Cooperative Learning: Moving from Theory to Practice in a Class of 80 Students

Ann B. Burgess

Biology Core Curriculum, University of Wisconsin-Madison
345 Noland Hall, 250 North Mills Street
Madison, WI 53706-1794
Email: aburgess@facstaff.wisc.edu
FAX: (608) 265-2870

***ABSTRACT**:* A team of faculty changed what was formerly a large lecture course to one focused on small group learning. Students work in structured teams of 4 to understand papers from the current biological literature and demonstrate their understanding by completing a challenging team worksheet in class each week. We see great improvement in students' abilities to apply their knowledge to new situations and to propose appropriate experiments to answer questions or test hypotheses. We think our model may be useful for others and in this paper describe components of the course and the process we went through in designing it.

KEY WORDS: small group work, cooperative learning, active learning, capstone course, biological literature

INTRODUCTION

Biological Interactions (Biocore 333) is the capstone course for a four-semester, cross-college introductory honors sequence at the University of Wisconsin-Madison. It is intended to give students opportunities to integrate and build on the material (evolution, genetics, ecology, cell and molecular biology, plant and animal physiology) they have learned over the previous three semesters and to prepare them for advanced work in any area of biological science. It is a semester-long, 3 credit class that enrolls about 80 students per year from a variety of biological science majors.

The course had been taught for many years as a traditional lecture class by faculty drawn from departments across campus. We were motivated to change the design because we were frustrated by the number of students who were unable to apply what they were being taught to new situations or to propose appropriate experiments to answer questions presented to them in hypothetical scenarios on assignments and exams. I worked with two teams of faculty in revamping the course. The first team, Lynn Allen-Hoffmann, Nansi Colley, Jeff Hardin, and Amy Moser, designed the new version of the course and taught it for 4 years. The second team, Richard Burgess, John Fallon, Anne Griep, and Donna McCarthy, took over the class in 2001 and successfully adopted the first team's model.

Much research on teaching and learning has shown that an effective way to enhance learning is to put students in small cooperative groups and have them work together on appropriate intellectual tasks (summarized for college math and science courses by Cooper and Robinson, 1998). All of us who teach have experienced the phenomenon of learning something much more deeply when we have to teach it. The idea behind cooperative learning is to help students teach each other. Someone who has just mastered a difficult concept is often better than the instructor at explaining it to a peer because the instructor has so thoroughly integrated the idea into her/his conceptual framework that she/he has forgotten what makes it difficult. Furthermore, part of learning is translating ideas into one's own language; discussing them with peers allows this to happen.

The effectiveness of this approach is well supported by data. The authors of a meta-analysis commissioned by the National Institute for Science Education reviewed a large number of college science, mathematics, engineering, and technology studies and found that small group learning methods are more effective than lectures in promoting academic achievement as well as positive attitudes towards science; they also reduce attrition (Springer et al., 1999). One study that compared two versions of an analytical chemistry course, a "responsive lecturing" version that emphasized well-taught lectures and a "structured active learning" version that emphasized small group work, is particularly notable for the thoroughness of its assessment of student outcomes. A team of unbiased faculty interviewed each of the students to judge his/her competence in chemistry. They perceived that students from the structured active learning course had better reasoning, problem-solving, and communication skills than those from the responsive lecturing course (Wright et al., 1998).

Our revised Biological Interactions course emphasizes small group work and gives students much more responsibility for their own learning. We see great improvement in students' abilities to apply their knowledge to new situations and to propose appropriate experiments. This paper describes components of the course and the process we went through in designing it.

COURSE DESIGN

The process of planning the revised course confirmed for us the power of cooperative learning. None of us knew how to do this but we figured it out together! We met many times to discuss various models for small group learning (an earlier version of Johnson et al., (1998) was particularly helpful) and to talk with colleagues who had implemented cooperative learning in their own courses. We particularly appreciated those who shared with us their failures as well as their successes, thus helping us to avoid many potential problems. We learned, for example: (1) the importance of having a well-defined structure for the course as well as a framework for the teamwork, (2) the necessity for individual accountability to assure that all team members are prepared for group work, and (3) the merits of incorporating honest feedback about team functioning by the team members.

