team-based learning method in that introductory level course. The results that I obtained were closely comparable to those that I have described here for the organic chemistry course. A number of the students, now seniors, who were present in that general chemistry class often comment favorably on their experiences in that course whenever we meet. They recall with special fondness the closeness and friendships that developed during that course that still survive today.

In summary, team-based learning is an effective method for teaching introductory level chemistry courses. It is involving, active, effective, and leads to higher student success rates than does the lecture method. It is also highly rewarding to the instructor. The student–instructor relationship is altered remarkably for the better. Instead of functioning as a lecturer and evaluator of the student's learning, the instructor becomes a coach who is part of a team that is there to help smooth out the rough parts on the road leading to their success. This change in role is frequently noted in comments made on student course evaluations, where satisfaction rates consistently run above the 90-percent level.

Based on the experience that we have gained over the past seven years, it seems evident that suitably modified team-based learning courses could also be used very effectively in other introductory-level science and mathematics courses. Student evaluations of their team-based learning chemistry classes strongly indicate they would like to use team-based learning in other science and mathematics courses.

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Chapter 6

Using Case Studies in Science—And Still "Covering the Content"

Clyde Freeman Herreid

Many professors worry about shifting to small groups and other forms of active learning because of a fear they will not be able to cover as much content. Herreid used case studies with team-based learning and found his students learned as much or more, and comments on why this was so.

In the summer of 1992, I was invited to come to Vanderbilt University and give a lecture on the art of teaching. They were having a faculty colloquium, an annual event hosted by their Office of Teaching Effectiveness. They had invited me to lecture on how to lecture. I entitled my talk "The Ten Commandments." I am sure they thought they were getting something divinely inspired. Not willing to dissuade them of their fantasy, I went calling.

I gave my presentation to a large and generous audience. Not long afterward, I found myself seated at lunch with another presenter who was scheduled to speak in the afternoon on something called "team-based learning." In our brief exchange I found out that Larry Michaelsen had given up lecturing and was enthralled with a new method of presenting material that was a cross between collaborative learning and mastery teaching. He did not attend my lecture; I suppose it would have been antithetical to his newfound wisdom.

For years I had been looking for alternative forms of teaching, reasoning that I had exhausted the nuances of the lecture method and was ready to move on. I was mid-career and still found many students failing my classes. They complimented me on my presentations, yet there was always an eternal stream of students coming to office hours complaining that they did not understand why they could not absorb the material and perform better on the tests. They looked like intelligent students; they sounded like intelligent students; they said everything was clear to them when they heard the lecture; and yet, they were failing. Indeed, what was the problem? Could it be the lecture method itself?

Team-based learning sounded as if it might be the antidote. I attended the afternoon session and I felt as though the scales had fallen from my eyes. I rushed home to Buffalo determined to try out the method immediately. I had a course called "Scientific Inquiry" that was scheduled to begin in a few weeks; its purpose was to show nonscientists how science really works. The course was a new addition to our State University of New York at Buffalo curriculum and was required for general education credit. The basis for the course was Case Method Teaching. I had never tried using case studies before but had become convinced by Bill Welty of Pace University that this style of instruction might be a solution to my dissatisfaction with lecturing. When I heard of team-based learning it seemed that I could combine the two methods into a perfect medley.

At this same time, my son was teaching a course in informal logic for the first time as a graduate student in the Department of Philosophy at Buffalo and he also became enthused about team-based learning when he heard of my trip to Vanderbilt. He decided to use the method in his course. Our experiences turned out to be radically different. Although my course went smoothly one week after the other, he had problem after problem using team-based learning. Students continually challenged him in the use of this novel method.

What was the difference between us? I will return to this topic at the end of the chapter, but for the moment let me turn to what I have learned over the past seven years about using the method in science courses, especially in my field of biology. Let us begin by taking a look at one of my initial concerns: "Could I possibly cover all of the content?" Then we'll move on to examples in which I have successfully used team-based learning, how students responded to this method, and how I am now living happily ever after.

