

## Want Brighter, Harder Working Students? Change Pedagogies!

### Some Examples, Mainly from Biology

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Teaching is great fun when it works. To really make it work, faculty members need a deep understanding of their higher-level goals, a set of effective pedagogical techniques for fostering the goals and the content learning that supports them, and a way of combining the goals and techniques within the time that both faculty and students can reasonably devote to the course.

In my case, serendipitous early exposure to Perry's (1968, 1970, 1999) study of students' intellectual development in college was a great boost. Perry helped me understand the tasks that students must master in order to retain the content, to understand scientific thinking and the nature of science, and to use critical thinking generally (Nelson, 1999). Equally important was an early exposure to cooperative learning techniques. My introduction to these techniques included ways of eliciting considerable student effort with minimal marking and an emphasis on including credit sufficient to make the students feel that the assignments were worth doing.

In talking with other faculty, I have found that they often need reassurance that adopting cooperative learning does not require inordinate amounts of time. The examples in the various chapters in this volume allow efficient implementation of cooperative learning. Nelson (2008a) lists books and websites with techniques that are appropriate to biology, as well as websites and review articles on the scholarship of teaching and learning in science.

Another faculty concern focuses on the apparent loss of content coverage that they fear might ensue with alternative pedagogies. Indeed, reducing coverage in order to foster better learning was quite challenging for me (Nelson, 2001). Good examples from biology courses show that reducing coverage increases learning. Sundberg and Dini (1993) showed for introductory-level biology that a course for non-majors taught as much content as a more content-dense course

designed for majors, even when both approaches used only traditional methods (see also Sundberg, Dini, & Li, 1994).

Russell, Hendricson, and Herbert (1984) used different lecture content densities in the same medical school course. Students in the lowest density treatment learned and retained the content best. Maier, McGoldrick, and Simkins (chapter 10), Robinson and Cooper (chapter 7), and Smith, Matusovich, Myers, and Mann (chapter 6) highlight further evidence that the approaches advocated in this book increase learning.

In this chapter, I specify the course and level from which each example is drawn. However, I have found that similar techniques and goals can be used in courses ranging from first-year general education and introductory biology to graduate courses. I urge readers to consider seriously how these approaches might work in courses they teach, whatever the level and content. For more on my uses of collaborative approaches, especially for critical thinking, see Nelson (1994, 1996).

I present the examples largely in the framework of my personal history as a way of showing how I moved from simpler applications to more significant ones. I hope that this approach encourages some readers to start small, as advocated by Cottell (chapter 2). Sometimes, however, larger-scale course transformation seems clearly preferable. Two examples where large-scale change is essential are process-oriented guided inquiry (Shadle, chapter 3) and the extensive use of cases (Herreid, 2004).

Most of my examples illustrate the outcomes-focused “backwards design” approach: i.e., start with higher-level learning goals, decide what learning experiences seem most likely to achieve these goals, and only then select the content. Ebert-May and Hodder (2008) explicitly advocate this approach for science and provide extended examples for large biology classes. Cohen (chapter 2) explains how larger contexts can shape the desired outcomes and shows how the educational psychology literature can provide a powerful “filter” to use in designing activities in any course.

## **COOPERATIVE LEARNING IS ESSENTIAL TO MAXIMIZING LEARNING IN SCIENCE**

Much of science teaching focuses on straightforward understanding, we hope as a prerequisite to more advanced goals ranging from right-answer problem solving to critical thinking. Faculty may believe that cooperative learning is not necessary for understanding basic concepts. However, very strong evidence shows that cooperative learning and other active learning approaches are essential even for fostering basic conceptual understanding. These

approaches also foster higher-level goals, such as application, and more complicated forms of critical thinking.