The plan we developed is for students to work in structured teams of 4 (see Table 1) to understand papers from the biological literature and to demonstrate this understanding by completing a challenging group worksheet in class each week. The faculty team chooses four topics each semester, and each member takes charge of one. We select topics that we think will engage students, that introduce them to current tools and methodologies, and that draw from more than one area of biology. Some examples of topics we have used: breast cancer, molecular mechanisms in infectious disease, and obesity. It is preferable for faculty not to choose their own area of research because they tend to assume too much prior knowledge when they do this. Each faculty member selects mainstream papers from the current literature (usually 1-2 per week) and then prepares study guides, individual quizzes, and team worksheets for each week. The faculty then study each other's materials and meet many times over the months preceding the course to provide constructive criticism. Although this makes extra work, it results in much more effective materials and better integration and connections among the units, and both teams of faculty have continued to use this process each year.

We wanted our grading system to reflect our course goals and decided on an absolute grading scale (rather than a curve) so that no one is penalized by helping another. The worksheets are a key part of the course and count for 45% of each student's final grade. The remaining 55% is from individual work, including quizzes and two exams.

Figure 1. *Teams of Biocore 333 students working together on worksheets.*

STRUCTURE FOR EACH WEEK

The class meets for 50 minutes three times per week in an ordinary lecture hall, bolted seats and all (Figure 1). We would much prefer a more congenial room arrangement but none are available for a class this large. The Monday class consists of a lecture introducing the topic and providing background material. The Wednesday class consists of "open book" worksheets that student teams complete in class while the faculty leader and TAs circulate and answer questions. (The faculty gain insight into students' understanding of the concepts as they answer their questions and observe their approach to the worksheet questions.) An example of a worksheet is shown in Figure 2. The Friday class consists of an interactive discussion of the worksheet answers led by the faculty leader, who calls on reporters from several teams to report their answers. He/she then gives a preview of the next week's paper(s). In addition, each student attends a small TA-led 50 minute discussion section on Tuesdays. To encourage all team members to study the assigned papers and background references ahead of time, there is a short individual quiz each week during the discussion sections. Students are on their honor not to reveal quiz questions or answers to those in other sections.

We deal with illness, out of town trips, and personal emergencies by allowing each student to drop his/her lowest quiz and lowest team worksheet score.

Teams spend 5 minutes at the beginning of class each Friday assessing how well their group functioned that week and discussing what and how they want to improve during the next week. We structure this with a short form that they complete in class. An example is available on the web site described below (http://www.wcer.wisc.edu/nise/cl1/CL/story/burgessa/TSABA.htm).

COURSE MATERIALS

Students purchase a reading packet at the beginning of the semester that includes study guides for each week and all of the assigned papers. Each study guide gives the learning goals for the week, lists terms and concepts students should review in their textbooks, defines new technical terms, briefly describes unfamiliar procedures, and supplies information that is sometimes missing from figure legends. It also poses questions to stimulate students' thinking, e.g., "If you had been a reviewer of this manuscript and believed you should ask for one more experiment, what would that be?"

The short weekly quizzes consist of straight-forward questions designed to be easy to answer by those who have reviewed the background material and read the week's papers. An example of one of John Fallon's quiz questions from the week devoted to telomeres and cloning is, "The nuclei for the cow and sheep cloning experiments were in the same part of the cell division cycle. What was it?"

Worksheet questions, on the other hand, require discussion and thought and often have more than one correct answer. Often they ask students to propose hypotheses and/or experiments to test them. An example of a worksheet from the cloning week is shown in Figure 2. We provide only one worksheet per team because we want all team members to discuss each question and work together on a consensus answer.