CONCERNS ABOUT COVERING THE CONTENT

A couple of years ago I wrote an article entitled "Why isn't cooperative learning used to teach science?" (Herreid, 1998). I listed at least a dozen barriers that faculty, students, and administrators need to surmount if the method is to be successful. None are unique to the sciences, but the problem that most science faculty cite as their biggest stumbling block is the question of content. They argue that cooperative methods always slow down the process of learning. They say they cannot cover as much material: "It's all right for the people in the humanities or social sciences to do it, but we can't afford to cut back on the content. We have other courses that follow this one that depend upon this knowledge and we have national standards to meet."

There is some truth to this claim for some styles of cooperative learning, such as Problem-Based Learning (PBL). Not as much subject matter can be covered, but the

learning is much deeper. What good is it if a faculty member covers the material and the students do not remember it?

More to the point, team-based learning is an exception because it does permit the coverage of the same amount of material as a normal lecture course. I have no difficulty covering exactly the same subjects to the same extent in my summer team-based learning class as during the fall lecture course. And I have the added luxury of teaching several wonderful evolution cases. It is significant to note that Frank Dinan, writing in his section of this book, and in an earlier paper (Dinan & Frydrychowski, 1995), reports that he has been able to cover even more material using team-based learning in his chemistry courses than when he used the traditional lecture method—and students received higher grades. So team-based learning is ideal for the sciences in which content is the issue.

EXAMPLES OF WHERE I CURRENTLY USE TEAM-BASED LEARNING

I use team-based learning whenever I have a small class. This means that I use it to teach my evolutionary biology course in the summer when I have only two dozen students. This is a course designed for freshmen, although many upper-division students take it as well. There is no occasion for me to use this method during the normal fall semester, when I teach this course to 500 students in a fixed-seat amphitheater. The best I can do in that situation is to do some interactive lecturing. The other setting in which I use team-based learning regularly is in honors seminars, in which, again, I teach about two dozen students.

The largest courses in which I have used team-based learning were an honors colloquium with 100 students, and a scientific inquiry course for seventy students. I found the latter two experiences workable but frustrating because I could not deal well with the application part of the method, when I give out case studies or problems for the groups to solve. I simply cannot be everywhere to ask questions and probe for answers. Similarly, people using problem-based learning, in which permanent teams are established, also find they cannot keep track of the group work during their case teaching without the use of tutors as a central part of each of the teams. Yet, I hasten to add that I have heard of instructors who have successfully used team-based learning in classes with up to 280 students. However, it is essential in larger classes that the application phase of team-based learning be especially well designed so that students cannot simply divide up the work load. The assignment must require that students work cooperatively to complete the tasks.

WHAT KINDS OF PROJECTS DO I ASSIGN IN TEAM-BASED LEARNING?

Typically, the assignments I use in team-based learning are case studies. I have published many of these in *The Journal of College Science Teaching* as well as on the

Web page for our National Center for Case Study Teaching in Science, supported by the National Science Foundation and the Pew Charitable Trusts: http://ublib.buffalo.edu/libraries/projects/cases/case.html.

Most of my cases extend for several class periods. Part of the case is presented on each day and the students are provided time between classes to look up material in the literature or on the Internet. When they reconvene, they pool their resources, try to solve problems, and are given another piece of the case. This follows the classic PBL strategy. For example, in my evolutionary biology course, I have one case that deals with the discovery of the first fossil bird, *Archaeopteryx*, and the evolution of flight. Other cases deal with the importance of the Galapagos Islands in the process of speciation, the possibility of life on Mars, and human evolution. All of these cases are on our website, along with detailed teaching notes explaining exactly how I handle them in the classroom.

To give you a flavor of these cases and how they fit into a course structure, let me walk you through the Galapagos case. I teach this about halfway through the summer course in evolutionary biology, in which class periods are two-and-a-half hours long. There is a reading assignment in the textbook for each day. I start each class briefly answering any questions from the students about the reading material. This is followed by the usual team-based learning Readiness Assessment Test (RAT), grading with a Scantron, and written appeals to ensure that students are familiar with key concepts. Then we take a brief break (after all, the classes are long). When the students return, it is on to the case.