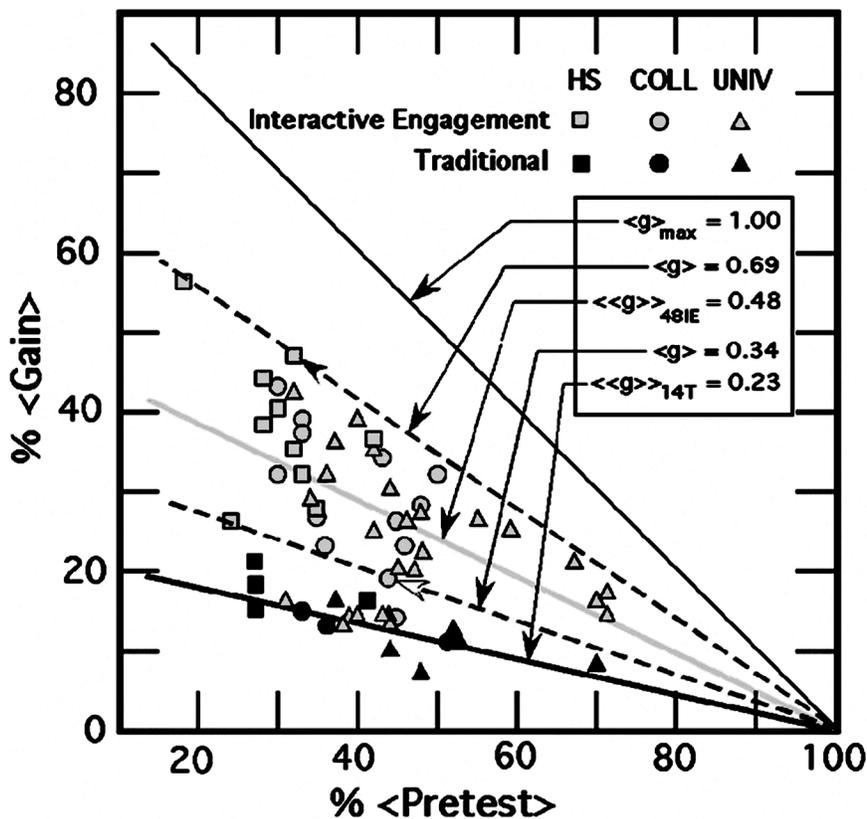
Hake (1998a, b; 2002) has assembled the most impressive data set assessing the effectiveness of alternative pedagogical strategies in science. Prior work (Halloun & Hestenes 1985a, b) had produced sets of concept-focused, qualitative pretests and posttests that cover central concepts from introductory physics—tests on which the wrong answers are based on common student misconceptions. One can construct such a measure for other courses as well. To do so, give students short-answer questions that assess understanding and applications of key concepts. Then use common wrong answers to generate multiple-choice questions for pretests and posttests. The wrong answers also provide a guide for more focused instruction. Even better assessments and teaching strategies can be designed by considering prior research on misconceptions (Duit, 2009).

Hake (1998a) compares traditionally taught courses with those taught with cooperative learning (“interactive engagement”) approaches. Traditional courses rely “primarily on passive-student lectures, recipe labs, and algorithmic problem exams.” Interactive engagement courses promote conceptual understanding through heads-on and, often, hands-on activities that yield immediate feedback through discussion. These range from inquiry labs without lectures to large classes in which short segments of lecture alternate with structured discussion (Crouch & Mazur, 2001).

Four key components of many of the cooperative learning approaches are (1) extensive structuring of the learning tasks by the teacher; (2) strongly interactive student-student execution of the tasks; (3) immediate debriefing or other assessments to provide the teacher and students with prompt feedback about the success of the intended learning; and, importantly, (4) instructional modifications by the teacher that take account of this feedback.

The results for physics are given in Figure 8.1. The horizontal axis is the class average for the percent correct on the pretest, %<pretest>. The vertical axis (“gain”) is the difference between class averages as percents on the pretest and the posttest. The measure of teaching effectiveness asks: How much of the total possible improvement in conceptual understanding did the class achieve? This “average normalized gain,” <g>, is defined as the ratio of the actual gain in the class average ( $\%<post> - \%<pre>$ ) to the maximum possible gain ( $100 - \%<pre>$ ). Here %<pre> is the class average (as a percent) on the pretest and %<post> is the class average on the posttest (Hake, 1998a). This measure gives the instruction credit only for net improvements in the average scores for students’ conceptual understanding.

Each symbol on the graph in Figure 8.1 is typically for one physics course. If every student had mastered each of the core concepts by the posttest, the



**Figure 8.1** Comparisons of pedagogies in introductory physics.  
Figure provided by R. R. Hake and used with his permission.

average posttest score (100%) would yield a gain that placed the class on the upper dark diagonal line. No class came close. The gains for traditionally taught (lecture) courses cluster tightly across the lower portion of the graph (darker symbols), with an overall mean or  $\langle\langle g \rangle\rangle$  of 23% of possible ( $0.23 \pm 0.04$ , mean  $\pm$  standard deviation) and a regression shown by the lower solid line (Hake, 1998a). The gains for courses with an important component of cooperative learning (“interactive engagement”) spread across much of the graph (lighter symbols), with an overall mean or  $\langle\langle g \rangle\rangle$  of 48% ( $0.48 \pm 0.14$ ) and a regression shown by the middle solid line.

Quantitatively, the average student taught cooperatively learned twice as much as the average student taught with traditional lectures. The most successful cooperative learning approaches taught almost three times as much as

the average lecture course (upper dashed line). Qualitatively, no traditionally taught course came close to the regression line for the gains for courses with an important component of cooperative learning (indeed, none were above the lower dashed line).