Every year students ask to have multiple copies of the worksheets, but the one time we experimented with allowing this, most teams split up the questions rather than working together. They say that it is difficult to read the questions because the paper is upside-down for some of the team, so we compromise by projecting an overhead of the worksheet at the front of the room.

The two exams (midterm and final) are completed individually and consist of essay questions that draw on the main concepts and approaches from the papers rather than the specific details.

Examples of a study guide, quiz, worksheet, and team feedback form can be found on the National Institute for Science Education's Collaborative Learning web site http://www.wcer.wisc.edu/nise/cl1/CL/story/burgessa/TSABA.htm.

TEAM MEMBER ROLES

We assign students to teams of 4 and attempt to balance ability levels and gender. Specific roles (see Table 1) rotate each week in a specified manner. All members of the team are responsible for being sensitive to the feelings and level of understanding of the others, promoting group interaction, and being prepared for group meetings. Team members sit together during class meetings and are strongly encouraged to meet outside of class to answer each other's questions and to go over the figures for that week's papers. Many, but far from all, do so, and this seems to vary from year to year. We have been open to rearranging teams at mid-semester; however, even students who start out unhappy with their team have wanted to stay together when given the opportunity to switch at mid-semester.

TEACHING ASSISTANTS

Graduate teaching assistants are a very important part of the team. In addition to leading the Tuesday discussion sections, which focus on answering students' questions (as soon as the quiz is over), they provide feedback to the faculty prior to the final versions of the quizzes and worksheets, circulate to answer questions during the Wednesday worksheet sessions, grade the worksheets in consultation with the faculty, and assist in preparing and grading the exams. A weekly on-line newsletter produced by the lead TA helps to create a sense of community for all involved. Graduate students who plan to become college teachers find the opportunity to be involved in a cooperative learning course particularly valuable; the experience has helped several to obtain desired positions.

Biocore 333 Spring 2001 - John Fallon

Include only those present:

Facilitator:_________________________

Team No. _________

Monitor:__________________________

Recorder:_________________________

Reporter:_________________________

Worksheet for Week 13

Stein GH, Drullinger LF, Soulard A, and Dulic V. (1999) Differential roles for cyclin-dependent kinase inhibitors p21 and p16 in the mechanisms of senescence and differentiation in human fibroblasts. *Molecular and Cellular Biology* **19**:2109-2117.

1. A. (4 points) Using Figure 1 of Stein et al., describe the relationship of p27 and p21 to the data on population doubling and cell density over the course of the experiment.

B. (4 points) Considering the data in Figure 1, what is the hypothesis that Stein et al. put forward about p27 and p21?

2. (6 points) Using Figure 1, what is the relationship of p21 and p16 at initial senescence and what is it at late senescence?

initial: ____

late: ____

3. How do the authors show that cyclin D associated phosphorylation of pRB at Ser-780 fails to occur in senescent fibroblasts and what is the importance of the observation?

Method (2 points)	Why important (4 points)

4. (6 points) You were asked to think about why p21 would appear during phase II (young cells). The authors do not really address this issue. **Considering information available in clonal analysis of HDFs**, propose an explanation why p21 appears during phase II and give an experiment to test your explanation and the predicted results if your explanation is correct.

Explanation	Experiment	Predicted Results

5. (12 points) Stein et al. propose that the action of p21 results in the observed G1 block **in early senescent cells.** Propose two **in vitro** experiments that would test this hypothesis using HDFs that have a total of 60 population doublings (PD) and the expected results if the hypothesis is correct.

General approach (or category) of experiments	Expected result - Early in experiment at 35 PD	Expected result - Late in experiment at 50 PD

6. (12 points) p16 is proposed to continue the G1 block late in senescence, at which time p21 declines. Propose two **in vitro** experiments that would test the hypothesis that p16 is responsible for the late senescence G1 block and the expected results if the hypothesis is correct.

