Cooperative Learning*

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The term *cooperative learning* (CL) refers to students working in teams on an assignment or project under conditions in which certain criteria are satisfied, including that the team members be held individually accountable for the complete content of the assignment or project. This chapter summarizes the defining criteria of cooperative learning, surveys CL applications, summarizes the research base that attests to the effectiveness of the method, and outlines proven methods for implementing CL and overcoming common obstacles to its success.

Introduction

Many students who have worked in a team in a laboratory- or project-based course do not have fond memories of the experience. Some recall one or two team members doing all the work and the others simply going along for the ride but getting the same grade. Others remember dominant students, whose intense desire for a good grade led them to stifle their teammates' efforts to contribute. Still others recall arrangements in which the work was divided up and the completed parts were stapled together and turned in, with each team member knowing little or nothing about what any of the others did. Whatever else these students learned from their team experiences, they learned to avoid team projects whenever possible.

Cooperative learning is an approach to groupwork that minimizes the occurrence of those unpleasant situations and maximizes the learning and satisfaction that result from working on a high-performance team. A large and rapidly growing body of research confirms the effectiveness of cooperative learning in higher education (*1-4*). Relative to students taught traditionally—i.e., with instructor-centered lectures, individual assignments, and competitive grading—cooperatively taught students tend to exhibit higher academic achievement, greater persistence through graduation, better high-level reasoning and critical thinking skills, deeper understanding of learned material, greater time on task and less disruptive behavior in class, lower levels of anxiety and stress, greater intrinsic motivation to learn and achieve, greater ability to view situations from others' perspectives, more positive and supportive relationships with peers, more positive attitudes toward subject areas, and higher self-esteem. Another nontrivial benefit for instructors is that when assignments are done cooperatively, the number of papers to grade decreases by a factor of three or four.

There are several reasons why cooperative learning works as well as it does. The idea that students learn more by doing something active than by simply watching and listening has long been known to both cognitive psychologists and effective teachers (5, 6) and cooperative learning is by its nature an active method. Beyond that, cooperation enhances learning in several ways. Weak students working individually are likely to give up when they get stuck; working cooperatively, they keep going. Strong students faced with the task of explaining and clarifying material to weaker students often find gaps in their own understanding and fill them in. Students working alone may tend to delay completing assignments or skip

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them altogether, but when they know that others are counting on them, they are motivated to do the work in a timely manner.

The proven benefits of cooperative learning notwithstanding, instructors who attempt it frequently encounter resistance and sometimes open hostility from the students. Bright students complain about begin held back by their slower teammates; weak or unassertive students complain about being discounted or ignored in group sessions; and resentments build when some team members fail to pull their weight. Knowledgeable and patient instructors find ways to deal with these problems, but others become discouraged and revert to the traditional teacher-centered instructional paradigm, which is a loss both for them and for their students.

In this chapter we describe cooperative learning methods that have been proven effective in a variety of instructional settings. We then suggest ways to maximize the benefits of the approach and to deal with the difficulties that may arise when cooperative learning is implemented.

What is Cooperative Learning?

Several definitions of cooperative learning have been formulated. The one most widely used in higher education is probably that of David and Roger Johnson of the University of Minnesota. According to the Johnson & Johnson model, cooperative learning is instruction that involves students working in teams to accomplish a common goal, under conditions that include the following elements (*7*):

1. **Positive interdependence.** Team members are obliged to rely on one another to achieve the goal. If any team members fail to do their part, everyone suffers consequences.

2. **Individual accountability.** All students in a group are held accountable for doing their share of the work and for mastery of all of the material to be learned.

3. **Face-to-face promotive interaction.** Although some of the group work may be parcelled out and done individually, some must be done interactively, with group members providing one another with feedback, challenging reasoning and conclusions, and perhaps most importantly, teaching and encouraging one another.

4. **Appropriate use of collaborative skills.** Students are encouraged and helped to develop and practice trust-building, leadership, decision-making, communication, and conflict management skills.

5. **Group processing.** Team members set group goals, periodically assess what they are doing well as a team, and identify changes they will make to function more effectively in the future.

Cooperative learning is not simply a synonym for students working in groups. A learning exercise only qualifies as cooperative learning to the extent that the five listed elements are present.

