested deliverables included: 15
- Appropriate level of detail: 15
- Completeness of analysis and interpretation of data: 10

**Organization (15%)**

- Introduction clearly identifies purpose & approach, and previews main points of report: 15
- 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%)**

- Presenters are professional in dress, language, and style
- Movement, eye contact, and gestures enhance presentation and do not distract from it
- 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 the whole

**Layout/Visuals (10%)**

- Visuals are clear, consistent, readable and understandable
- Visuals accurately follow the oral presentation and provide a “visual map” of the presentation

**Total Score**

100

* Courtesy of Dr. Lisa Bullard, Department of Chemical & Biomolecular Engineering, N.C. State University.
PEER EVALUATION RUBRIC*

This self and peer evaluation asks about how you and each of your teammates contributed to the team during the time period you are evaluating. For each way of contributing, please read the behaviors that describe a “5”, “3” and “1” rating. Then rate yourself and your teammates. If a team member behaved in ways consistent with more than one description, you should assign the rating in between.

### Contributing to the Team’s Work

<table>
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<tr>
<th>Your name</th>
<th>TEAM NAME / NUMBER:</th>
<th>Write the names of the people on your team.</th>
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#### 5 5 5 5 5
- Does more or higher-quality work than expected.
- Makes important contributions that improve the team’s work.
- Helps teammates who are having difficulty completing their work.

#### 4 4 4 4 4
- Demonstrates behaviors described in both 3 and 5.

#### 3 3 3 3 3
- Completes a fair share of the team’s work with acceptable quality.
- Keeps commitments and completes assignments on time.
- Helps teammates who are having difficulty when it is easy or important.

#### 2 2 2 2 2
- Demonstrates behaviors described in both 1 and 3.

#### 1 1 1 1 1
- Does not do a fair share of the team’s work. Delivers sloppy or incomplete work.
- Misses deadlines. Is late, unprepared, or absent for team meetings.
- Does not assist teammates. Quits if the work becomes difficult.

### Interacting with Teammates

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#### 5 5 5 5 5
- Asks for and shows an interest in teammates’ ideas and contributions.
- Makes sure teammates stay informed and understand each other.
- Provides encouragement or enthusiasm to the team.
- Asks teammates for feedback and uses their suggestions to improve.

#### 4 4 4 4 4
- Demonstrates behaviors described in both 3 and 5.

#### 3 3 3 3 3
- Listens to teammates and respects their contributions.
- Communicates clearly. Shares information with teammates.
- Participates fully in team activities.
- Respects and responds to feedback from teammates.

#### 2 2 2 2 2
- Demonstrates behaviors described in both 1 and 3.

#### 1 1 1 1 1
- Interrupts, ignores, bosses, or makes fun of teammates.
- Takes actions that affect teammates without their input. Does not share information.
- Complains, makes excuses, or does not interact with teammates.
- Is defensive. Will not accept help or advice from teammates.

---

* This rubric for team functioning was developed by an NSF-sponsored team headed by Dr. Matthew Ohland of Purdue University. For details, go to <http://www.catme.org>.
Write the names of the people on your team.

### Keeping the Team on Track

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- Watches conditions affecting the team and monitors the team’s progress.
- Makes sure that teammates are making appropriate progress.
- Gives teammates specific, timely, and constructive feedback.

4 4 4 4 4

Demonstrates behaviors described in both 3 and 5.

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- Notices changes that influence the team’s success.
- Knows what everyone on the team should be doing and notices problems.
- Alerts teammates or suggests solutions when the team’s success is threatened.

2 2 2 2 2

Demonstrates behaviors described in both 1 and 3.

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- Is unaware of whether the team is meeting its goals.
- Does not pay attention to teammates’ progress.
- Avoids discussing team problems, even when they are obvious.

### Expecting Quality

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- Motivates the team to do excellent work.
- Cares that the team does outstanding work, even if there is no additional reward.
- Believes that the team can do excellent work.

4 4 4 4 4

Demonstrates behaviors described in both 3 and 5.

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- Encourages the team to do good work that meets all requirements.
- Wants the team to perform well enough to earn all available rewards.
- Believes that the team can fully meet its responsibilities.

2 2 2 2 2

Demonstrates behaviors described in both 1 and 3.

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- Satisfied even if the team does not meet assigned standards.
- Wants the team to avoid work, even if it hurts the team.
- Doubts that the team can meet its requirements.
TIPS ON TEST-TAKING*

Richard M. Felder
North Carolina State University

James E. Stice
University of Texas

I. Preparation

• Study in small groups.
  – Make sure your study group contains only students who are serious about studying, at least some of whom are at your level of ability or better.
  – Go over as many different problems as you can (like old homework problems, unassigned problems in the course text, old exams). Set up the solutions, but don’t crunch numbers. Don’t quit on a problem until you’re convinced you could do it yourself.
  – Brainstorm possible things you could be asked and answers you might give.
  – Leave the beer in the refrigerator until you’re done studying.

• Make up a one-page summary sheet of the key ideas, equations, procedures, 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.

• Don’t stay up all night studying. Try to get a reasonable amount of sleep the night before the exam. If that’s not possible, try to get a nap before the exam, or at least a short rest.

• Set up a backup system for your alarm clock. Set a second alarm, or arrange for a wake-up call from a friend.

• Eat breakfast.

• Arrange backup transportation to campus.

• Bring everything you need to the exam:
  — textbook, if the exam is open-book
  — paper and several pencils with erasers
  — calculator, with fresh or extra batteries
  — allowed handbooks and tables (such as steam tables)
  — allowed class handouts
  — summary sheet (if allowed)

* View and download from Richard Felder’s web site, <http://www.ncsu.edu/felder-public>. Click on the “Handouts for Students” link on the home page, then click on “Tips on Test-Taking” or access it directly at <http://www.ncsu.edu/felder-public/Papers/testtaking.htm>.

C-20
II. Taking the Test

- **Read over the whole exam before beginning to write anything.**
- **Choose the problem or question that seems easiest to you and do it first.** Continue to do the problems in order of increasing difficulty.
- **Read the problem/question carefully, and make sure you answer what was asked.**
- **Show your work.** Give enough detail so that both you and the grader can tell what you’re trying to do. Even if you can do the problem in your head, don’t. If you’re wrong, you get a zero; if you’re right, you could be suspected of cheating.
- **Watch out for significant figures.** Some instructors don’t appreciate answers like 23.694028, even though that’s what the calculator says.
- **Think partial credit.** Try to put something down for each part of every problem/question. If you don’t have time to solve a problem, tell what you’d do if you had more time.
- **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.
- **Keep your work legible.** If the grader can’t read what you wrote, you aren’t likely to get full credit, and you may not get any.
- **If you don’t understand a question, ask the instructor/proctor for help.** You might get some, and it never hurts to try.
- **Don’t panic.** If you feel yourself sweating or hyperventilating, put down your pencil, close your eyes, take a few deep breaths, and consciously relax clenched muscles (jaw, neck, stomach). When you’re calmer, go back to work.
- **If you have time at the end, check your solutions.** Did you answer each part of every question? Did you answer the question(s) asked? Do your answers seem reasonable? Do your calculations check out? (Save this one for last.)
- **Hand in your paper when time is called.** Nothing makes an instructor/proctor more homicidal than having to wrestle you to the floor to get your paper.
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