General approach (or category) of experiments	Expected result - Early in experiment	Expected result - Late in experiment

Figure 2. *John Fallon's worksheet for the week on telomeres and cloning.*

Table 1. *Team Member roles.*

Facilitator	Makes sure everyone understands each worksheet question before the team begins to discuss it, encourages everyone to participate, encourages cooperative behavior, helps the group to reach consensus, and arranges out-of-class meetings.
Monitor	Keeps everyone on task, monitors time, and moves the group along to assure that the tasks get done in the allotted time.
Recorder	Writes down the group's consensus answers to the worksheet questions, hands in the worksheet at the end of the Wednesday class, and picks up the graded worksheet at the end of class the following Monday.
Reporter	Picks up a copy of the team's worksheet at the beginning of class on Friday, reports the team's answers on Friday when called on, makes sure the team discusses how it functioned that week, and turns in the team's feedback form each Friday.

STUDENT BOARD OF DIRECTORS

We want student input in accomplishing the course goals and ask each discussion section to choose a representative (and alternate) at the beginning of the semester to serve on the Board of Directors. Board members receive suggestions and concerns from class members and meet briefly to discuss them with the faculty leader and TAs after class each Friday. This gives us the opportunity to address problems together and also to explain the reasons behind certain course policies (e.g., providing only one copy of the worksheet per team to assure that they work together).

CONCLUSIONS

The present structure of the course makes us much more aware of students' level of understanding than we previously were. The first time we taught it in this manner we were surprised to discover that students did not understand many concepts that had been "covered" in previous courses. One of the most important roles this course now serves is to give students a chance to revisit important concepts and integrate them into current biological questions. We deal with the need for review by emphasizing the importance of understanding the terms and concepts listed at the beginning of each study guide (putting some of them on the quiz gets the message across quickly!) and by adding a bit more background to the overview lectures.

The course brings most of the students to the point where they begin to understand the current literature. They also learn that even experienced scientists make errors in their papers or sometimes fail to include the proper controls. Students are able to comprehend complex papers after working through them with their teammates. They are much better than those in the previous version of the class at making connections between different parts of the course and at suggesting hypotheses to explain findings and appropriate experiments (including controls) to test them. They demonstrate these abilities on the worksheets and exams.

Although most students are quite skeptical about our approach at the beginning of the semester, most are very enthusiastic about the class by the end. On the last spring's course evaluation questionnaire, we asked whether they felt they learned more, about the same, or less compared with a traditional lecture course. 85% returned the questionnaire and of these, 69% checked "more," with many adding "much" or many stars or exclamation points in front of "more." 25% checked "about the same" and 6% checked "less." Some illustrative comments are shown in Table 2.

Class participation and attendance are much higher than they were in the previous version of this course. We are convinced that the revised course helps students acquire deeper thinking and analytic skills and better prepares them for future careers, which are very likely to involve teamwork.

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A partial description of the second year of the revised course can be found on the National Institute for Science Education's Collaborative learning web site http://www.wcer.wisc.edu/nise/cl1/CL/default.asp.
The web site includes examples of a study guide, quiz, worksheet, and team feedback form.

Table 2. *Student comments from the Spring 2001 Biological Interactions course evaluations*

- *The format in which this semester was taught should be used for the other semesters. I learned more this semester than the other three semesters combined!*
- *I think we actually learned a new way to learn this semester. I feel we covered much less material than the other semesters, but I may take more away from this semester than the others.*
- *Understanding and analyzing the papers with some instructor help enabled us to think beyond the spoon-feeding box.*
- *This class was very useful, it taught me [to] think on my own and come up with unique and interesting ideas.*
- *The group learning experience was very good. The first real productive group learning experience I've had here. Our meetings out of class were the best learning tool of the class.*
- *I really enjoyed reading the papers, learning more about how to think like a scientist.*
- *Reading actual papers was very helpful; it helps you apply concepts/techniques in order to actually retain information.*
- *It was harder to know what knowledge we were supposed to master for this course.*
- *Working in teams is a great idea because that is how we'll work in our careers. Combining brainpower is good.*
- *This course tied everything together from 4 years of science at UW. Also, it helped to give us a great skill of interpreting and understanding journals.*

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