3

Extended small-group learning strategies such as jigsaw, structured controversy, and problem-based learning have proven so effective to many faculty members that they have moved to redesign their large classes to center around small-group learning.

Going Deeper: Formal Small-Group Learning in Large Classes

Karl A. Smith

> To teach is to engage students in learning; thus teaching consists of getting students involved in the active construction of knowledge. A teacher requires not only knowledge of subject matter but knowledge of how students learn and how to transform them into active learners. Good teaching, then, requires a commitment to systematic understanding of learning. . . . The aim of teaching is not only to transmit information but also to transform students from passive recipients of other people's knowledge into active constructors of their own and others' knowledge. The teacher cannot transform without the student's active participation, of course. Teaching is fundamentally about creating the pedagogical, social, and ethical conditions under which students agree to take charge of their own learning, individually and collectively [Christensen, Garvin, and Sweet, 1991, pp. xiii, xv, xvi].

This quote from the introduction to *Education for Judgment,* one of the most highly regarded books on case-method learning, advocates compellingly for the notion that meaningful learning develops from the active construction of knowledge. Many faculty members, impressed by the impact of short-term informal group activities in their classes, are moving to adopt more formal small-group learning arrangements and to ask those student groups to undertake more complex intellectual problems and tasks. This chapter describes some of these activities, proceeding from some that are slightly more involved than those described in Chapter Two to complex in-class activities and strategies that involve massive reorganization of large classes. The types of implementation that we will describe are as follows:

- Informal strategies with extensions
- In-class project work
- Jigsaw strategies
- Structured academic controversy
- Base groups
- Problem-based learning
- Restructured lecture-recitation-laboratory
- Eliminated lecture, substitution of hands-on laboratory

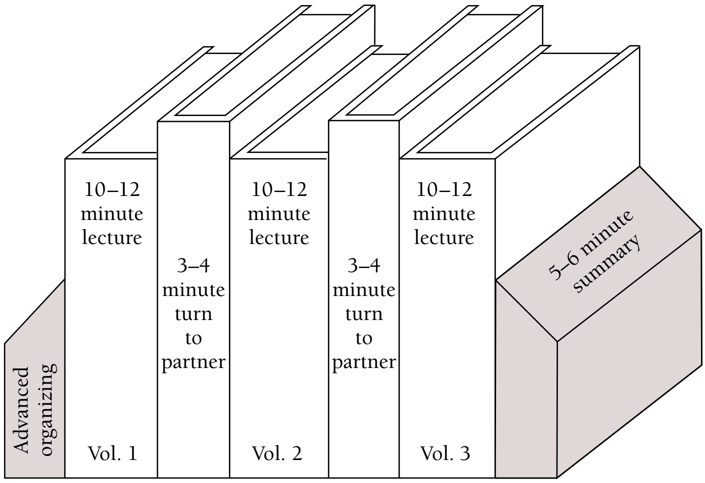
Informal Strategies with Extensions

Many faculty desire more extensive student involvement after successfully implementing informal, short-term, ad hoc grouping strategies. In this chapter we describe extensions of these strategies that incorporate more detailed individual preparation before student discussion in pairs or threes, several back-and-forth conversations between small groups and the whole class, and specific role assignments to the group structure, as well as many other extensions.

Most of the faculty interviewed for this chapter have expanded on the informal cooperative learning strategy commonly known as "turn to your neighbor," which is described in Chapter Two. Calvin Kalman, professor of physics at Concordia University, Montreal, deepens this procedure in his calculus-based physics course with one hundred students by involving them in extensive individual journal-writing assignments (Calvin Kalman, personal interview with the author, Oct. 1998; Kalman and Kalman, 1996). Students write about material before the class, produce a critique based on the concepts they have come to understand after the week's classes, and develop an overview of the course with the assistance of two student reviewers at the end of the semester. Students are assigned to collaborative groups of three or four and are given a specific role—reporter, scribe, timekeeper, or critic—that is rotated. They write individually and then work together to arrive at a decision with a rationale in their groups. Kalman samples the groups' decisions, compares and contrasts what they come up with, and works to create consensus and understanding with the whole class.

Several faculty members mentioned using the bookends procedure to provide a structure for these turn-to-your-neighbor student conversations (see Figure 3.1). The bookends procedure usually begins with an engagement activity—a question or task that both sparks the students' curiosity and helps the instructor discover what they already know about the material. A simple and commonly used engagement activity is, "List at least three insights you gained from the reading assignment and at least one question." The middle part is a series of back-and-forth transitions between the instructor talking and students working individually and then in pairs or threes. The final bookend activity is a guided reflection on the class using

Figure 3.1. Informal Cooperative Learning and the Lecture



questions such as, "What were the most important concepts today?" or "What was the muddiest point?" or "Explain the following concept in your own words." These and several additional questions may be found in Angelo and Cross (1993).

A few instructors combined the bookends procedure with permanent, fixed membership groups in order to create more cohesiveness and to deepen the level of conversation. Mano Singham, professor of physics at Case Western Reserve University, divides the 220 students in his Physics 121 into permanent groups after the first class. He forms the groups so students can conveniently meet outside of class, and he sends students an e-mail message with the group information before the second class so they can sit with the other members of their group. Three to four times per class, he poses questions or problems that stress some subtlety or difficulty worthy of a group discussion. A randomly selected individual in a randomly selected group is asked to present that group's answer. Others in the group may pitch in at this stage to help with the explanation. Once a week Singham assigns an outside-of-class group homework assignment that is submitted and evaluated.

Here are the specifics about group work rules that Singham gives his students (Mano Singham, personal interview with the author, Jan. 1999):

- Group members should sit together in lectures and recitations. When a question is asked in lecture, they should pool their ideas so that the one who is called on can use the knowledge of the entire group.

- Group members should exchange names and e-mail address (or addresses and phone numbers) with one another so that they can contact one another easily.
- Each individual's name and group number should be written on all assignments and exams that are handed in.
- Individual homework assignments should be handed in separately, but they can and should be discussed with others before being handed in.
- For group homework, only one assignment per group should be handed in.
- All assignments will be returned clipped together by group. The first member of the group to come to class should pick up the assignments for that group and distribute them to the other members.
- If a member of the group is absent, another member should collect his or her assignment and any handouts and give them to the absent student as soon as possible, along with lecture notes for that day.
- Only one member should pick up any handout for the whole group.