## Test Preparation Checklist

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

### Homework

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<td>Did you make a serious effort to understand the text? (Just hunting for relevant worked-out examples doesn't count.)</td>
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<td>Did you work with classmates on homework problems, or at least check your solutions with others?</td>
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<td>Did you attempt to outline every homework problem solution before working with classmates?</td>
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<td>Did you participate actively in homework group discussions (contributing ideas, asking questions)?</td>
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<td>Did you consult with the instructor or teaching assistants when you were having trouble with something?</td>
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<td>Did you understand ALL of your homework problem solutions when they were handed in?</td>
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<td>Did you ask in class for explanations of homework problem solutions that weren't clear to you?</td>
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### Test preparation

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<td>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?</td>
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<td>Did you attempt to outline lots of problem solutions quickly, without spending time on the algebra and calculations?</td>
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<td>Did you go over the study guide and problems with classmates and quiz one another?</td>
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<td>If there was a review session before the test, did you attend it and ask questions about anything you weren't sure about?</td>
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<td>Did you get a reasonable night's sleep before the test? (If your answer is no, your answers to 1-11 may not matter.)</td>
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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.
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. (Refer to page C-8 for ideas about grading homework.)
- 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? Effort?
- 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:
  – Guaranteed floors for letter grades (e.g. ≥92 = A, ≥80 = B, etc.)
  – Gray area between each two letters (e.g. 89-91 = A/B, 76-79 = B/C,…), with challenge problems, upward or downward trend in test grades, class participation, attendance, etc., used to decide between higher and lower grade.
  – State rules in writing on Day 1 of the course
- 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 <http://www.wcer.wisc.edu/nise/cl1/>.


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

Preparing for the lecture

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

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

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

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

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

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

- **Use technology wisely.** Interactive tutorials, multimedia presentations, hands-on simulations, concept tests with clickers, and anything else that gets the student involved in the learning experience can greatly enhance learning. On the other hand, *don’t turn your lectures into PowerPoint shows* (see “Death by PowerPoint” on p. D20).

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

- **Give out handouts with gaps.*** Turn some or all of your lecture notes into handouts that the students bring to class, leaving gaps for students to fill in, and sprinkle the handouts with questions. Tell students that some of the missing material and questions will be included on tests, then do it. Let students read through straightforward material by themselves during the lecture, and when you come to a gap, either lecture on it, use it as the basis for an in-class activity, or leave it as an exercise for the students to do after class. After you’ve taught a class a few times, consider putting the handouts into a course pack that student purchase as a supplement to—or replacement for—the text. Excerpts from two course packs are shown on pp. D4 and D5.

---

* 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.
### Instructional Applications of Technology

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<th>Application</th>
<th>Meets needs of</th>
<th>Improves computer skills</th>
<th>Enhances communications (student/student or faculty/student)</th>
<th>Promotes learning by providing practice and feedback</th>
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<tr>
<td>Show clips of real and simulated physical and chemical phenomena</td>
<td>active learners</td>
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<td>Use PowerPoint to deliver mostly text and equation-based lectures</td>
<td>visual learners</td>
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<td>Have students complete short in-class activities using laptop computers</td>
<td>sensing (real-world) learners</td>
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<td>Assign students to post to a class wiki, blog, or online discussion group</td>
<td>global learners</td>
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<td>Have students use clickers* to respond to conceptual questions in class, individually and then in pairs</td>
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<td>Show system simulations in class and have students predict the outcomes of system parameter changes</td>
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<tr>
<td>Give online quizzes before class on readings or key material presented previously</td>
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<td>Require students to complete interactive computer-based tutorials</td>
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<td>Assign students to do web research to find applications of course material</td>
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<tr>
<td>Hold virtual office hours using email or instant messaging</td>
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*“Clickers” or “Personal response systems” are hand-held devices that students in a classroom use to enter answers to multiple-choice questions. The answers are tabulated as they are entered, and the distribution of answers appears on a projector screen.
Laminar flow of an incompressible Newtonian fluid in a circular pipe

Water enters a 5-cm ID (inner diameter) x 10 m long pipe at a rate $2.0 \times 10^{-3}$ m$^3$/s and a pressure $P = 1.5 \times 10^5$ N/m$^2$ (150 kPa, 1.5 atm).

Our goal is to find out as much as we can about relations among system variables at steady-state:

- $v(z)$ (m/s) = volumetric flow rate
- $u(r,z)$ = local velocity profile
- $P(r,z,\theta)$ = local fluid pressure

Calculate the mass flow rate, $m$ (kg/s), at the inlet.

Does $m$ vary with $z$?

Explain.

Does $v$ vary with $z$?

Explain.
Example: Continuous air conditioning process. Take basis of 100 mol feed. (Note: We’ll label amounts instead of flow rates because of the basis, but we still need to use the open system balance equation.)

Calculate $Q$.

Question: What sign should the value of $Q$ have?

Solution: Assume enthalpies are independent of pressure.

(a) DOF Analysis:

unknowns: 

equations:

a. Write all equations but energy balance. Circle unknowns for which you would solve.

b. Choose references and prepare an inlet-outlet enthalpy table.

References: $\text{H}_2\text{O}(l, 80^\circ\text{C}, 1\text{ atm})$, DA (g, 25$^\circ\text{C}, 1\text{ atm})$ (Why?)

<table>
<thead>
<tr>
<th>Species</th>
<th>$n_{in}$</th>
<th>$\hat{H}_{in}$</th>
<th>$n_{out}$</th>
<th>$\hat{H}_{out}$</th>
<th>$n$(mol)</th>
<th>$\hat{H}$ (kJ/mol)</th>
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<tr>
<td>$\text{H}_2\text{O}(l)$</td>
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<td>$n_1$</td>
<td>$\hat{H}_c$</td>
<td>$n$(mol)</td>
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<td>$\text{H}_2\text{O}(v)$</td>
<td>10</td>
<td>$\hat{H}_a$</td>
<td>$n_2 y$</td>
<td>$\hat{H}_d$</td>
<td>$\hat{H}$ (kJ/mol)</td>
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<tr>
<td>DA</td>
<td>90</td>
<td>$\hat{H}_b$</td>
<td>$n_2(1-y)$</td>
<td>$\hat{H}_c$</td>
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C. Write and simplify the energy balance equation, substituting values and labeled variables from the enthalpy table.

$$Q - W_s = \Delta H + \Delta E_k + \Delta E_p \Rightarrow$$
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) If you have trouble learning names or if you have very large classes, try preparing a seating chart. Use it when calling on students and quiz yourself while students are taking tests, working on an assignment or discussing in small groups. (2) Ask students to bring you a small photo or take instant photos. Label them and use to match names and faces. (3) Ask students to photocopy their ID cards or driver’s licenses and use them to learn names. (4) Use 4” x 8” index cards folded lengthwise as tent-type name cards.

- **Make eye contact with students.** 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.

- **Make effective use of the board or overhead.** Be sure you are writing legibly and large enough for students at the back to see (To find out, ask them!). Don’t write with the left hand and erase with the right. Use different colors for chalk or transparency pens to highlight key ideas. Erase extraneous material to reduce distraction—but not before checking to be sure students have the material in their notes. Label charts and graphs so students will have clear information in their notes.

- **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.”

- **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 higher 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?”** (Check out “Any Questions?” in this section of the notebook for more ideas on formulating questions.)
  - What should the solution look like?
  - What do you think happens next?
  - 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?