Cooperative Learning Structures

Cooperative learning can be used in for any type of assignment that can be given to students in lecture classes, laboratories, or project-based courses. Following are some of the structures that have been used, with some recommendations for how they may be effectively implemented. (Additional suggestions are given at the conclusion of the chapter.)

Problem Sets

Students complete some or most of their homework assignments in teams. The teams are encouraged to include only the names of actual participants on the solution set that they hand in. The students are initially disinclined to leave anyone's name off, but eventually they get tired of letting nonparticipants ("hitchhikers," in cooperative learning parlance) get good grades for work they didn't do and begin to omit names, at which point many hitchhikers—unhappy about getting zeroes on assignments—start cooperating.

The team gets a grade for the assignment, but eventually the performance of each team member should be assessed and the results used to adjust the average team homework grade separately for each team member. Adjusting team grades for individual performance is one of the principal ways of assuring individual accountability in cooperative learning, second only in importance to giving individual exams. Later in this chapter we will describe systems for performing the performance assessments and making the adjustments.

We recommend using a mixture of individual and team assignments in a lecture course rather than having all assignments completed by teams. One obvious reason is to provide another measure of individual accountability. Another is that if there is a lot of dropping and adding in the first one or two weeks of the course, it is better to wait until the class population stabilizes before forming teams.

We also suggest advising teams not to simply meet and complete each assignment together. One team member is usually the fastest problem solver and begins almost every homework problem solution in the group sessions, and the other members then have to figure out how to get the solutions started for the first time on the individual tests, which is not a good time for them to have to do it. We recommend instead that all team members outline solutions individually before meeting to work out the details. On the first few assignments we require team members to sign and hand in their outlines to help them acquire the habit.

Laboratories and Projects

Laboratories and projects may be carried out by teams (as they often are in traditional curricula), except that again the team grades should be adjusted for individual performance.

The problem with team labs and projects as they are normally conducted is that there is no individual accountability at all. The result is the familiar situation in which some team members do the bulk of the work, others contribute little and understand little or nothing about the project, everyone gets the same grade, and resentment abounds. Adjusting the team project grades for individual performance goes a long way toward correcting these injustices. In addition, it is good practice to include some individual testing on every aspect of the project and have the results count toward the final course grade. If this is done, hitchhikers who understand either nothing or only the little they did personally will be penalized and perhaps induced to play a more active role in subsequent work.

Jigsaw

Jigsaw is a cooperative learning structure applicable to team assignments that call for expertise in several distinct areas. For example, in a laboratory exercise, areas of expertise might include experimental design, equipment calibration and operation, data analysis (including statistical error analysis), and interpretation of results in light of theory, and in a design project the areas might be conceptual design, process instrumentation and control, safety and environmental impact evaluation, and cost and profitability analysis.

Suppose four such areas are identified for a project. The students are formed into teams of four, and either the instructor or the team members designate which member will be responsible for each area. Then all the experts in each area are given specialized training, which may involve getting handouts or presentations by the course instructor, a faculty colleague, or a graduate student knowledgeable in the area in question. The students then return to their home teams and complete the assignment. The teams count on each member to provide his or her expertise, and if an expert does a poor job, the quality of the final project is compromised and everyone's grade suffers. Moreover, if the students are tested on all of the areas of expertise, the overall learning from the assignment improves dramatically. The tests require all students to understand the entire project, and not just the part that they were the experts in (individual accountability), and the experts have the responsibility of transmitting their expertise to their teammates (positive interdependence).

Peer Editing

When teams turn in written lab reports and/or give oral presentations, the usual procedure is for the instructor to do the critiquing and grading. A powerful alternative is *peer editing*, in which pairs of groups do the critiquing for each other's first drafts (written) or run-throughs (oral). The groups then revise their reports and presentations taking into account the critiquing teams' suggestions and then submit or present to the instructor. This activity lightens the grading load for instructors, who end up with much better products to grade than they would have without the first round of critiquing.

If a grading checklist or rubric is to be used for grading the team reports (which is always a good idea), it should be shared with the students before the reports are written and used for the peer editing. This practice helps the students understand what the instructor is looking for and invariably results in the preparation of better reports, and it also helps assure that the peer critiques are as consistent and useful as possible. If several rounds of peer editing are done and the instructor collects and grades the checklists or rubrics for the first one or two rounds, the students will end up giving much the same rubric scores as the instructor gives, and in good classes the instructor may only have to do spot checks of peer grades instead of having to provide detailed feedback on every report.