Singham highlights the importance of cooperation in his class by asking that each group have a private meeting with him at the beginning of the semester. In this way, he can get to know the students and give them an opportunity to voice any concerns. His use of an absolute grading system underscores the cooperative learning as he states emphatically in the syllabus: "Your grade for this course will *not* depend on how well your performance compares with that of the other students. You are *not* in competition with your peers. Conversely, you will find that you will do better if your fellow students do well too" (Mano Singham, personal interview with the author, Jan. 1999).

Diane Ebert-May, professor of botany and director of the Lyman Briggs School (a residential science college) at Michigan State University, uses a learning cycle model to involve her students during large introductory biology classes. The learning cycle model of instruction she uses is based on five phases: the *engagement phase* begins with a question to probe students' prior knowledge and help organize their thinking for subsequent activities; the *exploration phase* provides students with a common basis for understanding the concepts, processes, and skills for the topic being considered; the *explanation phase* builds on the engagement and exploration phases so that students can demonstrate their understanding of concepts with additional examples; the *elaboration phase* challenges students' conceptual understanding and skills; and in the *evaluation phase* students are given an individual or group quiz (short-answer format) daily to evaluate their understanding (Ebert-May, Brewer, and Allred, 1997).

Ebert-May and colleagues have conducted systematic experimentation on this cooperative learning cycle approach. They found that students in the experimental sections had significantly higher scores on process questions (conceptual understanding of a testable scientific question, designing a method for answering the question, interpreting quantitative relationships, and explaining results) and confidence, and similar scores on content questions compared with students in a traditional lecture section (Ebert-May, Brewer, and Allred, 1997).

In-Class Project Work

The faculty members whose stories are included in this section used assigned, relatively permanent groups of students who worked together both inside and outside of class. Compared with the periodic short-term group exercises described in the previous section, these exercises are longer-term, more hands-on, and more complex.

Steve Richardson (personal interview with the author, Oct. 1998), formerly professor of geology at Iowa State University, stresses the importance of hands-on activities in the nonmajor geology classes. He randomly assigned the 240 to 250 students to permanent groups of about 6 and provided them with a group folder in which he placed the syllabus and other handouts. During a typical class period he provided each group with a box of minerals and a set of photos or showed a video clip or set of slides. He asked the groups to "handle" the materials and perform a set of prescribed tasks or respond to a set of questions. He reports that the five- to fifteen-minute exercises made a great difference in his classes. He used twelve-minute individual quizzes and then provided five minutes for a group answer, and like many of the faculty members we interviewed, underscored the importance of an absolute grading scale. As a result of these activities, attendance rose to over 90 percent and the dropout rate declined to less than 2 percent.

In his classes of 144 students in Conceptual Physics, Dewey Dykstra of Boise State University (personal interview with the author, Oct. 1998) stimulates intense group discussion by inducing a sense of "disequilibration." Catherine Fosnot, professor of education at City College of the City University of New York (1989) describes a classroom implementation of cognitive disequilibrium as follows: "I [the teacher] point out exceptions that I'm aware of that cause problems for your [the student] rules, and I try to foster debates and discussion. By arguing and testing out ideas in groups, we come up with exceptions for each other to consider, and that also promotes construction" (p. 53).

In Dykstra's classes, disequilibration is usually introduced during the two-hour lab session, where students work in groups of four. It is then dealt with during one or both of the seventy-five-minute discussion periods that are held each week. Dykstra's students develop what for them is a new ray model of light and compare the models with the actual behavior of light, images, and lenses. In so doing the students experience disequilibration because they learn that the actual behavior of light challenges their present understanding of and beliefs about light, images, and lenses. Dykstra uses in-class group discussion to help students struggle with this disequilibration but tries to stay out of the resulting discussions by maintaining the role of moderator or referee. He interacts with groups but resists telling them what they should think, although he does make specific suggestions and requests concerning process (Dykstra, Boyle, Franklin, and Monarch, 1992; Dykstra, 1996). He began using this approach because he "wanted to have an impact, especially on the preservice teachers who take the course . . . to induce as many instances of conceptual change as possible, about the content, about science, about the nature of knowledge, and about their own personal meaning" (Dewey Dykstra, personal interview with the author, Oct. 1998).

Elizabeth Keating, professor of anthropology at the University of Texas at Austin, uses a combination of in-class project groups with out-of-class project assignments in two classes, Language in Culture and Society, and Culture and Communication, whose enrollments are routinely from sixty to one hundred students. She wants students to become involved in doing research on language both to make them more active learners and to teach analytical skills. In a typical assignment she asks students, in teams, to videotape people talking in technologically rich environments to see if or how language practices are influenced by technology and whether technology influences language practices. Their observations form the basis of an analytical paper that they turn in at the end of class. The students choose their own research sites around campus and are encouraged to use the concepts discussed in class in their projects. In class, Keating breaks students into small groups of three to discuss readings and to do language analysis using overhead slides made from their own transcripts of videotaped interaction (Elizabeth Keating, personal interview with the author, Jan. 1999).

Johanna Seibt, professor of philosophy at the University of Texas at Austin, uses a research group format in her Introduction to Philosophy class, which enrolls between 150 and 350 students. The present implementation of the instructional format, as well as the didactic-epistemological perspective it is based on, was developed in collaboration with Phil Hopkins (professor of philosophy as Southwestern University). Seibt began to employ various research group formats when she noticed that "students had the most satisfying and productive learning experience during office hours when I, to shorten the line, invited them in in small groups and started a discussion about the subject instead of simply answering their questions one by one." Now, from the perspective of great success with this approach, she comments,

> My goals may sound very ambitious but they are, I believe, the only possible ones for introductory philosophy courses. I am trying to initiate or boost a movement toward intellectual maturation, radically discouraging the "cramming and regurgitating" attitude. Instead I want my students to interact critically with their readings, to engage with the problems they encounter in their reading at a cognitive and even existential level. Even though I spend much

> time on teaching the tools of critical analysis and want my students to experience their intellectual independence with respect to dogmatically presented worldviews, I also want them to move beyond the easy route of skeptical relativism . . . and to understand that there is a third alternative between dogmatism and relativism, between getting "the" answer to life's important questions and getting no answer. I want them to experience that we receive concrete answers that are even the right answers for a particular context of questioning insofar—but only insofar—as we manage to sustain the activity of asking these questions [Johanna Seibt, personal interview with the author, Jan. 1999].