Further, only a few cooperative learning sections had gains so low as to fall within the cluster for lectures, and none were below this range. The worst outcomes realized by any teacher who used the cooperative learning approach was a gain no lower than those characteristic of lectures. Moreover, these low scores for interactive approaches were largely from classes in which the teacher knew that the method had been defeated (for example, by interrupting the exercises to provide the teacher's answers) (Hake, 1998b).

Some results from biology courses are even more distressing. For an understanding of natural selection, Sundberg (2003) found very little (2 sections) or no (15 sections) pretest to posttest gain in class average when traditional pedagogy was used. However, the average normalized gain was over 25% for each of three interactive engagement sections. The Conceptual Inventory of Natural Selection (Anderson, Fisher, & Norman, 2002) could be used as a pretest and posttest for similar studies.

Large improvements with no reduction of rigor have been shown in chemistry for students with low math SAT scores (Jacobs, 2000) and for talented African Americans studying calculus (Fullilove & Treisman, 1990; Treisman, 1992). More extensive reviews of the effects of cooperative learning in science were given by Handelsman, Ebert-May, Beichner, Bruns, Chang, and DeHann (2004); Smith, Sheppard, Johnson, and Johnson (2005; chapter 6); and, in a formal meta-analysis, by Springer, Stanne, and Donovan (1997).

The conclusion is clear. Effort spent improving lectures is wasted unless the pedagogy already has been transformed to use effective cooperative learning. This can be rather distressing initially for those of us who have spent a lot of time trying to improve lectures. Fortunately, it is easy to implement basic cooperative learning, even in large classes.

### **USING IN-CLASS EXAMPLES AND COOPERATIVE LEARNING TO INCREASE LEARNING IN LECTURE COURSES, LARGE OR SMALL**

Mazur's "Peer Instruction" technique for large classes has six parts: (1) a short lecture segment; (2) a multiple-choice question that is answered individually by the student; (3) a 2-minute discussion of the question in groups of two or three; (4) a second try by the student on the same question; (5) feedback to the faculty member on the results (originally by show of hands, now often by

using clickers); and (6) reinstruction if needed (Crouch & Mazur, 2001). The 2-minute discussion reduces wrong answers by an average of about 50% in 2 minutes and reinforces the learning of right answers. Pretest to posttest gain for the course as a whole doubles or even nearly triples.

I independently developed a similar approach. I needed to teach 350 students in an introductory biology course to do some kinds of multiple-choice questions. Students who had not had AP Biology in high school tended to do poorly on questions that required concept recognition, as well as on those that required higher-level skills such as application or synthesis. I decided to break the lecture into short segments (of no more than about 10 minutes) followed by a multiple-choice question presented on the screen.

The question typically had eight to ten answers, of which usually two or more were right. Sometimes only one was right, and, more rarely, none was right. The students were asked to select the right answers, if any, and then discuss the question with their neighbors in groups of two or three. This usually took 3 to 5 minutes total.

I debriefed the class either by asking for a show of hands or by taking a microphone up and down the aisles and asking individuals what answers their group had chosen and why. In doing this, I also emphasized why some answers were better and what was wrong with the others.

I found a substantial improvement in the students' ability to deal with similar questions on the exams. Sadly, I developed this approach largely in ignorance of the abundant literature on cooperative learning (e.g., Bonwell & Eison, 1991; Millis & Cottell, 1998).

### **USING PRE-CLASS WORKSHEETS AND WHOLE-PERIOD COOPERATIVE LEARNING TO FOSTER CRITICAL THINKING IN COURSES, LARGE OR SMALL**

My first attempts at cooperative learning were inspired by Judith Hanson. In a traditional lecture room with 150 students, she and one graduate assistant gave each student a preparation grade (based on a pre-class worksheet) and a participation grade (based on the roles they manifested, not on the details of what they said). Students liked these discussions, which lasted the entire period. When I combined this worksheet-structured discussion technique with approaches based on Perry's (1968, 1970, 1999) scheme, the students liked the changes so much that they secretly arranged for me to receive a campus-wide teaching award.

Four aspects of my approach now seem central. I assigned cognitively complex material for pre-class reading, material for which cooperative learning

would noticeably advance most students' understanding. The worksheet required step-by-step analysis of the assigned material using a specified critical thinking framework. In class, I assigned the students to groups of about five, usually by having them count off (see Cottell, chapter 2, for similar methods). I used different ways of grouping on different days so that the students couldn't predict what group they would be in. And I marked the worksheets on preparation effort, not on having the material completely correct. Indeed, if most students are likely to get the material essentially correct on the worksheets, it may be a bad idea to use extended discussion techniques.