Peer-Led Team Learning

In *peer-led team learning* (PLTL), lectures are supplemented by weekly 2-hour *workshops* in which students work in six- to eight-person groups to solve structured problems under the guidance of trained peer leaders. The problems must be challenging and directly related to the course tests and other assessment measures. The course professor creates problems and instructional materials, assists with the training and supervision of peer leaders, and reviews progress of the workshops. The materials prompt students to consider ideas, confront misconceptions, and apply what they know to the solution process. The peer leaders clarify goals, facilitate engagement of the students with the materials and one another, and provide encouragement, but do not lecture or provide answers and solutions (*8, 9*).

PLTL was developed by chemistry educators in the 1990s and may be the most prominent group-learning strategy in chemistry education. (We will later describe illustrative implementations of the approach.) It is not a cooperative learning strategy by definition, but as Tien *et al.* (*10*) point out, it shares a number of elements with CL. The students are confronted with difficult problems and must rely primarily on one another to develop solutions, which promotes positive interdependence, and face-to-face interaction is crucial to the workshop format. Students are tested individually on the knowledge required to solve the problems, and a function of the peer leader is to get team members to explain their understanding to their teammates, both of which provide individual accountability. There is no formal instruction in teamwork skills in PLTL, but informal instruction invariably occurs as the peer leaders facilitate the group interactions. The only CL criterion that does not appear to be addressed as part of the

PLTL model is regular self-assessment of team functioning, and it would be trivial to add that in PLTL implementations.

Applications in Chemistry Education

The literature of applications of cooperative learning in science, technology, engineering, and mathematics is quite large, and a comprehensive review of it is well beyond the scope of this chapter. We will confine ourselves here to describing several examples of applications in chemistry courses.

A bibliography assembled by Nurrenbern and Robinson (*11*) cites references to roughly 30 studies of team-based learning in chemistry lecture and laboratory courses, and a search for articles in recent issues of the *Journal of Chemical Education* that included cooperative learning among the key words revealed 47 articles published in 2004, 2005, and the first half of 2006. In the remainder of this section we describe several of these studies.

Hinde and Kovac (*12*) discuss two courses that introduced team-based learning in different ways. In the second semester of a physical chemistry course for chemistry and chemical engineering majors, biweekly computer-based group work sessions supplemented traditional lectures, and in the the second semester of a biophysical chemistry course taken primarily by biochemistry majors, an approach based on group work with occasional supplementary mini-lectures was used. The group sessions in both courses were inquiry-based. The self-selected teams of three or four in the biophysical chemistry course were given guidelines on effective teamwork, and both peer ratings and self-ratings of student performance on teams contributed to the final course grades. In the physical chemistry course there was little difference in performance between the class in question and previous classes that had been taught without group work, but this result is not surprising in view of the fact that the group activities were infrequent and most of the defining criteria for cooperative learning were not met. In the biophysical chemistry course the instructor's assessment was that the students gained considerable conceptual understanding and problem-solving ability as well as critical thinking and teamwork sklls, but no comparison with a control group was carried out that would elevate the assessment of the course beyond the anecdotal level. The author concludes that the course would have been improved by providing more structure and feedback, maintaining a better balance between individual and group work, and doing more to promote individual accountability (e.g., give more individual tests) and positive interdependence (e.g., establish and rotate assigned roles within teams).

A better example of cooperative learning implementation and assessment is provided by Tien *et al.* (*10*), who conducted peer-led team learning in a first-semester organic chemistry course over a three-year period and compared the performance of the students with the that of students who had taken a traditional version of the course in the preceding three years. The course instructor, text, examination structure, and grading system were the same for both the treatment and comparison groups. While instruction in teamwork skills is not necessarily a component of PLTL, in this case the peer leaders were trained in group dynamics and group skills and used their training to help the student teams learn to function effectively. It is therefore fair to say that the PLTL implementation described in this study fully qualifies as cooperative learning. On average, the workshop students significantly outscored their traditionally-taught counterparts on individual course exams, final course grades, retention in the course, and percentage earning the minimum acceptable grade of C– for moving on to the second semester organic chemistry course. Similar results were obtained specifically for female students and underrepresented minority students. The treatment group found the workshops and workshop problems their most important aids to learning in the course. Similar findings have been reported for PLTL programs in an organic chemistry class at another institution (*13*) and in a biology course (*14*), as well as for a cooperative learning implementation in organic chemistry (*15*).