- **Get students to generate answers (or questions) in small groups.** After finishing a section of material, break students into small groups (2-3 where they are sitting) to come up with 1-3 questions they have about the material.
• Avoid calling on individual students cold for answers—many find it intimidating. Do call on individuals (1) to report on small group exercise results or (2) after they have had a short amount of time to think about or work out a response.

• 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 acceptable to tell your students you aren’t sure of the answer to a question. Tell them you’ll check it out and then let them know what you found. (Then do it!)

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

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

- **Have students complete a midterm course evaluation.** A few weeks into the course, ask students to respond anonymously to at least two prompts: “What features of this course and its instruction are helping you learn?” “What features of the course and instruction are hindering your learning?” (You might also include a request for comments on a specific feature of the course, such as in-class activities, and requests for the students to list things they might do to improve their performance.) Reading the lists will give you a better idea of how the class is going, and you may find some items you can adjust to improve things. In any case, the midterm evaluation will give you student feedback while you still have a chance to improve.

- **Visit other classes.** 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.

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


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

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

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

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

2. "Do you have any questions?"

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

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

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

Define a concept in your own words

- Using terms a bright high school senior (a chemical engineering sophomore, a physics major, your grandmother) could understand, briefly explain the concept of vapor pressure (viscosity, heat transfer coefficient, ideal solution).¹

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

¹ Warning: Don't ask your students to give a comprehensible definition of something like $\tau_{xx}$ or entropy or temperature or mass unless you're sure you can do it.
gone. Sketch plots of $T$ and $h$ vs. time, labeling the temperatures at which abrupt changes in system behavior occur.\footnote{You will be amazed and depressed by how many of your students—whether they're sophomores or seniors—say the level remains constant until $T=75^\circ C$ and then the liquid boils.}

**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?\footnote{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.}
- Why would an intermediate reactor temperature be optimal for this pair of reactions? (Put another way, what are the drawbacks of very low and very high temperature operation?)
- The computer output says that we need a tank volume of $3657924$ cubic meters. Any problems with this solution?

**Brainstorm**

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

**Formulate questions**

- What are three good questions about what we covered today?
- Make up and solve a nontrivial problem about what we covered in class this week (about what we covered in class this month and what you covered in your organic chemistry class this month). Memory and plug-and-chug problems won't be worth much—for full credit, the problem should be both creative and challenging.
- A problem on the next test will begin with the sentence, “A first-order reaction $A \rightarrow B$ with specific reaction rate $3.76 \text{(min}^{-1})$ 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.

I could go on, but you get the idea.

Coming up with good questions is only half the battle; the other half is asking them in a way that has the greatest positive impact on the students. I have not had much luck with the usual approaches. If I ask the whole class a question and wait for someone to volunteer an answer, the students remain silent and nervously avoid eye contact with me until one of them (usually the same one) pipes up with an answer. On the other hand, if I call on individual students with questions, I am likely to provoke more fear than thought. No matter how kindly my manner and how many eloquent speeches I make about the value of wrong answers, most students consider being questioned in class as a setup for them to look ignorant in public—and if the questions require real thought, their fear may be justified.
I find that a better way to get the students thinking actively in class is to ask a question, have the students work in groups of 2–4 to generate answers, and then call on several of the groups to share their results. I vary the procedure occasionally by having the students formulate answers individually, then work in pairs to reach consensus. For more complex problems, I might then have pairs get together to synthesize team-of-four solutions.

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

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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)
- *Experimental study:* Class given 50-minute lecture, & immediately afterwards students tested on lecture content. Tests scored, % of correct answers to questions plotted vs. time in class when the information had been presented.

![Graph](image)

% Correct

| 0 | 10 | t (min) | 50 |

\[ t = \text{time in lecture when information was presented} \]

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


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

Active Learning Structures

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

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

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

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

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

  — Each student individually prepares two or three thought-provoking questions on the content presented in the lecture or reading. The generic question stems are designed to encourage higher level thinking skills.

  — Questions are discussed in small groups at the beginning of class, and the whole class then discusses questions that were especially interesting or controversial in the group discussions.

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• **Writing assignments**\(^3,4\) 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 to help them subsequently connect new ideas to what they already know.
  
  ➢ stop after about 10-15 minutes of lecture and ask students to summarize the main ideas.
  
  ➢ have students generate a list of practical applications of new material or questions they have about it.

  — In the lab
  
  ➢ have students summarize their results and reflect on what they might mean.
  
  ➢ ask students to connect lab activities with material presented in lecture.

  — Outside of class
  
  ➢ get students to summarize readings and write questions about the material (See Guided Reciprocal Peer Questioning on previous page).
  
  ➢ have students reflect on how their cooperative group activities are working.

  — If you have 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. Use a form at the front of the learning log and have students peer check for the presence of all required entries, signing to indicate completeness of the log. To keep the learning log to a reasonable size, consider asking students to use a “blue book” usually used for examinations.

• **Concept tests with clickers.**\(^5\) Ask class challenging multiple-choice conceptual questions, with distractors that reflect common misconceptions. Have students vote individually, then pair and discuss, then vote again. Discuss why wrong answers were wrong.

• **Pair programming.**\(^6\) 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.

• **Minute paper**\(^7\): 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.

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TAPPS⁸ (Thinking Aloud Pair Problem-Solving) Student pairs solve a problem, work out a derivation, or work step-by-step through a solved problem or derivation or case study or article or passage of text. Time-consuming, but powerful.

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

Implementing Active Learning in Class

- *Explain what you’re doing and why up front.*
- For pair or group activities, have the students form into groups of 2-4 where they are sitting.
- *Assign crucial roles.* Most often groups need a recorder to capture their ideas, but occasionally different roles might be appropriate (e.g. timekeeper, monitor).
- *Explain the task.* The explanation can usually be done orally. For more complicated exercises, make a transparency noting the steps to be taken or write them on the board.
- *Call randomly on individuals to report* (while working and after work is complete). This technique is an effective way to get individual accountability in the activity.
- *Keep activities short (30 seconds – 3 minutes).* This technique keeps students from wandering off-task and reduces the frustration level for groups that are struggling.
- For longer exercises, circulate around the classroom listening in, giving hints, and checking for understanding.
- *Remember the value of variety.* Don’t get into a pattern with in-class exercises of always doing the same thing (lecture 10 minutes, 2-minute exercise,…). Mix it up by using different structures (individual reflection, groups, think-pair-share,…) to keep the class interesting.
- *Put some course material on handouts, leaving gaps and inserting questions.* Doing this will save enough class time for you to do all the active learning exercises you want to.

What might happen if you start using active learning?