The minimal-effort marking requires explanation. Pre-class papers or in-class quiz answers were written in any color except red or pink. As the students arrived, I handed them a cheap red pen with no cap (not a good thing to put in a purse, pocket, or briefcase). Pens were handed back at the end of class. Students were responsible for changing their own papers, in red, to reflect any improvements or clarifications that arose during the discussion. I then graded only on whether or not the initial answers (the ones before the red pens) showed sufficient effort in preparation. Grading was credit or no credit and required a fraction of a minute per paper, even on a complex worksheet.

Marking for participation was done while I was observing the groups in class and focused on having each student participate usefully but not necessarily equally. A key move was making participation a group responsibility. Every student in the group and I could tell at a glance whether each student had filled out the worksheet. If a student's paper showed that the work was done but the student was not participating usefully, everyone in the group lost points unless they were collectively asking that person what she or he had written down. Prepared students invariably participated when asked.

Marking for participation required knowing the students' names. In larger classes, I took the students' pictures and used the photos as flashcards until I knew the names and faces. I also practiced names in the classroom while the students were writing or discussing. I have found this practice to be essential in large classes.

The structure of the worksheet was important for supporting the students' learning of critical thinking. The critical page had four columns that guided the student through an elementary decision theory analysis of the reading (it took most students several tries to learn to do this analysis successfully):

- 1. Summarize the author's argument.** List each main point separately. State it as if you were the author (not "the author thinks. . ." or "she says. . ."). Use complete sentences.

2. **Evaluate the strength of evidence.** A. List the factual claims relevant to each main point separately. Evaluate each (very solid, solid = normal science, suggestive, plausible, improbable, or very improbable). Explain (Quality and quantity of data? Other support?) B. Evaluate the strength of the overall argument (Internal consistency? Alternative hypotheses addressed? Overall probability?)
3. **For each main point and for the overall argument: Burden of Proof.** Accept until shown to be probably false? Or reject until shown to be probably true? Why? (Positive and negative consequences? Applications and societal impacts?) **And Level of Proof:** Normal as in basic science (5%), Stronger or Weaker? Why?
4. **Decisions (for each main point and for the overall argument).** Compare the strength of evidence to the level of proof to decide whether you should accept or reject.

At the end of the period, the students marked on a checklist the roles (positive and negative) that they had played individually and the ones they had observed in their small group. To help them remember and use the positive roles, a header on each worksheet page focused attention on key positive roles: “Try: Encouraging, Stating Uncertainties, Pausing, Listening, Contrasting, Summarizing, or Timekeeping.”

### AN ALTERNATIVE CRITICAL THINKING APPROACH USING MULTIPLE MODES OF COOPERATIVE LEARNING

As I came to understand more deeply the importance of teaching how each discipline approaches critical thinking (Nelson, 1996), I searched for a set of criteria that I could apply across multiple examples in teaching biology, especially in the evolution course. I then developed these criteria in lecture with extensive cooperative learning.

For example, a key way of comparing ideas in science is what I call a “fair test.” I defined this in about 5 minutes using an example as I went. Specifically, a fair test is a way of comparing competing hypotheses: (1) using a new kind of evidence (i.e., the new test is not based on a kind of evidence that led to any of the alternatives now being compared), and (2) where the evidence is not biased (i.e., it could have, in principle, supported any of the alternatives being compared). As an example, radioactive dating was a totally new kind of evidence unrelated to that for any prior claims for the age of the earth, and radioactive dating could have supported any age from very young to immensely old.

I then used a multiple-choice question that was first discussed with neighbors and then debriefed in the whole group to reinforce and clarify the concept:

Scientists think that a *fair test* is one that: (a) could have shown any of the alternatives to be either probably correct or probably wrong; (b) is based on a line of data or reasoning independent of those on which each alternative is based; (c) yields a lot of data; (d) contradicts popular ideas; (e) supports their own preferred answers; (f) none of the above, all of the above, or only two of the above.

I presented a series of criteria in this same pattern of mini-lectures alternating with bursts of cooperative learning. Using the same pedagogy, I applied each criterion as appropriate to five or six major examples. Essay questions for each example were coupled together and discussed in a whole-period session. Students were then asked to propose examples showing how each criterion could be applied in real life. These examples could be drawn from any nonscientific area. The students then compared and refined these examples in another whole-period discussion. Students frequently commented that it was only during this discussion that they fully understood the criteria as used in science.

Importantly, this sequenced approach took at least four rounds of cooperative learning: (1) in “lecture” as the criteria were introduced (multiple, short cooperative learning sessions), (2) in “lecture” as the criteria were applied to different parts of the content (more multiple, short cooperative learning sessions), (3) in whole-period cooperative discussion as the applications to the various course topics were compared, and, finally, (4) in whole-period cooperative discussion to process the student-generated applications. Each of these iterations were quite important to the higher-level outcome that I was focusing on: criteria-governed comparisons as the core of critical thinking.