A classical implementation of cooperative learning in chemistry is that of Hanson & Wolfskill (*16*), who used a "process workshop" format in the general chemistry class at SUNY-Stony Brook. Students worked in teams of three or four on activities that involved guided discovery, critical thinking questions that help provide the guidance, solving context-rich and sometimes open-ended and incompletely defined problems, and metacognitive reflecting. Most activities focused on a single concept or issue and could be completed in a 55-minute session. Following each workshop, students completed an individual quiz on the workshop content, thus promoting individual accountability. The use of this approach led to substantially improved examination grades relative to the previous year, in which the course was conventionally taught, as well as increased attendance at recitation and tutorial sessions and improvements in student self confidence, interest in chemistry, and attitudes toward instruction. The same authors report on an interactive computer-assisted learning model that supports and enhances the process workshop format by providing immediate feedback on student efforts, networked reporting capabilities, and software tools for both peer assessment and self-assessment (*17*).

Research Support for Cooperative Learning

Hundreds of research studies of team-based learning in higher education have been conducted, with most of them yielding positive results for a variety of cognitive and affective outcomes. Analyses of the research support the following conclusions:

- Individual student performance was superior when cooperative methods were used as compared with competitive or individualistic methods. The performance outcomes measured include knowledge acquisition, retention, accuracy, creativity in problem solving, and higher-level reasoning. Other studies show that cooperative learning is superior for promoting metacognitive thought, persistence in working toward a goal, transfer of learning from one setting to another, time on task, and intrinsic motivation For example, students who score in the 50^{th} percentile when learning competitively would score in the 69^{th} percentile when taught cooperatively (*1, 3*).
- Similar positive effects of group interactions have been found specifically for chemistry courses. In a meta-analysis of research on cooperative learning in high school and college chemistry courses, Bowen (*18*) found that students in the 50^{th} percentile with traditional instruction would be in the 64^{th} percentile in a cooperative learning environment.
- Several studies of active/collaborative instruction report positive effects on a variety of cognitive and affective outcomes. In a compilation of pre-post test gains in force concept inventory scores obtained by students in introductory physics courses, the use of instruction involving "interactive engagement" led to an average gain two standard deviations greater than was observed for traditionally-taught courses (*19*). Students in engineering capstone design courses taught with active and collaborative approaches outperformed traditionally-taught students in acquisition of design skills, communication skills, and teamwork skills (*4*). The use of collaborative methods had significant positive effects on understanding science and technology, analytical skills, and appreciation for diversity, among other outcomes (*20*).
- Affective outcomes were also improved by the use of cooperative learning. Relative to students involved in individual or competitive learning environments, cooperatively taught students exhibited better social skills and higher self-esteem (*3*), as well as more positive attitudes about their educational experience, the subject area, and the college (*7*). Towns *et al.* (*21*) used field notes and survey data to analyze students' attitudes toward group activities in a physical chemistry class. The students viewed the group work as a positive force in their learning, and they also valued the interactions for promoting a sense of community in the classroom.

Implementing Cooperative Learning

The benefits of using cooperative learning are well supported by theory and well established by classroom research, but the method is not without its problems, most of which have to do with individual student resistance and dysfunctional teams. Many techniques have been developed that minimize the problems, most of which involve addressing one or more of the five criteria for cooperative learning. The suggestions that follow are drawn primarily from Felder and Brent (*22, 23*), Johnson et al. (*7*), Oakley *et al.* (*24*) and Smith *et al.* (*2*).

Before we offer the suggestions, we should make clear that implementing cooperative learning successfully does not require adopting every one of them. In fact, trying to do so all at once might be a serious mistake: the instructor would have to juggle many unfamiliar techniques and end by doing none of them well, and the students would be deluged by an array of unfamiliar demands and many might rise up in rebellion. Rather, instructors new to cooperative learning should take a more gradual approach, choosing mainly the methods with which they feel most comfortable and adopting additional methods only when they have had time to get used to the current ones. If they do that, they will never stray too far from their comfort zones and will become increasingly adept at defusing student resistance long enough for the students to see the benefits of this new form of instruction for themselves.