Seibt describes her expectations and the course structure in a detailed handout titled "How to Study in This Course." Borrowing several metaphors from the Star Trek television series, the document opens with the following challenge:

> Philosophy is a subject matter that is difficult to pick up. This is not because there is so much to memorize or because one has to go through difficult calculations—in fact, as you will see, you will have to learn just a handful of new concepts, and the thinking to be done is quite simple. Rather, philosophy is a hard subject because understanding and doing philosophy requires that you adopt a new way of thinking. This new way of thinking—or better, a new cognitive attitude, a new mental posture—is best acquired by working in small groups. . . . Philosophy is often described as the adventure of thinking, but it is perhaps even better described as the adventure of *thinking together*. . . . Picture our course as a kind of flight of ideas, a mission to seek out new worlds and explore new conceptualizations, to boldly think what almost no one has thought before. Class (the lecture) is like the mother ship that carries you into various regions of the deep space of philosophical thought. The real adventure begins, however, when you get on an away team, and explore the contents of that region under your own command, making contact with what may appear alien to you in and about philosophy.

Seibt assigns students to permanent groups of four and she refers to the groups as "away teams" or journal groups. The groups meet during class and also schedule a weekly two-hour meeting outside of class. Each member of each team performs one of four roles—text researcher, life researcher, editor, and critic—that are rotated. The text researcher looks up definitions, compares definitions, searches for articles or Web sites, writes up the results, and e-mails them to the other group members. The life researcher interviews people, summarizes the results, and e-mails them to the rest of the group. The editor takes notes during group meetings and writes up the week's entries in the group's journal. The critic becomes active after receiving the data from the text researcher and the life researcher, summarizing the group's responses in the journal. Each week the groups submit their journals to the TA via e-mail and receive e-mail comments from the TA in response.

Seibt emphasizes that her redesigned courses are more consistent with professional philosophy, which has been done in groups since antiquity, and she reports extraordinary individual successes: "The particular format of the away teams, with specific rotating roles assigned to each member, should take care of differences in self-affirmation. I had one student in an upper-division course who was *extremely* shy, to the extent that I wondered about her professional future. She was just accepted to law school in Georgetown and wrote me that the research group format in my classes had turned things around for her" (Johanna Seibt, personal interview with the author, Jan. 1999).

Jigsaw Strategies

Jigsaw strategies have been used by highly effective student study groups for some time in content-dense disciplines such as medicine and law. They have been used on an ad hoc basis for many years to help all students learn an enormous amount of new conceptual material. First described by Elliot Aronson in 1978, the jigsaw procedure involves students working in a cooperative group where each student is responsible for learning a portion of the material and conscientiously teaching it to the rest of the group. The professor's role in a jigsaw involves carefully choosing the material to be "jigsawed," structuring the groups, providing a clear cooperative context for their working together, monitoring to ensure high-quality learning and group functioning, and helping students summarize, synthesize, and integrate the conceptual material. A typical template for a cooperative jigsaw is shown in Exhibit 3.1. An example of detailed guidance for learning in a jigsaw format is available in Smith (1996).

Many faculty report that the jigsaw approach provides a pleasant alternative to the lecture in helping students learn conceptual material and that it fosters interdependence among them. Although it takes preparation and time to set up the jigsaw, students usually learn more material and remember it longer, and become experienced in a procedure that they often begin using on their own.

Cathy Bristow, professor of entomology at Michigan State University, makes extensive use of the jigsaw strategy in her large life science classes (Bristow, 1995). She does a five-week case study on Mad Cow disease, currently a hot issue with many interdisciplinary elements. She asks her students to work in "research teams" to investigate and then prepare a report on Mad Cow disease, incorporating perspectives on the history, molecular biology, epidemiology, agricultural impact, and international policy aspects of this troubling and potentially dangerous disease. Each student on the team is asked to be responsible both for a specific perspective and for teaching everyone in the group the material in his or her section. Bristow writes:

> This worked well, because I added "bonus" points for folks whose teammates did above some acceptable cutoff (such as 70 percent correct) on that material on a more general exam. So for every teammate who scored over the cutoff on the molecular biology question on the exam, the student who taught the molecular biology got a bonus point. This also worked in part because I structured in a lot of individual accountability and group interdependence. Each team was asked to report in weekly on some aspect of their part done (individually), so no one could fall too far behind [Cathy Bristow, e-mail interview with the author, Jan. 1999].

Structured Academic Controversy

One of the most exciting forms of small-group learning is structured controversy discussion. Controversies and issues on which there are differing perspectives can animate almost any class or discipline. Furthermore, they can provide students with a sense that a course or discipline can be brought to bear on a thorny, interesting, and often contemporary concern. The goal is to understand the best arguments on all sides of the issue, but the students are stimulated to prepare better arguments when they are confronted with a compelling argument from the other side.

In a structured controversy, students working in groups of two to six are assigned a perspective on an issue and asked to prepare, present, and defend that assigned point of view. The interdependence involves a group goal of understanding all sides of the issue in order to write a group report integrating the best arguments on all sides (Johnson, Johnson, and Smith, 1997, 1986; Smith, 1984).

Tom Lord, professor of biology at Indiana University of Pennsylvania (1994, 1998a, 1998b, personal interview with the author, Jan. 1999), combines the jigsaw format just described with a structured controversy. He assigns teams of four students to pro and con sides of an issue such as, "Is nuclear power the answer to our future energy needs?" He subdivides each team into four specialties—usually biotic, abiotic, social, and economic—and asks each team member to research his or her specialty topic on the issue and then teach it to the other members of the team. Initially he had two opposing teams debate the issue with each other in a fishbowl-type format in front of the entire class, but he decided he wanted to get all the students more actively involved. Now he divides the members of the class whose issues are not being discussed that day into eight clusters of between five and seven students and sends one of the presenting students to each of the clusters. The pro and con presenters have about thirty minutes each to try to convince the group of their position. The presenters are then switched to a cluster that has not heard their side of the issue for a second thirty

Exhibit 3.1. A Jigsaw Procedure

When you have information you need to communicate to students, an alternative to lecturing is a procedure for structuring cooperative learning groups called *jigsaw*.

Task: Think of a reading assignment you will give in the near future. Divide the assignment into multiple (2–4) parts. Plan how you will use the jigsaw procedure. Script out exactly what you will say to the class using each part of the procedure. Practice talking students through their role.