Another discovery allowed me to free some of the class time from content coverage. This made the focus on critical thinking an even more reasonable investment of class time.

## **USING COOPERATIVE LEARNING TO REDUCE THE COVERAGE PROBLEM**

I have argued elsewhere that the urge to cover the maximal amount of content is perhaps the greatest problem that must be overcome to become an effective teacher (Nelson, 2001). It certainly was for me.

As soon as I began teaching, I told students that I was depending on them to actually read the assignments, stressing that the exams would include a significant number of questions from readings that we did not cover in class.

This approach, combined with my fondness for synthesis questions, produced fairly low exam scores during my initial years of teaching.

Indeed, I soon began to include in my syllabi the statement that a grade of 70% on an exam would be an A. Keeping an A at 90% and flunking perhaps half of the class was not viable because I was teaching senior courses to majors who had already passed several of my colleagues' courses.

Because I did not yet know how to get the students to learn more effectively, I justified this situation to myself by thinking that I was asking for more critical thinking and was spreading out the A students so that they could see what more they could have mastered.

From reading Perry (1970) and related later works, especially *Women's Ways of Knowing* (Belenky, Clinchy, Goldberger, & Tarule, 1986), I gradually came to understand that the crux of teaching higher-level critical thinking was to help students understand explicitly how to do thinking in the discipline. And I came to understand that this, in turn, required teaching them to read and write in the discipline (Nelson, 1996). With considerable reluctance, I decided to prepare study guides over the readings (mostly text chapters) in my senior majors course in evolution.

My past practice had been to go to the chapter as I wrote the exam and find the focus for what I thought was an interesting essay question. Now, I decided the best study guide might be a list of all the reasonable essay questions over each chapter.

The first chapter I tried this on almost killed me. I had written well over fifty essay questions and was only partway through the chapter when two things became evident. First, it was clear that the chapter contained much more material than the students reasonably could be expected to master and, further, that I had been giving them essentially no guidance as to what they should focus on. Second, and more depressing, I realized that I really had not thought very much about my deeper learning goals for the assignments and, consequently, did not have a framework for prioritizing the content.

It took a lot of effort—and time—to go back through the chapter and carefully decide what was most important—and why—and then to construct questions that would help the students understand this. It was also clear to me that what I wanted students to understand required several questions that asked for applications and for syntheses across different parts of the chapter, across different chapters, and among various parts of the course.

I noticed several effects when I distributed these study guides:

1. Students were more likely to do the reading ahead of the exam. The question sets made it clear to them that the amount and difficulty of the required learning was greater than they could undertake in a cram session.

2. Students were working much more extensively in informal cooperative learning groups outside of class. Some of them explained it this way: “In most courses our goal is to figure out what the professor wants and keep that a secret (except from our boyfriends or girlfriends).” The study guides made clear what I wanted. And students could cooperate freely without fear of hurting their own grades because I was not grading on a curve.
3. Students were much more likely to ask me questions about the text in and out of class and even to come to office hours and review sessions, often in small groups—again showing that they were working together. And they usually had specific questions in mind.

I then reinvented another in-class cooperative learning practice. I started by announcing that there would be an in-class quiz over two or three of the most difficult questions. Or I asked students to write the answers out and bring them to class ready to hand in. I carefully picked questions that would enhance the rest of the class period, ones that most students were unlikely to get entirely right by themselves. Once the quiz was finished, or, alternatively, starting with the answers prepared before class, I handed the students red pens, as indicated earlier. They then discussed the answers with their neighbors in small groups.

Grading was credit/no credit, based on preparation effort as manifested on the quiz or in the prepared answers. Grading, again, required only seconds per paper, and I could be certain that most students were actually preparing.

I usually distributed about 150 to 200 essay questions before each exam in the senior evolution class. These summarized and synthesized the readings and linked them to the course themes. I focused on the essential content of the course. I was thus using informal cooperative learning to largely solve the in-class coverage problem. This left me more time to foster critical thinking during the actual class periods.

An additional advantage soon became apparent. Students learned much of the content as well, or even better, from the guided readings than they had when I had lectured on those topics in class. In contrast, there were some key aspects that many could not learn from the text, even when given extensive step-by-step study guides. I could use part of the time I had freed up by using the study guides to teach these aspects more effectively, as in the next example.

### **FOSTERING AN UNDERSTANDING OF GRAPH-EQUATION-CONCEPT TRANSFORMATIONS**

One of the most general problems in teaching science and other quantitative disciplines is getting students to tie concepts accurately to their representations

in graphs and equations and vice versa (Arons, 1976, 1997). Grossman (2005) discussed the extent to which we leave these transformations “hidden” in standard presentations. When the faculty presentation goes around the triangle—from verbal expression of a concept to its expression in an equation and then in a graph—the faculty member has shown that he or she understands it deeply. But some of the students are often lost at each transformation, and virtually the entire class may be partially lost by the time all three forms are covered.