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

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LEARNING BY DOING

Richard M. Felder and Rebecca Brent
North Carolina State University

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

\[
dA = - P \, dV - S \, dT \rightarrow dA = \left( \frac{\partial A}{\partial V} \right)_T \, dV + \left( \frac{\partial A}{\partial T} \right)_V \, dT \quad \text{&} \quad dG = V \, dP - S \, dT \rightarrow dG = \left( \frac{\partial G}{\partial P} \right)_T \, dP + \left( \frac{\partial G}{\partial T} \right)_P \, dT
\]

\[
& \frac{\partial H}{\partial S}_p + \left( \frac{\partial H}{\partial P} \right)_s \rightarrow V = \left( \frac{\partial G}{\partial T} \right)_V = \left( \frac{\partial H}{\partial T} \right)_V
\]

so \( S = \left( \frac{\partial A}{\partial T} \right)_V \) \& \( \frac{\partial P}{\partial T} \) \( \frac{\partial S}{\partial V} \) \( \Rightarrow \beta \frac{\partial V}{\partial P} = -R / P \)

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

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

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

1. Give the students something to do (answer a question, sketch a flow chart or diagram or plot, outline a problem solution, solve all or part of a problem, carry out all or part of a formula derivation, predict a system response, interpret an observation or an experimental result, critique a design, troubleshoot, brainstorm, come up with a question, …).

2. Tell them to work individually, in pairs, or in groups of three or four; tell them how long they’ll have (anywhere from 10 seconds to two minutes); and turn them loose.

3. Stop them after the allotted time, call on a few individuals for responses, ask for additional volunteered responses, provide your own response if necessary, and continue teaching.

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

As little as five minutes of that sort of thing in a 50-minute class session can produce a major boost in learning. For starters, it wakes students up: we have seen some of them elbowing their sleeping neighbors when an active learning task was assigned. Academically weak students get the benefit of being tutored by stronger classmates, and stronger students get the deep understanding that comes from teaching something to someone else. Students who successfully complete a task own the knowledge in a way they never would from just watching a lecturer do it. Students who are not successful are put on notice that they don’t know something they may need to know, so when the answer is provided shortly afterwards they are likely to pay attention in a way they never do in traditional lectures.
The number of possible active learning tasks is limitless. At a minimum, you can ask the same questions you would normally ask in your lectures, only now you’ll get the whole class trying to answer them and not just the same two students who always answer the questions. You can also use any of the activities suggested in Item 1 of the list several paragraphs back, and you might occasionally run a TAPPS ("thinking-aloud pair problem solving") exercise, arguably the most powerful classroom instructional technique for promoting understanding. Have the students work in pairs through a complex derivation or worked-out problem solution in the text or on a handout, with one of them explaining the solution step-by-step and the other questioning anything unclear and giving hints when necessary. Periodically stop them, call on several of them for explanations, provide your own when necessary, and have the students reverse roles in their pairs and proceed from a common starting point. It may take most or all of a class period to work through the entire solution, but the students will end with a depth of understanding they would be unlikely to get any other way.

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

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

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

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

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

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

What about (3)—students who refuse to participate? There may indeed be several who just sit staring straight ahead when groupwork is assigned, even after the awkwardness of the first few times has passed. We never see more than two or three of them in our classes, but for the sake of discussion let’s say it’s as many as 10% in yours. That means that while you’re doing an active learning exercise, 90% of the students are actively engaged with the material and getting practice in the skills you’re trying to teach them, and 10% are out to lunch. On the other hand, at any given moment in a traditional lecture, if as many as 10% of your students are actively involved with the lecture material you’re doing very well. No instructional technique works for all students at all times: the best you can do is reach as many as possible, and 90% is more than 10%. If some students opt out, don’t let it bother you—it’s their loss, not yours.

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


SERMONS FOR GRUMPY CAMPERS*

Richard M. Felder
North Carolina State University

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

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

\* \* \*

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

***

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

Let me give you one more encouraging word about student resistance to learner-centered teaching methods. My colleague Lisa Bullard uses cooperative learning in both an introductory sophomore engineering course and the capstone senior design course. She once told me that she has always had problems with group work in the sophomore class but never with the seniors until one semester, when she got the Design Class from Hell. The students complained constantly about having to work in groups, many teams were dysfunctional, and things generally went the way they always had in the sophomore class only worse.
Lisa racked her brains trying to figure out what was different about the design class that semester and couldn’t think of a thing—and then she got it. Up until that year the seniors had previously been in her sophomore class and so were accustomed to group work. She had not taught this group of seniors before, however, and so she was experiencing the headaches that normally come when students first encounter active and cooperative learning. So if you find yourself experiencing those headaches, remember two things. First, you’re equipping students with skills that will serve them well throughout their careers, whatever those careers may be. Second, you’re making life much easier for yourself or colleagues who teach those students in subsequent courses using the same methods. It’s worth a few headaches.

References

IS TECHNOLOGY A FRIEND OR FOE OF LEARNING?

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

Scenario 1

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

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

Scenario 2

Fred goes to his 8 a.m. heat and mass transfer class, drops his homework on the front desk, takes his seat, yawns, and wonders if he’ll be able to stay awake until 9:15. Professor Maxwell greets the class and asks the students if they have any questions. One of them asks about a homework problem and she goes through the solution on the board. She then draws a block diagram of a heat exchanger and writes the energy balance and heat transfer equations. When she finishes writing the last equation she asks the class how they would determine the film coefficients in the expression for the overall heat transfer coefficient. Fred vaguely recalls something about correlations from the last lecture but doesn’t feel inclined to say anything. When no one volunteers a response the professor reminds the class about the correlations and writes an expression 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

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of them will learn more—the one taught in the live classroom or the one taught with technology? There’s no way to know for sure, of course—how much a student learns in a course depends on many things—but technology is the way to bet in this example. The rich mixture of visual and verbal information, self-tests of knowledge and conceptual understanding, practice in problem-solving methods, and immediate individual feedback provided by the technology in Scenario 1 are far more likely to promote deep learning than the passive environment of the traditional lecture class...and the fact that Sharon lives 750 miles away from her instructor’s campus and has never seen him in person doesn’t change the likelihood that she will learn more and at a deeper level than Fred.

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

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

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

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DEATH BY POWERPOINT

Richard M. Felder and Rebecca Brent

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

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

* * *

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

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

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

“After a few more weeks of this approach, two students approached me after class and said, in effect, 'Dr. Roberts, this class is boring. All we do is go over the transparencies, which you have already handed out. It's really easy to just tune out.' After my ego recovered, I asked whether they thought they would get more out of the class and be more engaged if I scrapped the transparencies and used the chalkboard instead. Both said 'yes.' For the rest of the semester, I went back to the chalkboard (no transparencies in or before class), attendance went back up to traditional levels, the class became more interactive, and my teaching evaluations at the end of the semester were consistent with the ones that I had received previously. Ever since that experience, I have never been tempted to structure my teaching around transparencies or PowerPoint.”

* * *

The point of this column is not to trash transparencies and PowerPoint. We use PowerPoint all the time—in conference presentations and invited seminars, short courses, and teaching workshops. We rarely use pre-prepared visuals for teaching, however—well, hardly ever—and strongly advise against relying on them as your main method of instruction.

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

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

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

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

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

- **Don’t** show complete sentences and paragraphs, large tables, and equation after equation. There is no
way most students can absorb such dense material from brief visual exposures on slides. Instead,
present the text and tables in handouts and work out the derivations on the board or—more
effectively—put partial derivations on the handouts as well, showing the routine parts and leaving
gaps where the difficult or tricky parts go to be filled in by the students working in small groups.1,2

If there’s an overriding message here, it is that doing too much of anything in a class is probably
a mistake, whether it’s non-stop lectures, non-stop slide shows, non-stop activities, or anything else that
falls into a predictable pattern. If a teacher lectures for ten minutes, does a two-minute pair activity,
lectures another ten minutes and does another two-minute pair activity, and so on for the entire semester,
the class is likely to become almost as boring as a straight lecture class. The key is to mix things up: do
some board work, conduct some activities of varying lengths and formats at varying intervals, and when
appropriate, show transparencies or PowerPoint slides or video clips or whatever else you’ve got that
addresses your learning objectives. If the students never know what’s coming next, it will probably be an
effective course.

