3. Cooperative Group Problem Solving in Discussion Sections

This chapter contains some materials we use in teaching problem-solving and cooperative group skills to our students. These materials are described briefly below.

Why Cooperative Group Problem Solving?

Students in introductory physics courses typically begin to solve a problem by plunging into the algebraic and numerical solution -- they search for and manipulate equations, plugging numbers into the equations until they find a combination that yields an answer (e.g., the plug-and-chug strategy). They seldom use their conceptual knowledge of physics to qualitatively analyze the problem situation, nor do they systematically plan a solution before they begin numerical and algebraic manipulations of equations. When they arrive at an answer, they are usually satisfied -- they rarely check to see if the answer makes sense.

To help students integrate the conceptual and procedural aspects of problem solving so they could become better problem solvers, we introduced a structured, five-step problem solving strategy (see Part 2 of this booklet). However, we immediately encountered the following dilemma:

> If the problems are simple enough to be solved moderately well using their novice strategy, then students see no reason to abandon this strategy -- even if the structured problem-solving strategy works as well or better.
>
> If the problems are complex enough so the novice strategy clearly fails, then students are initially unsuccessful at using the structured problem-solving strategy, so they revert back to their novice strategy.

To solve this dilemma, we (1) designed complex problems that discourage the use of plug-and-chug strategies, and (2) introduced cooperative group problem solving. Cooperative group problem solving has several advantages:

1. The structured problem-solving strategy seems too long and complex to most students. Cooperative-group problem solving gives students a chance to practice the strategy until it becomes more natural.

2. Groups can solve more complex problems than individuals, so students see the advantage of a logical problem-solving strategy early in the course.

3. Each individual can practice the planning and monitoring skills they need to become good individual problem solvers.

4. Students get practice developing and using the language of physics -- "talking physics."

5. In their discussion with each other, students must deal with and resolve their misconceptions.

6. In subsequent, whole-class discussions of the problems, students are less intimidated because they are not answering as an individual, but as a group.

Of course, there are several disadvantages of cooperative-group problem solving. Initially, many students do not like working in cooperative groups. They do not like exposing their "ignorance" to other students. Moreover, they have been trained to be competitive and work individually, so they lack collaborative skills.

Frequently Asked Questions (FAQ)
About Cooperative-Group Problem Solving

For a more extended discussion of the following questions, see Heller and Hollabaugh (1992), Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups, *American Journal of Physics,* **60**: 637-644.

What is the optimal group size?

We have found that groups of **three** work a little better than pairs or groups of four. With pairs, there is often not enough physics knowledge to solve the problem. In groups of four, one member tends to be left out of the process.

When the class size is not divisible by three, however, we end up with a few pairs or groups of four. In general, we prefer groups of four over pairs.

Should students be allowed to form their own groups? If not, what should be the gender and performance mix of the groups?

We found that mixed-ability groups (based on past performance on problem-solving tests) worked better than homogeneous-ability groups. Therefore, we assign members to groups based on test performance (one from the top third, one from the middle-third, and one from the bottom third of the class).

We also found that groups of two men and one woman did not work well, particularly at the beginning of the course. The men tend to ignore the woman, even if she is the highest ability student in the group. Until instructors get to know their students well, we advise assigning groups of three men, three women, or two women and one man.

How often should groups be changed?

Formal cooperative groups need to stay together long enough to be successful. On the other hand, they should be changed often enough so students realize they can make *any* group successful -- that their success is not due to being in a "magic" group.

Our students work in cooperative groups for three hours each week (1 hour in discussion section, 2 hours in lab). In the first quarter, we change groups every two to three weeks (i.e., 4 times in 10 weeks). In the second and third quarter, we change groups only twice.

In the beginning of the course, it is important to give students a rationale for assigning them to groups and changing groups often. We tell our students that:

(1) We want them to get to know everyone in the class, so we will change groups often. By the end of the quarter, they will should have worked with almost everyone in their class (section). This helps build a sense of community -- we are all working together to help each other learn physics.

(2) No matter what career they enter, they will have to work cooperatively with many different kinds of people (not just their friends). So they should begin to learn how to work in successfully in groups.

How can problems of dominance by one student and conflict avoidance within a group be addressed?

We use three key elements of cooperative learning groups to alleviate these difficulties:

(1) One Group Product: To promote interdependence in discussion sections, we specify that only one problem solution can be turned in by the groups, and all members must sign the solution.

(2) Roles: Students are taught specific roles (Manager, Checker/Recorder, Skeptic, and Energizer/Summarizer). The roles were selected to correspond to the planning and monitoring strategies individuals must perform independently when solving problems -- the manager who designs plans of action; the skeptic, who questions premises and plans; the recorder, who organizes and writes what has been done so far; and the summarizer, who keeps track of decisions and reasons for different actions. In addition, each person has a responsibility to make sure the group functions effectively. The Manager must ensure that everyone in the group participates and contributes. The Checker/Recorder must ensure that all group members can explicitly explain how the problem was solved. The Energizer/Summarizer must energize the group when motivation is low.

We normally assign groups of three (Manager, Checker/Recorder, and Skeptic): the fourth role of Energizer/Summarizer is used when the size of the class is not divisible by three, so some groups will have four members. In groups of three, the Manager takes on the summarizer role, and all members are asked to energize the group when motivation is low.

The first time students work together, each member is *assigned* one of these roles. Each subsequent time the group works together, the roles must *rotate.* The groups stay together long enough so each group member has each role at least once.

(3) Group Processing: Set aside time at the end of a class session to have students discuss how well they worked together and what they could do to work together better next time.