With good study questions, students could easily understand a nonquantitative chapter on predator-prey biology. But they would be lost in the chapter on algebraic models of the same ideas, even though they had taken calculus and even if I gave them 50 or 60 questions leading them step-by-step through the models. In many cases, the students’ problems appeared to represent math anxiety in science seniors similar to the anxiety that Panitz (chapter 4) addresses for remedial freshmen.

Despite these challenges, I wanted to teach these models for their intrinsic content and for their value as illustrations of the power of mathematical and graphical modeling in science. I decided to do this in small increments with much processing in cooperative groups. I began by saying: “I know that in past classes many of you have found mathematical models to be difficult and fundamentally a waste of time.” I assured them that this class was different: “I am going to do the material so slowly that each of you will find it easy.” I explained why I thought it was worth spending a significant amount of class time doing this careful analysis.

I then began by plotting a pair of axes, with time on the horizontal axis and population size on the vertical axis. I defined the initial population as  $N_0$  and defined the population at any subsequent time,  $t$ , as  $N_t$ . I asked each student to sketch and label the axes and to plot the line for  $N_t = N_0$  for all  $t$ . This is a horizontal line that starts at  $N_0$  on the population axis.

I then asked the students to compare their graphs with those of their neighbors, in groups of two or three, making sure that everyone was included in a group. After a bit, I asked each of several groups to tell us what their graphs looked like. Once we had consensus, I asked each student to write down what the equation and graph told us about the biology.

The students then compared their answers with those of their neighbors. Once we all understood why this was the graph and equation for an unchanging population, we proceeded in small steps to more complicated biology and the corresponding equations and graphs.

Needless to say, this was the most successfully I had ever taught this material. And the students clearly enjoyed the class (to their surprise). Some of these senior science majors even said that this was the first time they had really understood the connections between the three representations.

## **MULTIPLE APPLICATIONS OF COOPERATIVE LEARNING IN A FIRST-YEAR SEMINAR**

I taught a course for students in Indiana University's (IU) Intensive First-Year Seminars program for several summers before I retired. These seminars are 3-credit, 3-week courses offered in August that meet daily for 3 hours. The faculty are allowed to design exciting courses with few constraints. The topics have ranged broadly, from dance productions to personal law. Each course was limited to a maximum of twenty students. My course coupled evolution and creation with an introduction to applying postmodernism across disciplines.

First-year seminars elsewhere often focus on orientation and on fostering close ties among the students, faculty, and upperclass students. The IU program, from its inception, had intellectual excitement as the main goal with orientation and affiliation following in part from co-curricular components. To this, I added the design question: What could I do that would best foster the students' success over the next four years?

I picked two main goals. I wanted the students to have a strong overview of the college experience, a set of "maps" they could use to understand the academic terrain and track their own performance. And I wanted the students to understand fully and accept the importance to their own academic success of working cooperatively in small groups whether or not these were built into the course officially.

I chose three maps: (1) a personally chosen set of goals for four years against which each student could measure her or his own success; (2) an understanding of potential intellectual development during the college years, as laid out by Perry (1968, 1970, 1999) and subsequent work by others, against which they could chart their progress in more normative terms; and (3) an understanding of the academic landscape that they could use to tame more easily the menagerie of academic expectations that they were likely to encounter.

### **A PERSONAL MAP**

The students began work on a personal map before class started by answering two questions: "How is college going to help me earn more money?" "What are the three most important other things that should result from four years of college education?" They then asked the same questions of four college-educated adults and combined their own answers with those of their interviewees.

In class, in small- and whole-group discussions, we generated a set of general alternative goals and, importantly, lists of concrete steps that a student could take in the first two weeks of class to move toward each goal. Each

student chose four personal goals and two concrete steps for each goal and summarized these in a short paper.

Students also explained their goals and steps to each other in small groups, thus publicly committing themselves to doing the steps. In retrospect, I should have also organized groups of about three to co-monitor their own progress during the first weeks of the fall semester.

### Intellectual Developmental as a Map

Perry (1968, 1970, 1999) found four major modes of thinking among undergraduates: (1) dualism—one authority has the truth (teach me the facts); (2) multiplicity—any view is valid if someone chooses it (listen to me); (3) [contextual] relativism—paradigms and worldviews are ways of choosing better from worse within the context of their scope of expertise (conflicts among these perspectives are still a matter of personal perspective); and, much more rarely, (4) commitment—different worldviews and paradigms, when applied to the real world, have different consequences, often for different groups (seeing these, I can sometimes commit to one as better than the others for addressing particular problems in specific contexts).