**References**


2. R.M. Felder and R. Brent, “FAQs. II. Active Learning vs. Covering the Syllabus, and Dealing with
SCREENS DOWN, EVERYONE!
EFFECTIVE USES OF PORTABLE COMPUTERS IN LECTURE CLASSES
Richard M. Felder and Rebecca Brent
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Portable computers are getting more powerful and cheaper all the time. Most college students now own one, and many engineering and science curricula require all their students to have them. Once colleges do that, though, they are also obliged to give the students enough to do with the computers to justify that requirement. True, homework involving computers is routinely assigned in technical curricula, but the computer labs at most colleges are more than adequate to serve the students who don’t have their own computers. Few institutions have enough computer-equipped classrooms to host all their classes, however, and so it makes sense to have the students use their own computers in class. The question is, to do what?

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

The remedy for attention drift in class—with or without computers—is to use *active learning*,1 periodically giving the students things to do (answer questions, solve problems, brainstorm lists,… ) related to the course content. Extensive research has established that students learn much more through practice and feedback than by watching and listening to someone telling them what they are supposed to know.2

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

**Working through interactive tutorials**

Computer-based tutorials can be highly instructive, especially if they are interactive, prompting users for responses to questions and correcting mistakes. Tutorials are increasingly common on CDs bundled with course texts, and they may also be obtained from software companies and multimedia libraries such as MERLOT or SMETE.3 A problem is that students worry about how much time they will take and so tend to ignore them. An effective way to deal with their concern is to have them work through the first of a set of tutorials. If it is well designed, they will then be much more likely to work through the others voluntarily. (A recent research study illustrates this phenomenon.4)

**Getting started with new software and building skill in its use**

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

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

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

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

**Carry out web-based research**

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

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

**Explore system behavior with simulations**

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

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

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

**Implementation tips**

Several formats for computer-based activities in class should be used on a rotating basis. If all students have computers, they may work individually, or in pairs or trios, or individually.
first and then in pairs to compare and reconcile solutions. If there are only enough computers for every other student, the students may work in pairs with one giving instructions and the other doing the typing, reversing roles in successive tasks. After stopping an activity in any of these formats, the instructor should first call on several individuals for responses and then invite volunteers to give additional responses. The knowledge that anyone in the class might be called on will motivate most of the students to actually attempt the assigned tasks.¹

Finally, an indispensable device for effectively using portable computers in class is the simple command, “Screens down!” when you want the students’ attention for any length of time. As long as they can see their screens and you can’t, the temptation for them to watch the screens instead of you can be overwhelming. If you take away that option, at least you’ll have a fighting chance.

References


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

## Instructional Applications of Technology

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<thead>
<tr>
<th>Application</th>
<th>Meets needs of</th>
<th>Improves computer skills</th>
<th>Enhances communications (student/student or faculty/student)</th>
<th>Promotes learning by providing practice and feedback</th>
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<td>active learners</td>
<td>visual learners</td>
<td>sensing (real-world) learners</td>
<td>global learners</td>
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<td>Show clips of real and simulated physical and chemical phenomena</td>
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<td>Use PowerPoint to deliver mostly text and equation-based lectures</td>
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<td>Have students complete short in-class activities using laptop computers</td>
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<td>Assign students to post to a class wiki, blog, or online discussion group</td>
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<td>Have students use “clickers” to respond to conceptual questions in class, individually and then in pairs</td>
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<td>Show system simulations in class and have students predict the outcomes of system parameter changes</td>
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<td>Give online quizzes before class on readings or key material presented previously</td>
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<td>Require students to complete interactive computer-based tutorials</td>
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<td>Assign students to do web research to find applications of course material</td>
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<td>Hold virtual office hours using email or instant messaging</td>
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R. M. Felder & R. Brent, *Effective Teaching*
Additional Resources on Lecturing and Active Learning

Lecturing


Active Learning

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.
Resources on Cooperative Learning

To get an overview of CL:


To find practical suggestions for CL structures and troubleshooting:


To assess the performance of individual members of project teams

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

To explore the research base for CL:


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


For on-line resources:

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


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

25. *Online Collaborative Learning in Higher Education*. An excellent resource for articles and links maintained by the Central Queensland University. [http://clp.cqu.edu.au/]


27. *The University of Minnesota Cooperative Learning Center*. Information and references on different aspects of cooperative learning, including “Cooperative Learning Methods: A Meta-Analysis,” which summarizes the results of a large number of CL research studies. The site is maintained by David and Roger Johnson of the University of Minnesota. [http://www.co-operation.org/]

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

All in a day’s work

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

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

What might you do about all this? *

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

One in every crowd

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

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

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

What might you do?*

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

The old switcheroo

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

What might you do?
Cheating*

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

Answer: Yes

Question: How will they do it?

Answer:

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

Question: How can I minimize cheating?

Answer:

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

Suggestions for Addressing Academic Integrity Issues*

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

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

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

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

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

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

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

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* Written by Professor Lisa Bullard, Dept. of Chemical & Biomolecular Engineering, N.C. State University.
Examples of syllabus language that addresses academic integrity

Example 1:
Academic integrity. Students should refer to the University policy on academic integrity found at <http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php>

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

Example 2:
All work that you turn in for grading must be your own (this means that it is an independent and individual creation by you). Any attempt to gain an unfair advantage in grading, whether for oneself or for another, is a breach of academic integrity and will be reported to the Office of Student Conduct. Penalties for cheating can be as severe as suspension from the university. Students who are found cheating on a project or test will receive a grade of -100% (negative 100 percent) for that work. Turning in code that is written by other students is considered cheating. Giving code for other students to turn in is considered cheating. Cheating is simply not worth it. Cheating is much worse than not turning in an assignment at all. Cheating penalties are severe. They are permanent. The CSC department used special software to detect cheating violations for programming projects. In Spring 2004, approximately 60 students were charged with academic integrity violations. All of those students are on permanent academic probation. We will be using that same software this semester.

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

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

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

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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.

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

Richard M. Felder and Rebecca Brent
North Carolina State University

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 column³ we discussed what educational psychologists have termed a “deep approach” to learning. Students who take this approach do whatever it takes to gain a conceptual understanding of the
subject being taught. They routinely try to relate course material to other things they know, look for applications, and question conclusions—precisely the kinds of things that the students whose lack of motivation we complain about never do.

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

Teaching Underprepared Students

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

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

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

References

Additional Resources

Advising and Student Support


Academic Misconduct (Cheating)

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


Classroom Management


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

Message:

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

Untenured faculty stress points\(^a\)

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

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

- Chilly climate
- Excessive committee assignments
- Excessive student demands

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

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


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

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

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

• **Success Strategy #3. Network at least two hours a week**
  – Visit colleagues, go to lunch, have a cup of coffee with colleagues in and out of the department; discuss research, teaching, campus culture.
  – **Results:** Quickly learn culture, discover campus resources; cultivate allies and advocates.