Procedure: The steps for structuring a jigsaw lesson are as follows:

1. *Create cooperative groups:* Distribute a set of instructions (See "Notes to Students," below) and materials to each group. The set needs to be divisible into the number of members of the group (two, three, or four parts). Give each member one part of the set of materials.
2. Allow *preparation pairs:* Assign students the cooperative task of meeting with someone else in the class who is a member of another learning group, and who has the same section of the material, to complete two tasks:
   - Learning and becoming an expert on the material
   - Planning how to teach the material to the other members of the group
3. Allow *practice pairs:* Assign students the cooperative task of meeting with someone else in the class who is a member of another learning group who has learned the same material to share ideas about how the material may best be taught. These practice pairs review what each plans to teach their group and how. The best ideas of both are incorporated into each presentation.
4. Create *cooperative groups:* Assign students the cooperative tasks of
   - Teaching their area of expertise to the other group members
   - Learning the material being taught by the other members
5. *Evaluate:* Assess students' degree of mastery of all the material. Recognize those groups in which all members reach the preset criterion of excellence.

Notes to Students

For this session we will use a procedure for structuring learning groups called *jigsaw*. Each member will be given a different section of the material to be learned. Each member is dependent on the others for success in learning all the material. Each member is accountable for teaching his or her material to the others and learning the material they are teaching. The *purposes* of the jigsaw procedure are as follows:

1. To provide an alternative method of introducing new material besides reading and lecture
2. To create information interdependence among members to increase their sense of mutuality
3. To ensure that participants orally rehearse and cognitively process the information being learned
4. To provide an example of high-performance teamwork

Cooperative Group

Your *task* in this group is to learn all the assigned material. Make sure each member has a different section and that all sections are covered. Work *cooperatively* to ensure that all group members master all the assigned material.

Preparation to Teach in Pairs

Take one section of the material; then find a member of another group who has the same section of the material as you do. Work cooperatively to complete these tasks:

1. *Learn and become an expert in your material.* Read the material together, discuss it, and master it. Use an active reading strategy (such as *pair reading*):
    a. Scan section headings to get an overview of the material.
    b. Silently read a paragraph (or short section).
    c. Person A summarizes the content to Person B. Person B listens, checks for accuracy, and states how it relates to material previously learned.
    d. Reverse roles, and repeat the procedure.
2. *Plan how to teach your material to the other group members.* Share your ideas about how best to teach the material. Make sure your partner is ready.
    a. As you read the material, underline the important points, write questions or ideas in the margins, and add our own thoughts and suggestions.
    b. When finished, write down the major ideas and supporting details or examples.
    c. Prepare one or more visual aids to help explain the material.
    d. Plan how to make the other members of your group intellectually active rather than passive while they listen to your presentation.

Practice and Consulting Pairs

If you finish the preparation and have time, meet with another person from a different group who is ready and who also prepared the same section of the material as you did. Work cooperatively to complete these tasks:

1. Review what each person plans to teach his or her group and share ideas about how to teach the material. Incorporate the best ideas from both plans into each person's presentation.
2. Make sure the other person is ready to teach the material.

Teaching and Learning Group

Meet with your original group and complete the cooperative task of ensuring that all members have mastered all the assigned material by:

1. Teaching your area of expertise to the other group members
2. Learning the material being taught by the other group members

The *presenter* should encourage:

1. Oral rehearsal
2. Elaboration and integration
3. Implementation ideas

The *listening members* should:

1. Clarify the material by asking appropriate questions
2. Help the presenter by coming up with novel ways of remembering the important ideas or facts and think creatively about the material being presented
3. Relate (out loud) the information to previous learned knowledge and elaborate on the information being presented
4. Plan (out loud) how the information can be applied in the immediate future

Exhibit 3.1. A Jigsaw Procedure (*continued*)

Monitoring the Group Work

Collect some data about the functioning of the group to aid in later group processing. The instructor will also monitor and collect data about the material being learned and the functioning of the groups.

Evaluation and Processing

The instructor may assess participants' mastery of all the material by giving every participant an exam or randomly calling on individuals to explain the material they learned.

The instructor will ask each group to process briefly—for example, by asking the group to identify at least one thing that each member did to help the others learn and at least three actions that could be added to improve their learning next time.

Reminder

Learning material in a jigsaw is not a substitute for reading the material on your own later, just as listening to a lecture is not a substitute for doing individual work. The purpose of the jigsaw is to get you involved in the material, to give you an overview, and to try to motivate you to learn more on your own.

Source: Adapted from Johnson, Johnson, and Smith, 1991.

---

minutes. Afterward, the clusters decide who they think did the better job. Lord devotes six class periods during the semester to the structured controversy. He writes:

> The students really do a good job researching their issue. I use this experience still further! At the end of the semester, each group hands in a twenty- to twenty-four-page term paper summarizing its findings. The term paper has four sections to it, one for each student's aspect (biotic, abiotic, social, and economic). I tell the students that the entire term paper must flow together, have a common format, not have repeated information in it, and share a bibliography and a resource appendix. In order not to lose points on the term paper, a team will plan the paper ahead of time and even proofread each other's entries. . . . This peer review and peer writing improves the overall quality of the paper—and gives me twelve or thirteen first-class papers to read rather than forty-eight to fifty-two term papers of different qualities.

Base Groups

Beyond active involvement with course material, a sense of belonging is one of the most important conditions that can be created in a college classroom (Astin, 1993; Palmer, 1998; Seymour and Hewitt, 1997; Tinto, 1993). Being a part of a group not only promotes academic development but also enhances personal development and increases satisfaction. A relatively simple and straightforward way to start building a supportive community is through cooperative base groups.

Base groups are long-term, heterogeneous cooperative learning groups with stable membership whose primary responsibility is to provide each student the support, encouragement, and assistance he or she needs to make academic progress (Johnson, Johnson, and Smith, 1991, 1998a). Like many formal cooperative learning groups, they are intentionally formed by the faculty member, usually after collecting information from the students. Because they often stay the same during the entire course (and occasionally even beyond it), base groups can personalize the work required and the course learning experiences. When base groups complete and submit work in group folders, the paperwork burden for the faculty member is often much reduced. Like other formal groups, base group members must be carefully chosen (usually by the instructor after collecting information on preferences, available meeting times, and many other factors), monitored (the instructor observes their conversations and interactions and gives written feedback), and often coached to improve their communication and functioning as a group.