We used evolution as a way of understanding how science can tell us that some answers are better than others as science. A consideration of ways of comparing consequences and trade-offs allowed us to understand the wide variety of ways that individuals and religious organizations have chosen to combine science and religion (for details, see Nelson, 2000, 2007, 2008a).

To prepare the students for college-level lectures, I used short segments of lecture interspersed with short answer and multiple-choice questions (such as those discussed previously and used with the same cooperative learning techniques) to help them see what they should have learned from each piece of lecture. My intent was to teach them both the content and how to listen closely to lectures.

### The Importance of Learning Cooperatively and a Map of the Academic Landscape

Much discussion in academia and in U.S. politics might be encapsulated by questions such as “How much of what we believe or think is really true?” “How much of it is probably true?” “How much of it is simple social convention?” Freshmen at IU have had little preparation for understanding the constructivist frameworks that faculty in the humanities and social sciences often take as a given. They may do poorly in a course simply because it takes them too long to figure out what the teacher or the texts could possibly mean.

I selected a book that sketches the contrast between modernism and postmodernism across the curriculum, one that takes a constrained constructivist view of postmodernism (not a radical relativist view). The title says it all: *Reality Isn't What It Used to Be: Theatrical Politics, Ready to Wear Religion, Global Myths, Primitive Chic, and Other Wonders of the Postmodern World* (Anderson, 1990).

One example suffices to show how intriguing the book is. Anderson argues that science can be reasonably understood as currently the most fully developed postmodernist field. The book's emphases match several of those that Smith et al. (chapter 6) advocate (following Pink, 2005): the importance of story, the connection of patterns across fields, understanding diverse perspectives, and more. This presents quite a challenge for entering first-year students!

Anderson's book thus was perfect for my purposes. It provided my students with an overview of the academic landscape and of popular culture, too. And it was clearly a book that few of my students could have understood without extensive cooperative learning. Indeed, I had only a couple of students in seven years who seemed ready to understand it on their own.

The first problem was that most students had had no practice in understanding an argument in detail. They could say what a chapter was about, but not what it said or advocated. This clearly required multiple-level cooperative interventions. Usually, part of the day of the first class was cooperative reading of the first two pages of chapter one. These discuss Bloom's (1987) ideas against a heavily structured essay question that "merely" required an accurate summary of the text's argument:

"The conservative indictment is correct, and yet the strategy that follows from it . . . is doomed to fail." Summarize (i) the indictment, (ii) the strategy, and (iii) the reasons Anderson offers for its inevitable failure. So what, according to Anderson? (Include in your summary of the reasons for failure both diversity and the ultimately self-defeating aspects of the strategy.)

I had the students answer this question in pairs while reading the book. I then had them join with a second group to construct a consensus answer. They wrote these answers on the blackboard and discussed in their small groups the strengths and weaknesses of the answers written by each of the other groups. After listening to the other groups' comments on their own answer and hearing each of the other answers discussed, they rewrote their own consensus answer and again posted it on the board.

Still in their groups of four, they discussed the strengths and weaknesses of the other groups' second answers and of their own answer. By now, they

were beginning to see what the answer actually was, and some were beginning to see how to read the book, if given the questions. This exercise took perhaps 90 minutes, but it was clearly essential.

I reassigned the students to new groups of four, taking into account that some appeared to be “getting it” but some still appeared to be clueless. Each student was given a list of about a dozen study questions over the first five or six pages of chapter one. They were assigned to work in groups and had to report on their group efforts with the never-used possibility of voting non-participants out.

The next day, they were given a quiz on which each student in the group of four answered a different question. As soon as the students were done with their own questions, they put their pens away and were given red pens. Students who had finished their own questions exchanged papers within the group and commented on each others’ answers in writing—there were no spoken comments of any kind. The marking was largely done for me at this point. After they saw the comments on it, students were free to revise their own answer or not.

Each student received three grades: one was on the unmodified (pre-red ink) answer that the student wrote, one was the average of the grades on the unmodified answers written by their group (but each grade of at least 8/10 was raised by 1/10, up to a maximum of 10/10 before averaging), and one was the average of the grades on the modified answers written by their group. Individual grades below A did not count on the first two or three quizzes because I wanted the students to have a good chance at first understanding the basic themes of the book and to have time to learn how to study cooperatively and how to answer essay questions.

This cooperative practice was repeated almost daily for most of the three weeks using new material. New groups were assigned about once per week. Most of the initial questions simply required deep comprehension of the text (as in the prior example). However, synthesis and application questions became more frequent as we progressed.

With cooperative group learning, almost every student’s initial uncorrected answer to a randomly assigned question was at least a B (after the initial two or three practice quizzes). These strong performances were on questions that would have been too difficult for most of the students to master without cooperative learning. The students engaged in active group work almost every afternoon or evening. And the program director commented that my classes were typically the best bonded socially for at least the first half of the session and remained cohesive throughout.