Forming teams

Instructors should form teams rather than permitting students to choose their own teammates. When students self-select into teams, the best students tend to cluster, leaving the weak ones to shift for themselves, and friends cluster, leaving some students out of groups and excluding others from cliques within groups. Moreover, when graduates go to work in industry or business, they will be required to work in teams and will have no voice in the team formation, and their job performance evaluation will depend as much on their ability to work with their teammates as on their technical skills. Since that's what they'll be doing then, the job of their instructors is to prepare them for it now.

The following criteria are recommended for team formation:

1. *Form teams of* 3–4 *students for most tasks.* When students work in pairs, the diversity of ideas and approaches that leads to many of the benefits of cooperative learning may be lacking. In teams of five or more, some students are likely to be inactive unless the tasks have distinct and well-defined roles for each team member.
2. *Make the teams heterogeneous in ability level.* The unfairness of forming a group with only weak students is obvious, but groups with only strong students are equally undesirable. The members of such teams are likely to divide up the homework and communicate only cursorily with one another, avoiding the interactions that lead to most of the proven benefits of cooperative learning. In heterogeneous groups, the weaker students gain from seeing how better students approach problems, and the stronger students gain a deeper understanding of the subject by teaching it to others.
3. *If the assignments require work being done outside class, form teams whose members have common blocks of time to meet during the week.*
4. *When students in a particular demographic category are historically at risk for dropping out, don't isolate members of that category in a team*. Students belonging to at-risk populations are also at risk for being marginalized or adopting passive roles when they are isolated in teams (*22, 25, 26*). Once they reach the third year, however, they are very likely to graduate. The focus should then shift to preparing them for the professional world where no one will be protecting them, and so this criterion may be dropped.

There are three principal ways to get the information needed to form teams using those rules:

1. On the first day of class, have the students fill out a survey containing several questions and an hour-by-hour matrix of the week, similar to the form at <*http://www.ncsu.edu/felder-public/CL_forms.doc*>. On the form, the students write their grades in selected prerequisite courses, times they are not available to meet outside class with their teams, and—if the criterion related to at-risk minorities is to be used—their gender and ethnicity. Use the surveys to form the groups, following the guidelines given above and using grades in prerequisite courses as the measure of ability.
2. Use *Team Maker®*, an on-line team-forming instrument developed at the Rose-Hulman Institute of Technology (*27*). The students enter the requested information into a database, the instructor specifies the sorting criteria, and Team Maker does the sorting. Sorting with Team Maker tends to be more reliable and much faster than manual sorting.
3. Let students self-select into groups, stipulating that no group may have more than one student who earned A's in one or two specified prerequisite courses. While not perfect, this system at least assures that the very best students in the class do not cluster together, leaving the weaker ones to fend for themselves.

Promoting positive interdependence

- *Assign different roles to team members (e.g. coordinator, recorder, checker, group process monitor), rotating the roles periodically or for each assignment.* The coordinator reminds team members of when and where they should meet and keeps everyone on task during team meetings; the recorder prepares the final solution to be turned in; the checker double-checks the solution before it is handed in and makes sure the assignment is turned in on time.; and the monitor checks to be sure everyone understands the solutions and the strategies used to get them. In teams of three, the coordinator may also assume the duties of the monitor.
- *Use Jigsaw to set up specialized expertise within each team.*
- *Give a bonus on tests (typically 2–3 points) to all members of teams with average test grades above (say) 80%.* The bonus should not be tied to each person on the team getting a certain grade, which would put too much pressure on weaker members of the team and make it impossible for teams with one very weak student to ever get the bonus. Linking the bonus to the team average grade gives all team members an incentive to get the highest grade they can and motivates the stronger students to tutor their teammates.
- *If an oral report is part of the team project, a short time before the report is given the instructor arbitrarily designates which team member should report on each part of the project.* Normally different team members take primary responsibility for different parts of the project and report on those parts, making it unnecessary for their teammates to understand what they did. When the proposed technique (which should be announced when the project is first assigned) is adopted, each student must make sure everyone on the team can report on what he or she did. This method provides both positive interdependence and individual accountability.

Providing individual accountability

- *Give individual tests that cover all of the material on the team assignments and projects*. Tests are frequently not given in traditional project-based courses such as laboratories and capstone research or design courses. Even if the tests only count for a relatively small portion of the course grade, their presence works against the familiar phenomenon of some team members doing little or none of the work and getting the same high course grades as their more responsible teammates.