Base groups are used by several of the educators interviewed for this chapter: Cathy Bristow, Tom Lord, Steve Richardson, and Johanna Seibt. They all have their base groups stay together for the entire term, and they stress to their students the importance of helping one another to be successful. Several use the group folder format to help manage the paperwork during class time. In addition to using base groups for breaking the ice, providing support, and managing paperwork, Cathy Bristow incorporates an intriguing idea: a weekly base-group quiz. The quiz consists of a place for students' names (to give them credit for showing up) and typical multiple-choice exam questions (five or so), each with a space below to describe why the particular answer was chosen. Bristow says it is quite easy for her to review the exams because of the smaller number and higher quality; furthermore, the responses reflect deeper understanding (Cathy Bristow, personal interview with the author, Jan. 1999).

Problem-Based Learning

Problem-based learning (PBL) is a rapidly evolving strategy for developing student learning through the process of working toward the understanding or resolution of a problem. In PBL settings, the problem is encountered *first* in the learning process (Barrows and Tamblyn, 1980). PBL is generally built around the following features: problems are the organizing focus and stimulus for learning and the vehicle for the development of problem-solving skills; new information is acquired through self-directed learning; learning is student-centered and occurs in small student groups; and teachers act as facilitators or guides (Wilkerson and Gijselaers, 1996).

One leader in problem-based learning, Barbara Duch of the University of Delaware, succinctly gives her rationale for employing PBL: "'How can I get my students to think?' is a question asked by many faculty, regardless of their disciplines. Problem-based learning is an instructional method that challenges students to 'learn to learn,' working cooperatively in groups to seek solutions to real-world problems. These problems are used to engage students' curiosity and initiate learning the subject matter. PBL prepares students to think critically and analytically, and to find and use appropriate learning resources" (Barbara Duch, personal interview with the author, June 1999).

The most impressive implementations of PBL in large-class introductory courses is occurring at Samford University in Birmingham, Alabama, and the University of Delaware in Newark. Both schools have invested heavily in faculty development and are now becoming resources to other campuses around the country.

Faculty members at the University of Delaware have implemented PBL in many introductory courses, including biology, biochemistry, chemistry, criminal justice, education, international relations, marine studies, mathematics, nutrition-dietetics, physics, political science, and exercise science (Allen, Duch, and Groh, 1996; Groh, Williams, Allen, Duch, Mierson, and White, 1997). They started with grant support from the National Science Foundation (NSF-DUE) and the Fund for Improvement of Postsecondary Education (FIPSE) and have now had more than 25 percent of the faculty participate in weeklong formal workshops.

General PBL problems and sample problems from biology, chemistry-biochemistry, criminal justice, and physics are available on their Web site (http://www.udel.edu/pbl/problems/). Exhibit 3.2 shows the first page of a problem Barbara Duch uses in a general physics class with over one hundred students.

Confronted with just this introductory information, students set to work in small groups to formulate questions and discuss what information they need to collect and how they will gather it. What is notable about this PBL approach is that students work in stages; they start by assessing what they do know (stage one), then, more important, assessing what they do not know (stage 2), then determining what they need to learn (step 3) in order to attack the problem. Duch and the recitation TAs (including peer facilitators) monitor the groups, and after they have recorded questions at each stage, she randomly samples their ideas. Each problem is set up so that once students have asked questions and produced answers at each stage, they get additional information and move to a higher level of complexity (the next stage) (Barbara Duch, personal interview with the author, June 1999).

Deborah Allen, professor of biology, University of Delaware, acknowledges the enormous commitment of time, energy, and training that was involved in transforming her introductory biology courses to a PBL format. She writes her own problems and involves a cadre of well-trained undergraduate peer tutors. A course in tutorial methods of instruction, which she developed and teaches with a colleague (Harold White, professor of chemistry and biochemistry), helps prepare these and other peer tutors in large

Exhibit 3.2. A Day in the Life of John Henry, a Traffic Cop

At 13:20 on the last Friday in September 1989 a frantic call was received at the local police station. There had been a serious automobile accident at the intersection of Main Street and State Street, with injuries involved. Lt. John Henry arrived at the scene 10 minutes after the phone call and found that two cars had collided at the intersection. In one car, the driver was unconscious and in the other car both driver and one passenger were injured.

After the emergency vehicles transported the injured to the hospital, Lt. Henry's responsibility is to investigate the accident in order to determine whether one of the drivers (or both) are responsible. With the severity of injury in this accident, the investigation is critical because there may be a fatality involved.

What questions does John Henry have to answer in this investigation? What measurements does he need to take? What data should he collect? What other information does he need to record in order to aid the investigation? What physics principles will John Henry need to use in order to help analyze the data and answer his questions?

If two cars moving at right angles to each other collide, in what direction do you expect the cars to be moving after the collision? What factors will influence the direction and distance traveled after impact?

Source: Written by Barbara Duch, 1993. Revised 1995.

---

classes across the campus for this challenging role. She reports that she enjoys teaching more than ever (a common comment among the interviewees) and goes on to say:

> I prepare well for each class—script it out much as I would prepare for facilitating a teaching workshop for faculty—but like never quite being sure what will actually happen in the classroom. Students often turn my plans upside down, and usually it works out for the better. I like the fact that students are continually teaching more about the problems I've written. I can incorporate a whole new set of goals for student learning that would not have been realistic for the way I was doing things before. The classroom is a much more relaxed and user-friendly one from my perspective as well as that of the students. I prefer the role of experienced scholar in a community of scholars much more than that of the keeper of the right answer. I'd never go back to using a traditional format [Deborah Allen, personal interview with the author, Feb. 1999].

Two of Allen's problems are available on the University of Delaware PBL Web site noted earlier: a human genetics problem entitled "When Twins Marry Twins" and an approach to addressing global warming entitled "The Geritol Solution and Twenty-Five."

Allen stresses that preparation is extraordinarily important when sharing the intellectual work space with students in a problem-based learning environment. One part of the preparation is selecting or creating problems and another is choosing the procedure to use. Duch and Allen and their colleagues have written many problems for use in their introductory science courses, and they have spent a lot of time thinking and talking about what characterizes "good problems." Their thinking is summarized on the Delaware PBL Web site mentioned earlier.

