Engaging Engineering Students through Active and Cooperative Learning

Emily Allen

Bluesheet

Introduce yourself to the two students sitting beside you and determine which student speaks the most languages. That person is the Key Member, who should act as the *Project Manager*. The person to his/her right is the *Unit Analyst*, and the third person is the *Graphics Analyst*. All three of you are in the space shuttle, and an experiment has failed. Mission Control asks you to redesign the experiment with materials at hand. The objective is to build a system that will measure the amount of dust in the atmosphere inside the shuttle, using a solar cell, a photodetector, and a light-emitting diode (LED). The solar cell is used to power the experiment; the photodetector senses light from the LED, which can be blocked by dust. You have three semiconductor diodes made out of materials with different bandgaps (Si, GaP, and InAs) and need to use one diode for each of the three devices. Which material should be used for which device, and why? There may be more than one solution.

The bluesheet activity is an example of a cooperative-learning exercise. These activities are called "bluesheets" because I distribute the problems on blue paper. I typically assign this type of activity once a week in my class, "Electronic, Optical, and Magnetic Properties of Materials," taught at San Jose State University. This lecture/laboratory course is composed of about 70 juniors in materials engineering and electrical engineering. With only two 50-minute lectures per week, about 20% of class time is spent in cooperative learning.

During the bluesheet exercise, my undergraduate student assistant (TA) and I check in with each group two or three times. We question the Unit Analyst on his dimensional analysis, or ask if the Equation Manager has used the appropriate equations, or challenge the Graphics Analyst to check that her graph has the right axes. Invariably, challenging students to perform the roles I have assigned them leads the group to the right answers. At the end of the exercise, the TA collects the work and the next day provides me with a roster indicating who was present as well as a brief summary of the class performance. Individual students are not graded on the exercise, but 5% of the course grade can be earned simply by participating in the exercises. Solutions are posted on the course Web site immediately after class. The three-member groups are formed around existing seating arrangements, so they tend to stay the same all semester, but with a new Key Member assigned each week. Bluesheets would be considered an informal or ad-hoc method of cooperative learning. More formal cooperative learning activities require the use of "permanent" groups such as base groups, which may stay intact through one semester or even through many courses.

We also use bluesheets in the laboratory sections, which are highly structured and include experiments, group quizzes, the bluesheet exercises, and individual exit quizzes. The lab bluesheets typically require analysis of the experimental data, either by hand or using spreadsheets. Each group must complete the bluesheet and have it checked by the instructor, which ensures that they actually engage with the material while present in the laboratory, resolve misconceptions, and thus produce more effective laboratory reports. New groups of four or five members are formed each week in the laboratory.

A cooperative-learning exercise requires *active learning*, in the classroom itself, which implies a hands-on activity. It can provide an opportunity for the instructor to assess whether students are learning. For example, my interactions during the bluesheet exercises allow me to "take the pulse" of the class and see where confusion lies while I still have the chance to correct misconceptions during class time. Also, the bluesheet summary provided by the TA lets me know if the class as a whole understands and can apply the concepts I am teaching.

The difficult part of developing cooperative-learning exercises is to implement the *cooperative* aspect, which can be structured through different forms of *interdependence*. One type is *resource interdependence*. During my bluesheet exercises, student groups receive only one copy of the problem, so they have to read it together and strategize how to solve it. I also use *role interdependence*. Appointing a different student to each task enables them to learn problem-solving strategies, which students can later perform independently on homework and examinations. For effective cooperative learning, I use problems that can be broken into parts that can be performed partly in parallel, and I assign specific roles so that everyone has a job to do. Additional roles are Recorder, Equation Manager, and Checker. In the laboratory, I also assign Materials Managers and Equipment Managers.

The use of role interdependence usually ensures *individual accountability*, because if a student does not do his or her job, the problem cannot be solved. *Group accountability* also occurs, as each member of the group must agree with and understand the entire solution. I can assess progress in this area simply by calling on any of the individual students to report for the whole group.

A key aspect of cooperative learning is *face-to-face promotive interaction*, which refers to students sitting face-to-face and promoting each other's efforts to learn by the use of specific interactive techniques. This is sometimes difficult for engineering students who prefer to work alone, and must be structured, modeled, and constantly encouraged by the instructor. For example, when I circulate through the room, one student in a group will typically ask me if she is doing the problem right. Instead of answering that student, I refer the question to her group. After a few weeks, the students begin to turn to each other, and only refer a question to me when the group as a whole is confused. The noise level in the classroom should get very high during a cooperative-learning exercise. In general, I find that stronger students strengthen their own skills by helping their peers absorb difficult conceptual material, and weaker students gain confidence in their own abilities. At the beginning of the course, I provide simple problems; toward the end, I incorporate more open-ended design problems.

One particular benefit to cooperative learning at my institution is that many students are first-semester transfers from community colleges who often do not yet

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have a peer community. In a class of 70 students, it is not uncommon to have 30 different languages spoken. Many students are commuters, have families, and work part- or full-time; as a result, they do not spend much extra time on campus. Combining the students into groups each week creates bonds that help them through their upper-division coursework. I frequently see students working in senior-project teams who met in my class, working together on bluesheets.

The use of active and cooperative learning in the classroom has "broken the ice" for me, removed my dependence on lecture orientation, and taught me a unique approach to my class. The first day of class, I provide a five-page list of course learning objectives. I view my lectures, the bluesheet exercises, the homework, the laboratory sessions, the exams, the tutoring sessions, and my office hours, all as equal opportunities for students to master the learning objectives. Perhaps contrary to first perception, preparing for a cooperative-learning exercise in a classroom takes more work than preparing for a lecture, but it is worth it. Lectures have become more interactive and Socratic. I have learned to wait the long wait for students to answer my questions and to wait the even longer wait for students to ask their own questions. Every week, more students ask questions in class, including those in the back of the room. Although I may "cover" less, my students "uncover" more for themselves. That is, after all, the purpose of a college education.

Emily Allen *is an associate professor at San Jose State University. She welcomes letters and comments regarding cooperative-learning experiences as well as interest in research collaborations on the scholarship of teaching. She can be reached at elallen@sjsu.edu.*

Web Sites:

- For examples of bluesheets used in this course, access www.engr. sjsu.edu / eallen / MATE153
- For resources on cooperative learning, see www.clcrc.com.

Books

For books on the practice and theory of cooperative learning, see:

- D.W. Johnson, R.T. Johnson, and E.J. Holubec, *The Nuts and Bolts of Cooperative Learning* (Interaction Book Company, Edina, MN, 1994).
- D.W. Johnson, R.T. Johnson, and K.A. Smith, *Active Learning: Cooperation in the College Classroom* (Interaction Book Company, Edina, MN, 1991).
- D.W. Johnson and R.T. Johnson, *Meaningful and Manageable Assessment through Cooperative Learning* (Interaction Book Company, Edina, MN, 1996).
- D.W. Johnson and R.T. Johnson, *Cooperation and Competition: Theory and Research* (Interaction Book Company, Edina, MN, 1989).
- K.A. Smith and A.A. Waller in *New Paradigms for College Teaching*, Chap. 9, edited by W.E. Campbell and K.A. Smith (Interaction Book Company, Edina, MN, 1997).

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