- *In lecture courses (as opposed to project-based courses), include group homework grades in the determination of the final course grade only when a student has a passing average on the individual exams.* This policy—which should be announced in writing on the first day of class—is particularly important in required courses that are prerequisites for other courses in the core curriculum.

- *Make someone on the team (the process monitor) responsible for ensuring that everyone understands everything in the report or assignment that the team hands in.* The monitor should also make sure everyone participates in the team deliberations and that all ideas and questions are heard.

- *Make teams responsible for seeing that non-contributors don't get credit.* A policy that only contributors' names should go on assignments and reports should be announced at the beginning of the course, and reminders of the policy should be given to students complaining about hitchhikers on their teams. Most students are inclined to cut their teammates some slack initially, but if the the hitchhikers continue to miss meetings or fail to do what they were supposed to do, eventually the responsible team members get tired of being exploited and begin to implement this policy.

- *Use peer ratings to make individual adjustments to team assignment grades.* In a fairly simple but effective peer rating system, students rate one another on specified criteria for good team citizenship and the ratings are used to compute individual multipliers of the team grade that may range from 1.05 to 0 (*28*). An on-line system currently under development called CATME (Comprehensive Assessment of Team Member Effectiveness] computes a similar adjustment factor but also provides detailed feedback to team members on the skills and attitudes they need to work on and alerts the instructor to the existence of problematic situations (*29*). The ratings should be based primarily on responsible team behavior and not the percentages of the total effort contributed by each team member. Schemes of the latter sort move instruction away from the cooperative model toward individual competition, with a consequent loss in the learning benefits and skill development that cooperative learning promotes.

- *Provide last resort options of firing and quitting.* When a team has an uncooperative member and everything else has been tried and failed, the other team members may notify the hitchhiker in writing that he/she will be fired if cooperation is not forthcoming, sending a copy of the memo to the instructor. If there is no improvement after a week or if there is and the behavior later resumes, they may send a second memo (copy to the instructor) that he/she is no longer with the team. The fired student should meet with the instructor to discuss options. Similarly, students who are consistently doing all the work for their team may issue a warning memo that they will quit unless they start getting cooperation, and a second memo announcing their resignation from the team if the cooperation is not forthcoming. Students who get fired or quit must find a team of three willing to accept them, otherwise they get zeroes for the remaining assignments.

Help students develop teamwork skills

- *Establish team policies and expectations.* As part of the first assignment, have teams generate and sign a list of policies and expectations (e.g. being prepared before team sessions, calling if they have time conflicts, etc.). Have them sign the list and make copies for themselves and you. For an illustrative set of procedures, see <*www.ncsu.edu/felder-public/CL_forms.doc*>.

- *Keep groups intact for at least a month.* It takes at least that long for the teams to encounter problems, and learning to work through the problems is an important part of teamwork skill development.

- *Provide for periodic self-assessment of team functioning.* Every 2–4 weeks, have teams respond in writing to questions such as:

How well are we meeting our goals and expectations?
What are we doing well?
What needs improvement?
What (if anything) will we do differently next time?

- *Give students tools for managing conflict.* Caution them that dealing with conflicts quickly and rationally can avoid later serious problems that are almost certain to arise if they attempt to ignore the conflicts. Introduce them to *active listening*:

  – Students on one side of a dispute make their case without interruptions, then students on the other side have to repeat it to the initial group's satisfaction,

  – The second side then makes its case uninterrupted, and the first side has to repeat it to the second side's satisfaction.

  – The students then work out a solution. Once the students have articulated their opponents' cases, the solution frequently comes very easily.

  The instructor should facilitate active listening sessions for groups in conflict, mainly making sure the rules of the procedure are followed.

- *Use crisis clinics to equip students to deal with difficult team members.* Two to three weeks after group work has begun, you will start hearing complaints about certain problematic team members, such as hitchhikers or dominant students who insist on doing the problems their way and discount everyone else's opinions. Use these characters as bases for ten-minute *crisis clinics* in class, in which the students brainstorm and then prioritize possible group responses to specified offending behaviors (*23*). At the end of this exercise, the teams leave armed with several excellent strategies for dealing with the problem, and the problem students in the class are on notice that their team members are likely to be ready for them in the future, which may induce them to change their ways.