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

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

Richard M. Felder

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

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

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

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

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

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

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

- **Learn to identify the students in your classes, and greet them by name when you see them in the hall.** Doing just this will cover a multitude of sins you may commit in class. Even if you have a class of over 100 students, you can do it—use seating charts, labeled photographs,
whatever it takes. You'll be well compensated for the time and effort you expend by the respect and effort you'll get back from them.

- **When you're teaching a class, try to give the students something active to do at least every 20 minutes.** For example, have them work in small groups to answer a question or solve a problem or think of their own questions about the material you just covered.* In long class periods (75 minutes and up), let them get up and stretch for a minute. Even if you're a real spellbinder, after approximately 10 minutes of straight lecturing you begin to lose a fraction of your students—they get drowsy or bored or restless, and start reading or talking or daydreaming. The longer you lecture, the more of them you lose. Forcing them to be active, even if it's only for 30 seconds, breaks the pattern and gets them back with you for another 10-20 minutes.

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

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

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

- **Create some private space for yourself and retreat to it on a regular basis.** Pick a three-hour slot once or twice a week when you don't have class or office hours and go elsewhere—stay home, for example, or take your laptop to the library, or sneak into the empty office of your colleague who's on sabbatical. It's tough to do serious writing or thinking if you're interrupted every five minutes, which is what happens in your office. Some people with iron wills can put a "Do not disturb!" sign outside their office door, let their secretaries or voice mail take their calls, and Just Do It. If you're not one of them, your only alternative is to get out of the office. Do it regularly and watch your productivity rise.

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

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* Many other ideas for active learning exercises are given in References 1 and 2.

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

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

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

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

References

SORRY, PAL—IT DOESN'T WORK THAT WAY
Richard M. Felder

P.S. We are attempting to clear our inventory of back papers and so I would appreciate your returning the review by next Tuesday.

...and I know I got a 36 on the final exam, Dr. Felder, and it was my high grade so far, but I really think I should get an A in the course because I really worked hard on it and I really understand the material and...

Dear Professor Felder: I am a chemical engineering student at East Indiana Tech. We are using your book, Elementary Principles of Chemical Processes, this semester. I think I would learn much better if I could check my solutions against yours. Please send me a solution manual. Sincerely, Alvin Wimbish.
P.S. Please send it by Federal Express.

Um, Dr. Felder—the TA missed this here test page completely on that quiz we took last January and it's got everything right on it—I think I should get full credit.

Hey, am I speaking to the Chemical Engineering Department at State?...Who's this?...How you doin', Professor?...You don't know me, but my wife got some black crud on our white linoleum floor and the 409 won't get rid of it, and I said, I'll bet you one of them chemical engineering fellers over at State will know just the thing to clean it up...so what should I get, Doc?

Rich, do me a favor. I just got this manuscript to review from JPFM and I'm tied up with a proposal deadline...it's right up your alley—Snaveley's latest work on nonnewtonian cheese flow...pick up this one for me, ok—I'll owe you. Thanks. Walt.
P.S. By the way, could you get it out by Tuesday?

Hello, is this Dr. Felder?...This is one of your 205 students...I know it's past midnight, but I can't figure out the recycle problem that's due tomorrow and I thought you might...

Dear Professor Felder: We have received the reviews of the paper you submitted in April 1991. All the reviewers agree that the work is publishable but only after major revisions are made. Reviewer 1 wants you to expand the experimental section considerably, providing details of all sample preparation steps and adding a glossary of the terms in Figure 6. Reviewer 2 wants the experimental section to be shortened and Figure 6 replaced with a simple flow chart. Reviewer 3 proposes deleting the experimental section, since everyone knows how to do this sort of measurement, and substituting a Far Side cartoon for Figure 6. I agree with the reviewers' suggestions and request that you comply with all of them. Sincerely, E. Wombat, Editor.
P.S. We're trying to clear our back paper inventory and so I'd like to get the revision back by next Tuesday.

Hello, is this Dick Felder?...Dick, you don't know me but I've got a fantastic opportunity for you to earn big bucks. Let me just have a few minutes of your time to explain....
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.\textsuperscript{19}

Richard M. Felder and Rebecca Brent
North Carolina State University

- Set 2–3 year goals along with reasonable steps necessary to reach them. For example
  1. Stay in good health
     - Exercise 3 times a week
     - Get sufficient sleep
  2. Get promoted to associate professor
     - Write __ papers in refereed journals
     - Write __ proposals.
  3. Learn to wind-surf
  4. Remain married
- Prioritize goals. Find an order that satisfies you now—you can always change it. \textit{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\textsuperscript{20}:
  I. Urgent and important. (Deadline-driven activities that further your goals.)
  II. Important but not urgent. (Long-term professional, family, and personal activities that further your goals.)
  III. Urgent but not important. (Much e-mail, many phone calls and memos, things that are important to someone else but don’t further your goals.)
  IV. Neither urgent nor important. (TV, computer games, junk mail.)
Commit to several hours a week on Quadrant II items, and cut down on time spent in Quadrants III and IV.
- Work on Quadrant I and II items when you’re at peak efficiency.
- If you’re trying to write a book, put it on the Quadrant II list, otherwise it will never get written.
- Keep a log for time spent writing (30-45 minutes daily or longer blocks 2-3 times a week) and preparing for lectures (2 hours or less for each lecture hour) until the work pattern becomes a habit.\textsuperscript{21}

\textsuperscript{21} R. Boice, \textit{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.
- Learn to type if you don’t know how already and do your own manuscript composing on a word processor.
- Avoid perfectionism—don’t keep revising until the deadline, and don’t revise unimportant letters and memos at all. Be aware of the point of diminishing returns.
- Be careful of computer graphics—they’re a time sink.
- Piggyback work—use the same notes or manuscripts for multiple applications.
- Keep research projects in the pipeline. Well before a project ends, start writing the next proposal.
- Reward yourself—take breaks.

Learn how and when to say no!

- Always give yourself a chance to think about a commitment overnight before agreeing to it. The time will give you a chance to see if it fits in with your goals and priorities.
- Keep an updated list of all your service responsibilities. Refer to it when the next request comes in.
- Check out service requests with your mentor or department head. Consider showing the latter your list if he or she is the one making the request.
- Practice declining requests:
  1. “That sounds interesting, but can I call you back tomorrow? I need a little time to think about it before I can decide.”
  2. “I’m sorry, but I’ve just got too many other commitments right now.”
  3. “I’d love to help, but I really don’t have time for a formal commitment. Maybe we could just talk once or twice.”
  4. “I’m afraid I’m not the best person to help you with this. Have you thought about asking ______?"

(Penny Gold)
Additional Resources

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

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

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

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

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

Reading for new faculty on starting a career in academia:

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

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

  Menges takes an in-depth look at the problems facing new faculty and offers practical suggestions for dealing with them. Special suggestions aimed at women and faculty of color are also included.
G. Epilogue
Student ratings of teaching get a bad rap in some academic circles. Faculty members are repeatedly and authoritatively assured that “They’re just popularity contests,” “High ratings go to the easy graders,” and “If I get low ratings it’s only because I set high standards and students don’t like demanding teachers.”

In fact, student ratings have been repeatedly shown to have a high level of validity, and those complaints about them have been debunked by research.1–3 Students are in a better position than anyone else to judge certain aspects of teaching, such as how clear, interesting, respectful, and fair a course instructor is, and they’re the only ones who can say how an instructor has influenced their attitude toward the course subject, their motivation to learn it, and their self-confidence. For these and other reasons, student ratings should be considered an essential component of faculty teaching performance evaluation.