The Galapagos case takes up part of four class periods; that is a lot of time, but it is worth it because of its importance in covering many of the principles of evolution. On day 1, I give out the first part of the case, which involves a graduate student named "Kate," who is considering what her research topic should be and musing on the history of the islands. There are many questions embedded in the piece that must be answered by the groups. Following the typical problem-based learning model, the students identify the learning issues and then subdivide the work so that when they leave class they know what to search for.

On day two, after the RAT exercise, the students share information with their team members. As a group, they must turn in a written set of answers to key questions about the formation and colonization of the islands by the flora and fauna. They are then given the second part of the case, which involves "Kate" talking to the director of the Darwin Research Station as he tells her about speciation problems. Again, the students ferret out the learning issues, subdivide the workload and leave class to search for the answers to their questions.

On day three, after they have shared their information and answered the key questions, they get part three of the case and read it. Here is a new wrinkle based on a real incident: Kate is caught in a crisis. Sea cucumber fishermen who have had a running argument with the government of Ecuador have taken over the Darwin Research Station and are holding scientists hostage along with a lab colony of endangered Galapagos tortoises. Now the students are told that each group must take on the role of one of the stakeholders in the controversy: fishermen, tourists, scientists, store owners, conservationists, and Ecuadorian politicians. Each group must outline its demands and develop a negotiating position on how to deal with the question of accessibility to the unique islands.

On day four, I give the groups thirty minutes to clarify their positions. Then I form negotiating teams, splitting up the group members. Each negotiating team has a politician in charge and includes a fisherman, store owner, scientist, and conservationist. The groups are all charged to draft a compromise policy statement that would form the basis for a law governing the islands; each member must be faithful to his own constituency yet must be committed to devising an equitable settlement. The policy document must be outlined by the end of the period and the politician must write it out in detail for the next class. The other members of the group individually must write out an analysis of Kate's research options in light of the crisis, which jeopardizes her thesis work.

Turning to another course, scientific inquiry, in which the purpose of the class is to have students understand how scientists really go about their work, human foibles and all, I follow the usual team-based learning approach with RATs, and so on. Again, I use cases involving contentious issues such as DNA fingerprinting, AIDS, and the Tuskegee syphilis experiments. But first, so that students understand the background of the scientific enterprise, I have them read an essay on the ethics and canons of science developed by the National Academy of Sciences entitled "On Being A Scientist." After a RAT on the reading, I give them their first application exercise. I ask the teams to develop a list of "commandments" describing what is appropriate and inappropriate behavior on the part of scientists. In thirty minutes they must develop at least thirty statements that begin with either "Thou shalt" or "Thou shalt not." For example, "Thou shalt repeat experiments," and "Thou shalt not plagiarize." The purpose of the list, which they hand in for my evaluation and criticism, is to solidify in their minds what ethical standards scientists must meet daily in their work. Then, to show how the scientific enterprise really functions, I have them read reports and articles about the cold fusion affair for the next class period. On the basis of the reading, in the ensuing class the groups must evaluate the problematic behavior of the scientists who claimed that they had discovered cold fusion. I have the teams rank on a scale of 1 to 10 how Professors Pons and Fleishman lived up to each of the standards of science the students had previously described in their commandments. Teams finish the evaluation with a brief written summary of their overall assessment of the scientists' behavior.

Another very effective application approach that I have used has been to have students develop lesson plans for kindergarten through twelfth-grade students. This is the requirement that I made for students taking my "Science and the Paranormal" course. The purpose of this course is to develop critical thinking skills in students by asking them to analyze extraordinary scientific and pseudoscientific claims. Student teams had to examine one paranormal phenomenon such as pyramid power, ghosts, hypnotism, and so forth. They had to research it and develop a lesson plan with activities for a K–12 classroom with the purpose of sharpening these students' critical thinking skills. Teams had to give an oral report to the class on their subject, turn in a written lesson plan, teach it to a K–12 class, prepare a poster for display in the library, and develop a website for a national skeptics' organization, the Committee for the

Scientific Investigation of Claims of the Paranormal. By the time the teams had finished the project, they had an excellent grasp of the nature of "evidence" for various paranormal claims. They also had developed a healthy skepticism of the media and learned one of the fundamental tenets of science: "Extraordinary claims require extraordinary proof." Just as importantly, they produced work that could be used by instructors in classrooms across the country.