General Suggestions

- *Start small and build.* If you've never used cooperative learning, consider starting with small group activities in class. See Felder and Brent (*30)* for suggestions about how to implement active learning effectively. Once you're comfortable with that, try a team project or assignment, and gradually build up to a level of cooperative learning with which you are comfortable.

- *At the start of the course, explain to students what you're doing, why you're doing it, and what's in it for them.* Let them know what they'll be doing in teams, what procedures you'll follow, and what your expectations are. Then tell them why you're doing it, perhaps noting that it will help prepare them for the type of environment most of them will experience as professionals, and sharing some of the research results (particularly those relating to higher grades). The section in this chapter on research support for cooperative learning provides useful material of this nature.

- *Make team assignments more challenging than traditional individual assignments.* CL works best for challenging problems and activities that require higher-level thinking skills. Students resent having to spend time in teams on assignments they could easily complete individually.

- *Don't curve course grades.* It should be theoretically possible for every student in a class to earn an A. If grades are curved, team members have little incentive to help each other, while if an absolute grading system is used (e.g., a weighted average grade of 92–100 is guaranteed an A, 80–91 is guaranteed a B, etc.), there is a great incentive for cooperation.

- *Conduct a midterm assessment to find out how students feel about teamwork.* At about mid-semester, ask students to report anonymously on what's working and what's not working in their team. If many teams are having problems, spend some time in class on the relevant team skills.

Most of the time, however, the assessment will show that most teams are working well. (Without the assessment, the instructor usually only hears the complaints.) If this is the case, announce the results at the next class session, so the few resistors become aware that they're in a small minority.

- *Expect initial resistance from students.* See Felder and Brent (*31*) for information on why the resistance occurs, what forms it is likely to take, and suggestions on how to deal with it.

Summary

Cooperative learning refers to work done by student teams producing a product of some sort (such as a set of problem solutions, a laboratory or project report, or the design of a product or a process), under conditions that satisfy five criteria: (1) positive interdependence, (2) individual accountability, (3) face-to-face interaction for at least part of the work, (4) appropriate use of interpersonal skills, and (5) regular self-assessment of team functioning. Extensive research has shown that relative to traditional individual and competitive modes of instruction, properly implemented cooperative learning leads to greater learning and superior development of communication and teamwork skills (e.g. leadership, project management, and conflict resolution skills). The technique has been used with considerable success in all scientific disciplines, including chemistry.

The benefits of cooperative learning are not automatic, however, and if imperfectly implemented, the method can create considerable difficulties for instructors, most notably dysfunctional teams and student resistance or hostility to group work. This paper offers a number of suggestions for forming teams, satisfying the five defining criteria of cooperative learning, and minimizing the problems. Instructors who have never used the approach are advised to move into it gradually rather than attempting a full-scale implementation on their first try, and to increase the level of implementation in subsequent course offerings. To an increasing extent, they should see the learning benefits promised by the research, and as their expertise and confidence in implementing the method continue to grow, student evaluations of the team experience should improve concurrently. Most importantly, instructors who are successful in using cooperative learning in their classes will have the satisfaction of knowing that they have significantly helped prepare their students for their professional careers.

Some years ago, one of us (RF) taught five chemical engineering courses in consecutive semesters to a cohort of students using cooperative learning (*32*, *33*). The superiority of their performance and attitudes relative to a comparison group that was taught traditionally was consistent with the many other results reported on earlier in this chapter. Five years after most of the students had graduated they were surveyed and asked to reflect on what in their undergraduate college experience best prepared them for their post-graduation careers (*34*). Of the 50 respondents (out of 72 surveyed), 25 mentioned the problem-solving and time management skills they acquired by working on so many long and difficult assignments, 23 mentioned a variety of benefits gained from working in teams on homework, and no other feature of the curriculum got more than eight mentions. In their open comments, almost every respondent spoke positively about group work, mentioning its learning benefits and/or the interactions with classmates that it fostered. For example, "*I formed very close relationships with my group members that remain today. I realized that I wasn't alone in struggling with new concepts and could garner support and help from teammates.*" and "*Being forced to meet other students through required groupwork…kept me in the course long enough to develop the skills and self-confidence necessary to continue on in the CHE curriculum*." No one said anything negative about group work, although two respondents indicated that they disliked it initially and only later came to see its benefits. We don't guarantee a retrospective evaluation this positive to everyone who uses cooperative learning, but we believe the possibility of it makes the effort worthwhile.

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