But it makes little sense to use only student ratings. Few students are equipped to judge whether a course is accurate and up-to-date, the assignments and tests are appropriately challenging, and the content and learning objectives are consistent with the course’s intended role in the department (for example, to serve as a prerequisite to other departmental courses or to address certain outcomes in the department’s accreditation plan). Only faculty colleagues are in a position to make such judgments.

Moreover, classroom teaching may only be a small part of a faculty member’s educational activities. He/she may also advise students, develop new courses and redesign old ones, adapt and develop courseware and innovative teaching strategies for use in both traditional classroom instruction and distance education, coordinate departmental preparation for accreditation, offer seminars, workshops, consulting, and mentoring to help faculty colleagues and/or graduate students improve their teaching skills, write textbooks, and conduct educational research. All of these activities can have a dramatic effect on a department’s teaching quality, student retention, and chances of receiving full accreditation, but student ratings don’t indicate whether and how well an instructor is doing them.

In short, a key to effective teaching evaluation is to collect data from multiple sources (triangulation), making sure that all education-related activities are rated by the people best qualified to rate them. Figure 1 presents a multiple-source evaluation model designed to work that way. The remainder of this column briefly elaborates on the model components.

Peer Ratings

The usual form of peer evaluation, in which an observer visits a lecture and jots down whatever happens to catch his or her attention, has its own drawbacks. Most obviously, a single observed class may not be representative of someone’s normal teaching. Even if it is, faculty members have widely disparate ideas of what constitutes good teaching, so that the same class could get an excellent rating from one observer and a poor rating from another. More importantly, a single class observation provides no assessment data at all on aspects of teaching performance other than lecturing.

A far more effective procedure is for two or more reviewers to use standardized checklists to rate instructional materials and at least two class observations independently and then to reconcile their ratings.4 The checklists should consist of items taken from a list of attributes known to correlate with effective teaching,5,6 and should be approved by the department faculty before they are used. This procedure has a high level of inter-rater reliability and includes measures to address commonly expressed concerns about peer review, including possible rater bias and excessive time demands imposed on reviewers.4

Student Ratings

Tested forms for student evaluation of teaching are given in a recent National Research Council publication,7 and more information about how to make student evaluations effective is provided in that reference and by Felder.8 Faculty performance evaluations should take into account student ratings collected over a period of several years, with relatively little weight being attached to ratings of someone’s first semester of teaching.

The Teaching Portfolio

Just as some performance assessment data can best be provided by students and some by peers, certain important information can only be supplied by the faculty member being reviewed. Instructors should assemble materials summarizing all of their education-related activities, including developing new courses and redesigning old ones, developing and evaluating innovative instructional methods, advising and mentoring students, writing new texts and courseware, providing instructional development to faculty colleagues and graduate students, and carrying out educational research. All of these materials except those related to educational research (which we discuss in the next section) should be incorporated into a teaching portfolio, along with summaries of student ratings over the past two or three years, peer ratings, and reference letters from alumni and colleagues at other institutions who are familiar with the instructor’s educational activities. The portfolio provides a solid basis for evaluating the faculty member’s teaching performance and contributions to education.9–11

The Scholarship of Teaching and Learning

When done properly, educational research is every bit as demanding, rigorous, and important to the future of an academic discipline as traditional disciplinary research.12 There is no legitimate reason to separate the two categories of research by making educational scholarship just another component of teaching performance, or worse, not to count it at all in faculty performance reviews. Any material related to educational research (including lists of grants, publications, presentations, and awards, along with supporting letters) should be combined with documentation of disciplinary research in faculty activity reports and in tenure and promotion dossiers, and the same high standards should be applied to the evaluation of performance in both research categories.

Consistency of Multiple-Source Ratings

For triangulation to be most effective, data from different sources should overlap to the greatest extent possible. For example, items on student rating forms related to aspects of teaching that both students and peers are equipped to evaluate (e.g., the instructor’s preparedness, clarity, responsiveness to questions, and respect for students) should parallel items in peer review checklists. If the two sets of ratings lead to the same conclusions, it affirms the validity of both, while if they disagree substantially it suggests that at least one of the sets is suspect and further investigation should be undertaken. For example, the department head might bring in someone from outside the department (such as a consultant from the campus center for teaching and learning) to conduct focus group interviews with students related to the issues in question.

Summative and Formative Evaluation

Evaluation of teaching may be summative (to provide data for use in making decisions regarding reappointment, tenure, promotion, and merit raises, and for selection of award recipients) or formative (to improve the teaching of the instructor being evaluated). The full procedure depicted in Figure 1 and described above should be implemented for summative evaluation. Once the portfolio is assembled, only minor effort should be required to update it in successive years. For formative evaluation, a subset of the procedure should be carried out (for example, only one peer rater may be used), and the results should be shared only with the instructor rather than being passed on to the department head or a performance review committee. Carrying out formative reviews in the first few years of a faculty member’s career should substantially increase the chances that a subsequent summative review will be favorable.
References


R. M. Felder & R. Brent, *Effective Teaching*

**Students rate**
- Classroom instruction
- Assessment tools/methods
- Out-of-class interactions
- Advising/Mentoring

**Peers rate**
- Classroom instruction
- Assessment tools/methods
- Course materials
- Learning outcomes

**Instructor discusses and self-rates**
- Philosophy and goals
- All education-related activities
- Learning outcomes

**Administrator and/or committee rate**

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**Portfolio**

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**Figure 1. Teaching Performance Evaluation Model**

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- Including assignments, tests, graded products, & mechanisms for getting student feedback
- Including availability outside class and helpfulness in office hours
- Including research supervision
- Including syllabus, learning objectives, policies and procedures, test & course grades
- Including teaching, advising, mentoring (students and colleagues), developing courses, creating instructional materials, and educational research. Materials in the last category should be included in the summary of the faculty member’s research, and the rest of the materials in the figure should be assembled into a teaching portfolio.
- Including letters from students, alumni, local faculty, and faculty at other institutions
STUDENT RATINGS OF TEACHING: MYTHS, FACTS, AND GOOD PRACTICES*

Richard M. Felder
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Rebecca Brent
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Myths about student ratings of teaching abound on every campus, usually accompanied by confident assurances that ratings are just popularity contests that reward entertainers and punish the best teachers. (The second group invariably includes the ones doing the assuring.) Some years ago we surveyed the myths and summarized the extensive research that showed most of them to be wrong.1 Now it’s 15 years later and a lot more research has been done, with similar outcomes. Unfortunately the myths are still alive and well, so here is the 2008 version of what “everyone knows” about student ratings and how much of that wisdom is supported by research.

* * *

Myth. Student ratings are not valid assessments of teaching quality.

Fact. False. Thousands of research studies have shown that student ratings correlate positively with every other measure of teaching effectiveness, including alumni ratings, peer ratings, administrator ratings, measures of learning (e.g., standardized tests, common exams in multi-section courses, and ratings of student portfolios), and student motivation.2 The magnitude of the observed correlations varies considerably across individual studies and a few studies report contradictory results, but the weight of the evidence is clear. If students consistently say someone’s teaching is good or bad, they’re almost certainly right.

Myth. The highest ratings go to the easiest courses.