GRADES AND PEER EVALUATIONS

I think peer evaluations are essential if we expect students to take group work seriously. Many students have worked in groups somewhere along the line, and frequently have had an awful experience. This is especially true for good students. The use of peer evaluations not only serves as an encouragement for all students to contribute their fair share, but can serve as a remedy for any misbehaving team members. The good students will get their just reward for the extra work they put in and the laggards will get their just desserts.

In setting up my grading schemes, I have found that individual scores should be worth about 75 percent of the grade and group work 25 percent. I have experimented with other strategies, such as permitting the students to collectively decide at the beginning of the course to set the grade proportions for the semester, but I have found that grade inflation sets in because group grades are typically higher than individual scores. A way to compensate for this is to shift the grading curve upward because the conventional 90 percent-equals-an-"A" is no longer appropriate. However, I have found that such an upward curve shift causes more dissension than it is worth. I solve the problem by a 75 percent-to-25 percent split, which keeps the grades more in line with expectations.

I use peer evaluations as a modifier of the group work score. Each student must evaluate his team mates anonymously using a numerical scale at the end of the course. If there are, say, five individuals in a group, they each have forty points to distribute to their team mates. In a group that is functioning perfectly, each person should receive an average score of ten points. Any student receiving an average of ten will receive all the points his team has earned for group work. On the other hand, if he receives an eight, he will receive only 80 percent of the group score. I have also set a lower limit on the peer evaluation score that a student can obtain. That is, if a student receives less than an average of seven from his teammates, I will fail him regardless of his individual or group score. I give them fair warning of this rule in the syllabus. Originally, I devised this scheme because our school has a regulation that allows students to take some of their courses on a pass-or-fail basis. Students choosing this option invariably did not contribute to their groups, expecting to slide by with a pass and crippling their groups in the process. I created the rule to stop this behavior. I have continued using this grading rule even in courses in which the pass-or-fail option does not exist, because it prevents any student from coasting through the course satisfied with a "C" or "D" effort. This strategy has almost always stopped lazy behavior.

WHAT KINDS OF RESPONSES DO STUDENTS HAVE TO TEAM-BASED LEARNING?

Whenever I have done evaluations of team-based learning and other cooperative strategies in which we set up permanent groups, invariably students say the thing they liked best about the class was working in groups. Most even enjoyed taking examinations with one another. Clearly, however, whenever people are thrown together, it takes time to adjust. Groups pass through a series of stages that have been described as "forming, storming, norming and performing." I believe that it takes at least a third to a half of a semester before students are comfortable with the method.

The use of peer evaluations tends to make them work harder at getting along. I always have the groups do a practice peer evaluation about a third of the way into the semester. By this time the groups have been together long enough for any interpersonal problems that exist to be evident. I have them turn in their practice peer evaluations to me and I tally the individual scores. At the next class period I hand students their scores with the comment that anybody that does not like their score needs to correct the situation by asking their group what they can do to improve the situation. In addition, I may have to take some people aside and have a conversation with them about their work. This usually sets matters right. Recalcitrant students getting low peer evaluation scores generally make amends rapidly.

