LEARNING BY SOLVING SOLVED PROBLEMS

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

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

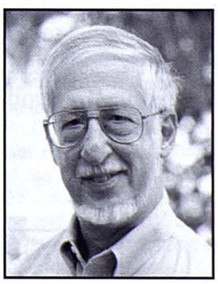
A few of our students may be guilty of those things, but something else is behind their apparent inability to do more than rote memorization of material in lectures and readings. The problem with lectures is that it's impossible for most people to learn much from a bad one, while if the lecturer is meticulous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

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

A powerful alternative to traditional lectures and readings is to have students go through complete or partially worked-out derivations and examples in class, explaining them step-by-step to one another. One format for this technique is an active-learning structure called *Thinking-Aloud Pair Problem Solving*, or TAPPS.[1,2] It goes like this.

1. *Prepare a handout containing the derivation or solved problem to be analyzed and have the students pick up a copy when they come in to class. Tell them to form into pairs (if the class has an odd number of students, have one team of three) and designate one member of each pair as* A *and one as* B *(plus one as* C *in the trio).*
2. *When they've done that, tell them that initially* A *will be the* explainer *and* B *(and* C*) will be the* questioner(s).

Rebecca Brent *is an education consultant specializing in faculty development for effective university teaching, classroom and computer-based simulations in teacher education, and K-12 staff development in language arts and classroom management. She codirects the ASEE National Effective Teaching Institute and has published articles on a variety of topics including writing in undergraduate courses, cooperative learning, public school reform, and effective university teaching.*



Richard M. Felder *is Hoechst Celanese Professor Emeritus of Chemical Engineering at North Carolina State University. He is co-author of* Elementary Principles of Chemical Processes *(Wiley, 2005) and numerous articles on chemical process engineering and engineering and science education, and regularly presents workshops on effective college teaching at campuses and conferences around the world. Many of his publications can be seen at* <www.ncsu.edu/effective_teaching>.

The explainers will explain a portion of the handout to the questioners, line-by-line, step-by-step, and the questioners will (a) ask questions *(if the explainers say anything incorrect or confusing), (b)* prompt the explainers to keep talking *(if they fall silent), and (c)* give hints *(if the explainers are stuck). If both members of a pair are stuck, they raise their hands and the instructor comes over and helps. The second function is based on the fact that vocalizing one's thinking about a problem sometimes leads to the solution.*

3. *The students first individually read the description of the formula or model to be derived or the statement of the problem to be solved; then the explainers explain it in detail to the questioners and the questioners ask questions, keep the explainers talking, and offer hints when necessary. Give the class 2–3 minutes for this activity.*
4. *Stop the students when the allotted time has elapsed, randomly call on several of them to answer questions about the description or problem statement they just went through, and call for volunteers if additional responses are desired. Add your own explanations and elaborations (you're still teaching here). Then have the pairs reverse roles and work through the first part of the derivation or problem solution in the same manner. When results are obtained that are not in the handout, write them on the board so everyone can see and copy them. Proceed in this alternating manner through the entire derivation or solution.*

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

Cognitive science provides an explanation for the effectiveness of this technique.[3,4] Experts have developed cognitive structures that enable them to classify problems in terms of the basic principles they involve and to quickly retrieve appropriate solution strategies, much the way expert chess players can quickly plan a sequence of moves when they encounter a particular type of position. Novices—like most of our students—don't have those structures, and so they have the heavy *cognitive load* of having to figure out how and where to start and what to do next after every single step. Faced with this burden, they frantically scour their lecture notes and texts for examples resembling the assigned problems and focus on superficial details of the solutions rather than trying to really understand them. They may learn how to solve nearly identical problems that way, but even moderate changes can stop them cold.

Sweller and Cooper[3] and Ambrose *et al.*[4] report studies showing that students are indeed better at solving new problems when they have first gone through worked-out examples in the manner described. When they have to explain a solution to a classmate, their cognitive load is dramatically reduced because they don't have to figure out every trivial detail in every step—most of the details are right there in front of them. Instead, they have to figure out *why* the steps are executed the way they are, which helps them understand the key features of the problem and the underlying principles. The effect is even greater if they are given contrasting problems that look similar but have underlying structural differences, such as a mechanics problem easily solved using Newton's laws and a similar one better approached using conservation of energy. Having to explain why the two problems were solved in different ways helps equip the students to transfer their learning to new problems.

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

REFERENCES

1. Lochhead, J., and A. Whimbey, "Teaching Analytical Reasoning Through Thinking-Aloud Pair Problem Solving," in J.E. Stice (Ed.), *Developing Critical Thinking and Problem-Solving Abilities: New Directions for Teaching and Learning*, No. 30. San Francisco: Jossey-Bass (1987)
2. Felder, R.M., and R. Brent, "Active Learning: An Introduction," *ASQ Higher Education Brief*, **2**(4), August 2009, <*http://www.ncsu.edu/felder-public/Papers/ALpaper(ASQ).pdf*>, accessed 11/1/2011
3. Sweller, J., and G.A. Cooper, "The Use of Worked Examples as a Substitute for Problem Solving in Learning Algebra," *Cognition and Instruction*, **2**, 59-89 (1985)
4. Ambrose, S.A., M.W. Bridges, M. DiPietro, M.C. Lovett, and M.K. Norman, *How Learning Works: 7 Research-based Principles for Smart Teaching*. San Francisco: Jossey-Bass (2010) ❐

All of the *Random Thoughts* columns are now available on the World Wide Web at
http://www.ncsu.edu/effective_teaching and at http://che.ufl.edu/~cee/