Fact: False. Up to a point, courses rated as more difficult on average get higher ratings than easier courses, with ratings only beginning to fall when courses reach levels of difficulty beyond the backgrounds of most enrolled students. In a recent study of 1045 engineering, science, and humanities courses at two universities, Dee3 found that student perceptions of course workload were not significantly different for courses in the top and bottom quartiles of student ratings, with the marginally higher workload rating coming from the courses in the top quartile.

Myth. Bad teachers who are easy graders get higher evaluations than good teachers who are strict graders.

Fact: False. Individual instructors who give high grades relative to local averages may get higher ratings than they would if their grades were lower,4 but no studies have turned up ineffective teachers who got high ratings just by giving high grades.5 However, the possibility that it could happen supports the common recommendation to use multiple sources of assessment data.

Myth. They may not like me now because I’m rigorous and maintain high standards, but in a few years they’ll appreciate how good a teacher I was.

Fact: Generally false—it happens sometimes, but not often.1,2 Alumni ratings correlate significantly with student ratings given previously to the same instructor. If your students think you’re a great teacher now, most will still remember you fondly in the future, and if they think you’re lousy, don’t expect to start getting holiday greetings from them in five or ten years.

Not all common beliefs about evaluations are wrong, of course. It’s true that teachers who are enthusiastic and caring tend to get better ratings than those who are reserved and distant, but so what? Enthusiasm and caring of instructors also correlate with motivation and learning of their students, suggesting that the higher ratings are probably deserved. It’s also true that other things being equal, elective courses tend to get higher ratings than required courses, upper-level courses tend to get higher ratings than lower-level courses, small and moderately-sized classes get higher ratings than very large classes, student ratings in engineering and the sciences are lower than ratings in other fields, and female instructors in engineering and the physical sciences get lower ratings than male instructors. On average these effects are small, but they exist and should be taken into account when ratings are used to make decisions about such things as reappointment, tenure, promotion, and merit raises.

In short, student evaluations have high levels of reliability and validity and should always be part of the process used to evaluate teaching. There are some aspects of a course that students are in no position to evaluate, however, including whether the course learning objectives are appropriate, the content is current with the state of the field, and the course adequately prepares the students for subsequent courses in the curriculum. Those things can only be evaluated by knowledgeable peers. Student ratings should therefore not be the sole source of teaching assessment data but should be supplemented with peer ratings and other measures of teaching effectiveness. If different sources agree, as they usually will, it’s a good indication that the overall assessment is a fair one; if they disagree, it’s a red flag, and an effort should be made to find out what’s going on.

Since student ratings will undoubtedly remain central to teaching evaluation (as they should), everything possible should be done to make them as effective as possible. The following recommendations—most of which are drawn from the papers cited in Reference 2—address that goal.

- **Use a rating form that has been developed with the assistance of someone knowledgeable about educational measurements.** There is a science to survey construction in general and educational rating instrument construction in particular. Either use a form that has been developed and validated elsewhere, such as the IDEA Student Ratings of Instruction system (<http://www.idea.ksu.edu/>) or TCETools (<http://tcetools.com>), or work with an education specialist on your campus or an external consultant.

- **Don’t trust ratings collected from fewer than ten students or less than 2/3 of a class, and don’t make personnel decisions based on ratings from a single semester.**

- **Use a few global or summary items with Likert-scale (1–5) ratings for summative evaluation (evaluation used to help inform personnel decisions), and a longer list of more specific items for formative evaluation (diagnostic evaluation used to help instructors improve their teaching).** Global items correlate more strongly with student learning than more specific items do, and you’ll get a higher rate of return if there are fewer questions.

- **When evaluating ratings, remember that they may be slightly affected by factors other than the quality of instruction, such as the nature and level of the course, the class size, and the gender of the instructor.** The IDEA system and TCETools include provisions for taking these factors into account.
• Try to persuade students that their ratings will be considered carefully and may have an impact on faculty personnel decisions and decisions about teaching assignments. If you can make this case convincingly, most students will take the ratings seriously and you should get a good rate of return. If you can’t make the case, there is no reason the students should take the ratings seriously and you should not be surprised if they don’t.

References


Additional Resources on Evaluation of Teaching

- **IDEA Center** (Individual Development and Educational Assessment) Website. The IDEA Center, which is housed at Kansas State University, has developed a widely used student rating system in both paper-and-pencil and on-line versions, and also contains numerous on-line articles that discuss different aspects of teaching, learning, and assessment of both. [www.idea.ksu.edu](http://www.idea.ksu.edu)


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 “Getting Started” in Section B.)
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
Rebecca Brent

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

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

Level I — New or traditional instructor.

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

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

- Put some long derivations and prose passages from your course notes in handouts, leaving gaps and inserting questions or exercises. Don’t cover the handouts in detail in class—focus on the gaps and the most important or conceptually difficult material. Just doing this can save dozens of hours of class time that would normally be wasted on board stenography. [Notebook: pp. D3–D4.]

- In the time you save by not having to write everything out on the board, give small–group exercises in class. Take five minutes before each lecture to think of at least two questions or problems to be posed to groups or assigned as think-pair-share exercises. You will always be able to think of questions during this five-minute planning period, but you may not think of them spontaneously during class. Use different types of questions in these exercises, so the students will never know what to expect in any given class. [Notebook: pp. D8–D10.]
• Periodically do a “minute paper” in class. Following a lecture, ask the students (sometimes individually, sometimes in pairs) to write the main point and the muddiest point in the lecture. Collect the responses and use them to plan the beginning of the next lecture. [Notebook: p. D13.]

• Write detailed learning objectives (including some at higher Bloom levels) and give them to the students in the form of study guides for tests. Provide practice in the required skills in class activities and homework assignments. (You may not want to write objectives for the whole course the first time you try this.) [Notebook: p. B2–B5, B7–B8.]

• 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. [Notebook: p. C7–C14.]

• 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, using the recommendations on p. A10 as a guide.

Level II — Instructor accustomed to nontraditional methods but with minimal development time

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

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

• Write detailed instructional objectives (including some at higher Bloom levels) for an entire course and give them to the students in the form of study guides for exams. Adjust your syllabus and learning objectives to provide a reasonable balance between concrete material (facts, experimental data, physical phenomena) and abstract material (theories, mathematical models). Try to achieve a largely inductive presentation of course material that moves from the concrete to the abstract. [Notebook: pp. B2–B5, B14–B16.]

• If the course notes are reasonably well worked out, consider adding learning objectives for each major section, gaps to be filled in by students, and self-tests, and giving or selling the complete package to the students at the beginning of the course. Once you have done so, you can include as many active learning experiences in class as you want to and still cover more material than you ever did when you wrote everything on the board or on transparencies.
• **Write homework assignments to match your objectives, especially the objectives that involve higher-order thinking skills.** Routinely include questions that call for written explanations of observable—and preferably familiar—phenomena in terms of course concepts. Occasionally, assign students to make up and solve straightforward problems or problems that call for higher-level thinking skills.

• **Pick a particularly important example or derivation and devote a complete class period to a TAPPS exercise on it.** [Notebook: pp. D14.]

• **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 [Notebook: pp. D26–D36]

• **Undertake problem-based learning, using complex, real-world, open-ended problems to provide context for the knowledge and skills to be learned in the course.** [Notebook: pp. B14–B16]

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

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