I am often asked how frequently groups have problems in getting along (Herreid, 1999). Over the years I have queried hundreds of faculty who have attended workshops I have given on collaborative learning. The average answer seems to be that around 15–20 percent have difficulties, and that is my experience as well. Nonetheless, I have been able to fix virtually all of these problems by using practice peer evaluations and by talking to the students involved. Additionally, I find it useful to have the groups evaluate their own progress in team work. This is especially valuable during the early days of the course. To do this, I might ask them to write a list of characteristics that identify good and poor team members; this starts a little introspection about their own behavior. Alternatively, I might hand out profiles of fictional students and ask the groups what kind of peer evaluation they would give to these individuals. Or I might ask them to use a numerical scale and to rank how well their group is performing and ask what they could do as individuals to improve the team's work. All of these techniques make the students aware of how individual performances can be improved to produce a better group project.

WHAT ARE THE OUTCOMES OF TEAM-BASED LEARNING?

First, I notice a dramatic difference in student attendance in classes using team-based learning or any other type of collaborative learning in which permanent teams are used. At my institution, the average attendance when the lecture method is used may fall to 50 percent. In contrast, collaborative learning strategies produce an attendance of about 95 percent. The students tell me there are several reasons for this:

(1) the in-class RATs determine a large part of their grade, so they can't afford to miss them; (2) group projects are done in class and figure significantly in their grade; and (3) most important, they feel that they cannot let their team mates down. This is not only because I use peer evaluation, but also because once groups have bonded, the students realize their absence hurts their new friends.

Second, the grades in the course are always higher than during the normal year when the lecture method is used. With team-based learning, most of the grades are "As" and "Bs." Part of the reason is that a significant portion of the grade comes from group work and the groups usually produce higher scores on quizzes and projects than individuals. Additionally, students work much harder at grasping the material, and retain it better once they have to work on their own to digest the reading and have to apply the general principles they have learned to real life problems. They cannot escape the work load. It is relentless. In normal lecture-based classes, students can remain passive, hidden throughout the semester. This is impossible to do in team-based learning. They must keep up with the work or everyone will know it. It is no wonder the grades are better.

HINTS FOR USING TEAM-BASED LEARNING

I have often been asked by faculty how much time it takes to prepare for a team-based learning class. My answer is that if you are devising a new course, then you will need to put in the same amount of effort to prepare either the lectures or team-based learning material. There is a huge investment of time required either way. On the other hand, if you have been teaching a lecture course for years and have the bulk of the work done, then there is a large extra investment of time needed to convert to team-based learning. You must create RATs and applications for every class. Lots of teachers understandably balk at this. Furthermore, you might even have to create original written material for the students to read. Text book readings are not designed for teaching using this approach. When using the lecture method, we are apt to give assigned readings in almost a casual way, more as an enrichment than as a central part of the learning. The content or the quality of the chapters doesn't necessarily have to be right on target. In contrast, in team-based learning, in which the students must get everything from their reading materials, such an approach will not work. As a result, many of us find we must write our own text material to get the job done right or at least we must write study guides to aid the students as they wade through a morass of text material. This takes a lot of time.

Fortunately, there are some helpful ways to survive without the heroic effort of rewriting the text. In evolutionary biology, I use a commercial text book. Consequently, I take special care to provide a detailed list of important key points that the students must know in the assigned reading. For each chapter I give them a printed list with three columns. Its headings read: "Must Know," "Good to Know," and "Nice to Know." Under each heading I list the appropriate key words and concepts, depending on their level of importance. Students pay close attention to these helpful signposts while doing their reading. I also place the lists on my course website, where

students may take practice quizzes on the reading. In a similar fashion, I have heard of a physics instructor who produces an audiotape reading guide for his text that the students listen to at the start of their reading and study sessions, and a statistics professor who uses Web-based problem walk-through examples in his course. These aids are always helpful in any course, but particularly valuable when there are no lectures. Naturally, these guides have the added advantage that the students see that you really are earning your salary (something they are not always sure about when they see you standing by as they work feverishly in their groups).

Finally, let us turn to the problem(s) that bedeviled my son in his one and only foray into team-based learning. First, let me say that my son seemed like a natural for team-based learning. His undergraduate schooling was at St. Johns College where all of the classes were seminars. He had the patience of Job in helping students. Furthermore, he did not covet the lecture platform, nor was he concerned about relinquishing power in the classroom. He had no apparent barriers to a successful team-based learning experience. What was it then?