## STUDENTS' JOURNALS AS A BASE FOR COOPERATIVE LEARNING IN A GRADUATE BIOLOGY COURSE

I intermittently offered a graduate biology course on “Alternative Approaches for Teaching College Biology” in a science department that has a strong research emphasis (Nelson, 2008b). As Smith et al. (chapter 6) advocate, a key objective was “modeling and coaching graduate students in the use of cooperative learning.” In addition, graduate courses on teaching can address both general problems of undergraduate learning and special problems of the field.

The strong persistence of students’ alternative conceptions or misconceptions is a general problem in science (Duit, 2009). Similarly, many learning difficulties that limit students’ ability to work with equations and models reflect incompletely developed abstract thinking skills (Arons, 1976, 1997). Evolution and other topics with complex real-world applications provide special problems that are difficult to address adequately without simultaneously considering adult cognitive development (Nelson, 2000, 2008a). Such essential topics may be too esoteric for many general courses on college teaching, but they can make a departmentally based course more interesting and important.

In the more recent versions of the class, I used discussions based on structured written journals both as the main class activity and as the major assessments. I required printed copies of the journals 24 to 48 hours before each weekly class. Each journal had to provide the following:

1. A summary of each reading assigned for the week with a consideration of its implications for or applications to undergraduate biology teaching.
2. For the prior week’s class meeting, a summary of the key points that emerged with their implications for teaching, especially in biology.
3. A discussion of what did you learn about teaching and learning—from the way the class session was conducted and from the patterns of participation.
4. An evaluation of the class session, both in terms of the value of the material and the way the class played out.
5. A self-evaluation (“What were the strong points in your participation? What were the weaker points? How are these ideas and processes related to the strengths or weaknesses of your past teaching and learning experiences?”)

I read the journals before each class session and made quick comments on each one. Class began by the students taking five minutes to read my comments

and refresh their memories of their considerations of the articles in preparation for discussion.

Some sessions or pairs of sessions were structured in part as learning cycles (Svinicki & Dixon, 1987). For example, we began a consideration of learning styles by having the students read descriptions of the styles for a couple of tests and decide which one or two seemed to fit them best.

Each student then took the learning styles tests and compared the results with their own assessments. We then tabulated the amount of agreement and the variation across students. I took this to be the “concrete experience” step of the Kolb learning cycle (Svinicki & Dixon, 1987).

Journaling on the class session provided “reflection.” Reading a couple of papers on learning styles and their applications provided “abstract conceptualization.” Writing on the applications and discussing applications in class provided some elementary “active experimentation.”

Overall, this journal and discussion approach was quite successful in producing deep learning as demonstrated in the journals, in the discussions in class, and in the draft teaching philosophies that the students wrote toward the end of the course. A molecular biology professor who audited the class decided to use a similar journal-based cooperative learning approach in her graduate molecular biology courses.

## CLOSING OVERVIEW

I have tried to illustrate the deep power of cooperative learning as developed and applied in a succession of increasingly effective strategies for fostering deeper learning. Learning to use cooperative learning for one goal—fostering critical thinking, for example—led to trying it for another.

In my case, I turned to using it to produce a deeper understanding of the text. As I became successful with this, I freed up time that I had previously felt compelled to use in covering content. This, in turn, allowed me to turn to the applications of cooperative learning in teaching material that had previously seemed unlearnable for many students. As refinements within a course became more successful, I had a base for expanding these approaches to other courses and to deeper goals.

In beginning this chapter, I argued that one key component of effective higher education is a deep understanding of the higher-level learning goals that one seeks to advance. As my understanding of higher education and of effective pedagogies matured, I turned, in the first-year seminars, to asking how I could make the biggest difference over the student’s entire academic career.

I chose to provide the students, through cooperative learning, with three maps that would help them obtain more deeply meaningful total education and to show the students how to do effective cooperative learning on their own. Cooperative learning had thus become both essential to my goals and part of what I felt was the core of higher education. These foci were, in turn, reflected in my course on teaching for prospective college science faculty.

As change continues to accelerate in the larger world—as issues such as environmental changes, equitable social structures, and geopolitical changes have become ever more important—content, in the traditional sense, has become both more transitory and easier to access. If higher education is to be a major part of the solutions—instead of a distraction or barrier—each faculty member and program needs to look more systematically for more effective ways of fostering deeper learning; faculty also need to think more deeply and systematically about the core goals and values of higher education.

We collectively have a variety of answers, but few curricula and courses survive without substantial change. And, as our goals become clearer and our methods more effective, we improve not only achievement but also retention and equity. This book is one set of maps and tools for helping us on these journeys.

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