The role of the instructor is as crucial to the success of problem-based learning as it is in structured academic controversy and jigsaw. A learning environment must be designed, set up, and maintained so that students take more responsibility for their own learning and the learning of others (Johnson, Johnson, and Smith, 1991, 1998a; Millis and Cottell, 1998). In addition to structuring the learning environment and posing complex, absorbing, and muddy problems, the faculty member usually serves as a facilitator or coach. Those whose stories and insights appear above all use a formal cooperative learning format that incorporates positive interdependence (students are linked through common learning goals, single product from the group, and many other ways), individual accountability (a process to make each student responsible for learning that is operationalized by faculty randomly calling on individual students to explain his or her group's answer as well as by giving individual quizzes, exams, and written assignments), face-to-face promotive interaction (students talk through the material with one another), teamwork skills (students learn and practice communication, decision-making, conflict-management, and leadership skills), and group processing (students are given a time and structure to reflect on how well their group is working). Additional information on these five key elements as well as the instructor's role in formal cooperative learning groups is available in Johnson, Johnson, and Smith (1991, 1998a; Smith, 1995, 1996). A typical problem-based cooperative learning format is shown in Exhibit 3.3. (See Chapter Six for details.)

Duch and Allen have written extensively on the procedures, results, and cautions of the University of Delaware project, and they offer worth-

Exhibit 3.3. Problem-Based Cooperative Learning Format

Task:	To solve the problem, accomplish the task.
Individual:	To estimate answer, note strategy.
Cooperative:	To provide one set of answers from the group, strive for agreement, make sure everyone is able to explain the strategies used to solve each problem.
Expected criteria for success:	Everyone must be able to explain the strategies used to solve each problem.
Evaluation:	Best answer within available resources or constraints.
Individual accountability:	One member from any group may be randomly chosen (a) to explain the answer and (b) to explain how to solve each problem.
Expected behaviors:	Active participating, checking, encouraging, and elaborating by all members.
Intergroup cooperation:	Whenever it is helpful, check procedures, answers, and strategies.

while advice for any instructor considering using of PBL with a small group. Readers are strongly urged to go to this literature for a more thorough understanding of the PBL process. Also, extensive evidence is available documenting the effectiveness of formal cooperative learning (Johnson, Johnson, and Smith, 1991, 1998b; Springer, Stanne, and Donovan, 1999).

Restructured Lecture-Recitation-Laboratory

Several faculty have become so committed to small-group learning that they have moved to redesign their large classes completely to foster it. Three examples involving large-enrollment classes are described here: chemistry at the University of Wisconsin-Madison, physics at the University of Minnesota, and the ModularCHEM Consortium at the University of Calfornia-Berkeley.

John Wright, professor of chemistry at the University of Wisconsin-Madison, teaches five different courses, including Chem 110, which has 120 students in each section. He reports, “I’d always been frustrated because of the really good students, the A-level students who always get the test questions right. When I would talk with these students about something practical, they often could not connect to an application” (John Wright, personal interview with the author, Oct. 1998).

Wright provides a lot of variety during his class sessions. Sometimes he lectures; other times he structures total involvement on the part of the students. For example, he often assigns different rows different conditions for a problem and the different rows have to come up with answers. Students’ schedules are arranged so that each lab section and quiz section has the same group of students and same TA. Wright concedes that having the students stay together “takes some logistical organizing but it is the only way to go” (John Wright, personal interview with the author, Oct. 1998).

Wright establishes a student board of directors, a group of six to fifteen students who meet with him once a week for twenty minutes to provide feedback on the course. This is similar to Ed Nuhfer’s student management teams approach (Nuhfer, 1997). Wright says, “This weekly feedback is one of the really important things I do, especially when I am trying new methods in the class. I am trying to walk the fine line in group learning where the problems are tough enough to make students want to work in groups but not so tough that students get frustrated. I truly value the weekly feedback from the board of directors. There have been times when I’ve walked into the board meeting really trembling, because I do push to the edge of students’ capabilities” (John Wright, personal interview with the author, Oct. 1998).

Wright and colleagues (Millar, Kosciuk, Penberthy, and Wright, 1996; Wright, Millar, Kosciuk, Penberthy, Williams, and Wampold, 1998) documented the effects of cooperative learning in a fascinating study comparing Chem 110 taught by a highly experienced faculty member using a lecture-centered approach (response lecturing, or RL) with one taught by a cooperatively structured approach (structured active learning, or SAL). Randomly selected students from each section were examined individually and orally by about three of twenty-five faculty from chemistry and related disciplines. Students in the SAL section outperformed students in the RL section in all subcategories—analogy, analysis, meta-awareness, and agility—with the largest difference in the meta-awareness subgroup.

The University of Minnesota (collaborative) model for large introductory courses, headed by Patricia and Ken Heller, is an elaborate integration of formal cooperative groups, context-rich problems, and a detailed and explicit problem-solving strategy that is developed throughout the course (Heller, 1999). The introductory physics course has five different lecture sections, each taught by a different lecturer. The lecture sections vary in size from about 150 to 300, totaling about 900 students per quarter. All lecture sections use the cooperative group structure for laboratories and discussion sections. The formal three-member groups (assigned by the teaching assistant for that laboratory or discussion section) work together during the discussion section and laboratory. Informal, self-chosen groups participate in informal activities during the lecture. Formal roles—manager, recorder-checker, skeptic, and energizer-summarizer (if there is a four-person group)—are assigned and rotated. Students spend the most of their time clarifying and solving physics problems working in groups, guided by the course manual, *The Competent Problem Solver: A Strategy for Solving Problems in Physics* (Keith, Heller, and Heller).

The course Web site provides a comprehensive look at the educators' approach to helping students learn physics. They summarize, for example, their implementation of the cognitive apprenticeship approach (modeling, coaching and scaffolding, fading) for helping students participate in the "culture of expert practice"—an environment in which teachers and students not only are engaged in solving problems but also are actively communicating about them with fellow students and teachers. Ken Heller sums up the shift to cooperative learning as follows: "Individual performance on problem solving is one of the reasons we went to cooperative learning. That cooperative groups are effective for individual learning is something that many people don't appreciate" (Ken Heller, personal interview with the author, Mar. 1999). Further details on the Hellers' approach is available in several systematic studies (Heller, Keith, and Anderson, 1992; Heller and Hollabaugh, 1992).

The large-scale experimentation taking place in the ModularCHEM Consortium in chemistry is similar to the Minnesota and Wisconsin models in that the lecture format continues to be used but major renovations have been made to the discussion sections. Funded by the National Science Foundation, the ModularCHEM Consortium is developing and evaluating a modular approach to teaching chemistry. The project has developed several evaluation instruments to help assess the effectiveness of their materials. The evaluation forms are available on the project Web site (mc2.cchem .berkeley.edu).