I think it was his lack of experience in the classroom. Here he was, a new instructor trying out a new method never seen before by him or his students. Not only was he facing the task of dealing with a new teaching style in which he had to give up a lot of authority to the students, but he did not have the depth of experience in dealing with the normal classroom problems. As a graduate student, he did not have the stature of a professor, nor was he considered by them a seasoned veteran. He did not have ready responses to such age-old questions as "I wasn't able to finish my homework. May I have an extension?" Or, "I have a conflict with the test time. May I take the test on another day?" Or, "What can I do for extra credit?" and "Are you going to curve the grades?" His uncertainty in how to deal with these problems as well as team-based learning produced an anxiety in him as well as in his students. He was vulnerable to attack by the students, who were not accustomed to working in groups and didn't know what group grading, individual grading, or peer evaluation were all about. His was a disastrous experience, and he has never tried to teach with team-based learning again.

It is not always that way with beginning teachers. I know of several young assistant professors who were so captivated by team-based learning that they immediately started using the method—successfully. It clearly depends on the person and the circumstances. The key variable seems to be how comfortable the instructor is in being challenged by his students. There are veteran teachers who cannot abide it and there are those who thrive. Still, the bottom line is that I do think inexperienced teachers have a more difficult task in instituting team-based learning. They should be especially cautious in adopting it if they are in a school that is not tolerant of novel teaching or if their tenure depends on a high productivity in research.

IS TEAM-BASED LEARNING WORTH THE EFFORT?

The answer to whether team-based learning is worth the effort is obviously "yes" in my case. One great benefit for me in using team-based learning, or any other

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collaborative learning strategy, is that I get to know my students extraordinarily well. In a lecture course, I see the students sitting there taking notes as I pontificate on weighty matters. I assume all is well. I am doing a good job. All is right with the world. Then comes the exam. There are all those "Fs" and "Ds." Well, I think, it was their fault: they were lazy or stupid. And yet?

In lecture classes, I generally did not see students as individuals. They were simply there—as an audience. All of this changed the moment I started using team-based learning. While students are working on their projects, I have plenty of time to observe every nuance of their interactions with the material and with each other. The openness of the classroom is much like a second-grade class in which a certain amount of chaos reigns. Students have less hesitancy to ask me questions or to approach me as a human being rather than as an authority figure. Not surprisingly, I get to know them; most are neither stupid nor lazy.

I began to have real fun in the classroom again. And that was not all.
There were the better grades.
The better retention.
And they liked it—
a whole lot.
So did I.

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CHAPTER 7

Working with Nontraditional and Underprepared Students in Health Education

Patricia Goodson

Team-based learning calls for students to gain their first introduction to the content on their own, through reading assignments. Contrary to what one might expect, Goodson found that team-based learning enhanced the ability of nontraditional and underprepared students to learn on their own.

My first exposure to team-based learning was at a workshop conducted by Dr. Larry Michaelsen at the University of Texas at San Antonio (UTSA) in 1997. The Teaching and Learning Center sponsored this workshop as an effort to motivate and equip professors to undertake new strategies that would motivate learning, contribute to student retention, and nourish professors' enthusiasm for teaching.

At the time, I was teaching in the Division of Education in the College of Social and Behavioral Sciences, and my area was health promotion. I taught two undergraduate classes: understanding human sexuality, and survey of human disease. My classes averaged forty students with many being nontraditional, and of Hispanic descent. While 44.2 percent of UTSA students range in age from 17 to 22 years, 31.4 percent are aged 23–29, and 24.4 percent are thirty years old or older. More than 42 percent of UTSA students are Hispanic, and more than 50 percent are from groups underrepresented in higher education (http://www.utsa.edu).

Before using team-based learning, I applied a mixture of lecture and group discussion formats to my classes with a reasonable degree of success, as measured by formal student evaluations. While successful by institutional standards, I had mixed feelings regarding my teaching experience and felt there was something absent from my achievements. Students had difficulty engaging in the lectures and asked very few