Eliminated Lecture, Substitution of Hands-On Laboratory

Michigan State University's introductory nonmajor computer science course CSE 101 is taken by about four thousand students each year. Until recently it was taught in classes of fifty to sixty, with students viewing tapes of faculty teaching computer science. Mark Urban-Lurain, instructor in the Department of Computer Science and Engineering at Michigan State, said that they put everything they knew how to do into the tapes (professional studio quality, great graphics and animations, careful scripts) but that students did not learn the material in these presentations. In fact, students not only performed poorly on laboratory exercises covering the lecture materials but also had poor retention of concepts (Mark Urban-Lurain, personal interview with the author, Jan. 1999).

Don Weinshank, professor of computer science at Michigan State University, and Urban-Lurain volunteered to redesign the course completely. They started by surveying of all departments that required the course, asking, among other things, "What would you like students who are successful in the course to be able to do?" They then developed a core sequence with three follow-on tracks (general, spreadsheets for data analysis, and spreadsheets for fiscal analysis).

Now, at the beginning of each two-hour class period, students sign in and are assigned a partner for the day. The classes of thirty students are facilitated by a lead graduate teaching assistant, who is assisted by an undergraduate TA. The two-hour laboratory sessions, which meet twice each week, are scripted in great detail because sixty laboratory sessions go on each week. For example, the TAs' script for day twenty of the general track on "Designing a Web Site" is ten pages long. At the beginning of the term, tasks have five- and ten-minute limits; toward the end, the tasks become more complex and last twenty minutes or more.

In their course redesign, Weinshank and Urban-Lurain implemented a modified mastery evaluation system. In this model, bridge task tests are administered in each laboratory section once each week. They are computer-generated, unique for each student, and administered by a TA who is different from the one teaching the section. They are graded pass or fail, and students must pass each successive bridge task before being permitted to take the next one. Or they may stop and take the grade they have currently earned. Because bridge task tests are given only twelve times during the semester, some students exhaust their opportunities for a higher grade. Students may earn a grade as high as 3.0 by passing the bridge tasks. To earn a 3.5 or 4.0, students must complete an individual project that integrates their earlier learning.

One of the great surprises for these teachers was the grade distribution. The average GPA for the course has consistently been at about 3.0, and the distributions are skewed to the right. Weinshank and Urban-Lurain worried about this until they explored the literature and found this quote from Bloom, Madaus, and Hastings (1981): "If we are effective in our instruction, the distribution of achievement should be very different from the normal curve. In fact, we may even insist that our educational efforts have been unsuccessful to the extent that the distribution of achievements approximates the normal distribution" (p. 52).

Weinshank and Urban-Lurain designed a tightly integrated system where textbooks are custom-published, laboratories are carefully and thoroughly designed, TAs are well trained, and everything works together. They try to be as authentic as possible by using realistic problems and tasks and having students work in teams. Several papers describe their work (Urban-Lurain and Weinshank, 1999a, 1999b, 1999c), and the CSE 101 Web site is very thorough (www.cse.msu.edu/~cse101).

Constructivist Pedagogy

Several faculty members with whom we spoke (Allen, Duch, Dykstra, Lord, Urban-Lurain, and Weinshank) talked about their understanding of and commitment to the notion of constructivism. Some have referred to it in their published work (Dykstra, 1996; Lord, 1994; Urban-Lurain and Weinshank, 1999c). According to Catherine Fosnot (1996), constructivism is not a theory about teaching but rather a theory about knowledge and learning. The theory defines knowledge as temporary, developmental, and socially and culturally mediated, and thus, nonobjective. Learning from this perspective is understood as a self-regulated process of resolving inner cognitive conflicts that often become apparent through concrete experience, collaborative discourse, and reflection.

As is no doubt now clear, the faculty members interviewed for this chapter—whether or not they are conversant with the literature on the subject—are practicing elements of constructivist pedagogy. They are trying multiple things at once, inside and outside the classroom. They are exploring different ways of conceiving courses to engage students, facilitate problem solving, build critical-thinking and reasoning skills, and create community. Once faculty members start treating students as emerging scholars and developing professionals, and once they open up the classroom to student-student interaction, they discover endless opportunities for sharing the intellectual feast. Involving students in these more engaging (and time-consuming) activities is a challenge for many educators, given the lecture-centered tradition that is so firmly entrenched in college and university teaching. But as the examples described in this chapter indicate, doing this is not only possible, it is happening!

References

Allen, D. E., and Duch, B. J. *Thinking Toward Solutions: Problem-Based Activities for General Biology*. Philadelphia: Saunders College Publishing, 1998.

Allen, D. E., Duch, B. J., and Groh, S. E. "The Power of Problem-Based Learning in Teaching Introductory Science Courses." In L. Wilkerson and W. H. Gijselaers (eds.), *Bringing Problem-Based Learning to Higher Education: Theory and Practice.* New Directions for Teaching and Learning, no. 68. San Francisco: Jossey-Bass, 1996.

Angelo, T. A., and Cross, K. P. *Classroom Assessment Techniques: A Handbook for College Teachers*. San Francisco: Jossey-Bass, 1993.

Aronson, E. *The Jigsaw Classroom*. Thousand Oaks, Calif.: Sage, 1978.

Astin, A. *What Matters in College? Four Critical Years Revisited.* San Francisco: Jossey-Bass, 1993.

Barrows, H. S., and Tamblyn, R. *Problem-Based Learning.* New York: Springer, 1980.

Bloom, B. S., Madaus, G. F., and Hastings, J. T. *Evaluation to Improve Learning*. New York: McGraw-Hill, 1981.

Bristow, C. M. "Applications of Environmental and Organismal Biology Teaching Science as Parable." *The Scholarship of Teaching,* 1995, *1*(1), 17–24.

Christensen, C. R. *Teaching by the Case Method.* Cambridge, Mass: Harvard Business School, 1981.

Christensen, C. R., Garvin, D. A., and Sweet, A. *Education for Judgment: The Artistry of Discussion Leadership.* Cambridge, Mass.: Harvard Business School, 1991.

Duch, B. J. "Problem-Based Learning in Physics: The Power of Students Teaching Students." *About Teaching,* Jan. 1995, *47*.

Dykstra, D. I., Jr. "Teaching Introductory Physics to College Students." In Fosnot, C. T. (ed.), *Constructivism: Theory, Perspectives, and Practice.* New York: Teachers College Press, 1996.

Dykstra, D. I., Jr., Boyle, Franklin C. and Monarch, I. A. "Studying Conceptual Change in Learning Physics." *Science Education,* 1992, *76*(6), 615–652.

Ebert-May, D., Brewer, C., and Allred, S. "Innovation in Large Lectures: Teaching for Active Learning." *BioScience,* 1997, *47*(9), 601–607.

Fosnot, C. T. *Enquiring Teachers, Enquiring Learners: A Constructivist Approach for Teaching*. New York: Teachers Collee Press, 1989.

Fosnot, C. T. (ed.). *Constructivism: Theory, Perspectives, and Practice.* New York: Teachers College Press, 1996.

Groh, S. E., Williams, B. A., Allen, D. E., Duch, B. J., Mierson, S., and White, H. B. "Institutional Change in Science Education: A Case Study." In A. P. McNeal and C. D'Avanzo (eds.), *Student Active Science: Models of Innovation in College Science Teaching*. Philadelphia: Saunders College Publishing, 1997.

Heller, K. "The University of Minnesota (Collaborative) Model for Large Introductory Courses." [www.physics.umn.edu/groups/physed]. 1999.

Heller, P., and Hollabaugh, M. "Teaching Problem Solving Through Cooperative Grouping. Part 2: Designing Problems and Structuring Groups." *American Journal of Physics,* 1992, *60*(7), 637–645.

Heller, P., Keith, R., and Anderson, S. "Teaching Problem Solving Through Cooperative Grouping. Part 1: Group Versus Individual Problem Solving." *American Journal of Physics,* 1992, *60*(7), 627–636.

Johnson, D. W., Johnson, R. T. and Smith, K. A. "Academic Conflict Among Students: Controversy and Learning." In R. Feldman (ed.), *Social Psychological Applications to Education.* Cambridge: Cambridge University Press, 1986.

Johnson, D. W., Johnson, R. T., and Smith, K. A. "Cooperative Learning: Increasing College Faculty Instructional Productivity." ASHE-ERIC Higher Education Report No. 4. Washington, D.C.: George Washington University, 1991.

Johnson, D. W., Johnson, R. T., and Smith, K. A. "Academic Controversy: Enriching College Instruction with Constructive Controversy." ASHE-ERIC Higher Education Report No. 25. Washington, D.C.: George Washington University, 1997.

Johnson, D. W., Johnson, R. T., and Smith, K. A. *Active Learning: Cooperation in the College Classroom* (2nd ed.). Edina, Minn.: Interaction Books, 1998a.

Johnson, D. W., Johnson, R. T., and Smith, K. A. "Cooperative Learning Returns to College: What Evidence Is There That It Works?" *Change,* 1998b, *30*(4), 26–35.

Kalman, J., and Kalman, C. "Writing to Learn." *American Journal of Physics,* 1996, *64,* 954–955.

Lord, T. R. "Using Constructivisim to Enhance Student Learning in College Biology." *Journal for College Science Teaching,* May 1994, pp. 346–348.

Lord, T. R. "A Comparison Between Traditional and Constructivist Teaching in College Biology." *Innovative Higher Education,* 1998a, 2(3), 197–216.

Lord, T. R. "Cooperative Learning That Really Works in Biology Teaching." *American Biology Teacher,* 1998b, *60*(8), 580–588.

Millar, S. B., Kosciuk, S. A., Penberthy, D. L., and Wright, J. C. "Faculty Assessment of the Effects of a Freshman Chemistry Course." *Proceedings of the 1996 Annual Conference of the American Society for Engineering Education.*

Millis, B. J., and Cotell, P. G., Jr. *Cooperative Learning for Higher Education Faculty.* Phoenix: Oryx Press, 1998.

Nuhfer, E. "Student Management Teams: The Heretic's Path to Teaching Success." In W. E. Campbell and K. A. Smith (eds.), *New Paradigms for College Teaching.* Edina, Minn.: Interaction Books, 1997.

Palmer, P. *The Courage to Teach.* San Francisco: Jossey-Bass, 1998.

Seymour, E., and Hewitt, N. M. *Talking About Leaving: Why Undergraduates Leave the Sciences.* Boulder, Colo.: Westview Press, 1997.

Smith, K. A. "Structured Controversy." *Engineering Education,* 1984, *74*(5), 306–309.

Smith, K. A. "Cooperative Learning: Effective Teamwork for Engineering Classrooms." IEEE Education Society/ASEE electrical engineering division newsletter, Mar. 1995, 1–6.

Smith, K. A. "Cooperative Learning: Making 'Groupwork' Work." In C. Bonwell and T. Sutherlund (eds.), *Active Learning: Lessons from Practice and Emerging Issues.* New Directions for Teaching and Learning, no. 67. San Francisco: Jossey-Bass, 1996.

Springer, L., Stanne, M. E., and Donovan, S. "Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering, and Technology: A Meta-Analysis." *Review of Educational Research,* 1999, *69*(1), 50–80.

Tinto, V. *Leaving College: Rethinking the Causes and Cures of Student Attrition* (2nd ed.). Chicago: University of Chicago Press, 1993.

Urban-Lurain, M., and Weinshank, D. "Vignette: Computing Concepts and Competencies." *Computer-Enhanced Learning: 100 Courses at 50 of America's Most Wired Colleges.* Winston-Salem, N.C.: International Center for Computer Enhanced Learning, Wake Forest University, Jan. 7–10, 1999a.

Urban-Lurain, M., and Weinshank, D. "I Do and I Understand: Mastery Model for a Large Nonmajor Course." SIGSCE (Special Interest Group, Computer Science Education). Annual meeting of the Association for Computer Machinery, New Orleans, March 1999b.

Urban-Lurain, M., and Weinshank, D. "Mastering Computing Technology: A New Approach for Noncomputer Science Majors." AERA 99, Division C, Section 7; American Educational Research Association, Montreal, April 1999c.

Wilkerson, L., and Gijselaers, W. H. (eds.). *Bringing Problem-Based Learning to Higher Education: Theory and Practice.* New Directions for Teaching and Learning, no. 68. San Francisco: Jossey-Bass, 1996.

Wright, J. C., Millar, S. B., Kosciuk, S. A., Penberthy, D. L., Williams, P. H., and Wampold, B. E. "A Novel Strategy for Assessing the Effects of Curriculum Reform on Student Competence." *Journal of Chemistry Education,* 1998, *75,* 986.