At the beginning of the quarter, we do this *every* class session. After three to four weeks (i.e., after students have worked in two different groups), we do group processing every two to three weeks, as it seems necessary -- usually the first time new groups are working together.

How can individual accountability (hitch-hiking) be addressed?

We use four techniques to alleviate the "hitch-hiker" problem (one student relying on the other group members to do all the work):

(1) Assign a role to each student, and allow time for group processing (see above).

(2) Make sure the seats are arranged so students are facing each other, "knee-to-knee." This makes it much harder for a student to remain uninvolved with a group.

(3) In both discussion sections and lab, individual students are called on randomly to present their group's results. This person is *not* usually the Checker/Recorder for the group.

(4) In discussion section, occasionally a group problem counts as a test question. The group test problem is given the day before the rest of the test. If a group member was absent the week before the group test (i.e., did not get to practice with his/her group), then s/he cannot take the group test question. (Note: Towards the end of the first quarter, we let the rest of the group members decide if the absent group member can take the group test problem.)

In lab, each member of the group receives bonus points if all group members earn 80% or better on their individual reports.

Outline for Teaching a Discussion Section

	What the Students Do	What the TA Does
Opening Moves: 2 min.	• Sit in groups. • Read problem. • Checker/Recorder puts names on answer sheet.	0. Get to the classroom early. 1. Briefly introduce problem. 2. Pass out group problem and answer sheet. 3. Tell class time they need to stop and remind managers to keep track of time.
Middle Game	• Do the assigned problem: - participates in discussion, - work cooperatively, - check each others work.	4. Take attendance. 5. Monitor groups and intervene when necessary 6. A few minutes before you want them to stop, remind the students of the time and to finish working on their problem. Also pass out group functioning forms at this time.
End Game: 5-10 min.	• Finish problem. • Check answer. • Participate in class discussion.	7. Select one person from each group to put their results on the board. 8. Lead a class discussion of these results. 9. If necessary, lead a class discussion of group functioning 10 Pass out the solution.

Detailed Advice for TAs about
General Discussion Section Lesson Plan

0. Get to the classroom early.

When you get to the classroom, go in and close the door, leaving your early students outside. The best time for informal talks with students is after the class

Prepare the classroom by checking to see that there is no garbage around the room and that the chairs and desks are properly arranged. If you have changed groups, list the new groups on the board at this time also. Let your students in when you are prepared to teach the discussion session.

1. Briefly introduce problem.

Spend a minute or two telling students about the problem - remind them what physical principles they have been discussing in class, and tell them why this particular problem has been chosen. **DO NOT LECTURE YOUR CLASS ON PHYSICS!**

2. Pass out group problem and answer sheet.

Give a copy of the problem to each student, but only one answer sheet to each group. This will help the students work in groups since they can only turn in one answer sheet for the group.

3. Tell class when (at what time) they need to stop and remind managers to keep track of time.

If you are planning on doing the group functioning worksheet, be sure to leave time at the end of class. Be sure to leave time for your end game!

4. Take attendance

Take attendance as soon as the groups are working. Doing this early will cut down on tardiness.

5. Monitor groups and intervene when necessary

When students work in cooperative groups, they make hidden thinking processes overt, so these processes are subject to observation and commentary. You will be able to observe how students are constructing their understanding of physics concepts and the problem-solving strategy.

While groups are working, a significant fraction of your time should be spent monitoring (observing and listening to group members) in order to see

- what they do and do not understand, and
- what problems they have working together cooperatively.

With this knowledge, your interventions can be more efficient. **DO NOT** get trapped into going from group to group explaining the task/physics or answering questions. If you begin intervening too soon, it is not fair to the last groups. By the time you recognize that all groups may have the same difficulty, the last groups will have wasted considerable time.

a Monitoring

- Establish a circulation pattern around the room. Stop and observe each group to see how easily they are solving the problem and how well they are working together. Don't spend a long time with any one group. Keep well back from students' line of sight so they don't focus on you.
- Make notes about student difficulties with the task and with group functioning so you know what end-game moves to make.
- If several groups are having the **same** difficulty, you may want to stop the whole class and clarify the task or make additional comments that will help the students get back on track (e.g., I noticed that you are all … Remember to …) Another strategy is to stop the class and have one group (or several groups) **show** the class how they decided to draw their diagrams or what steps they are using. You can then spend a few minutes discussing how that drawing or plan could be done most effectively.

b. Intervening

- From your observations (circulation pattern), decide which group (if any) is obviously struggling and needs attention most urgently. Return to that group, watch for a moment and then join the group at eye level. One way to intervene is to point out the problem and ask the appropriate group member what can be done about it. This establishes your role as one of coach rather than answer-giver. Another way to intervene is to ask them (a) What are you doing? (b) Why are you doing it? and (c) How will that help you? Try to give just enough help to get the group on track, then leave.
- One way to coach is to first diagnose the type of problem (e.g., managerial, came to decision too quickly without considering all the options, can't agree on what procedure to use, etc.) Then ask: "Who is the manager (or skeptic, or checker)? What should you be doing to help resolve this problem?" If the student doesn't have any suggestions, then you could model several possibilities.
- If you observe a group in which one student does not seem to be involved in the discussion and decisions, ask that student to explain what the group is doing and why. This emphasizes the fact that all group members need to be able to explain each step in solving the experimental problem.
- If a group asks you a question, try to turn the question back to the group to solve. Again, try to give just enough help to get the group started, then leave.

6. A few minutes before you want them to stop, remind the students of the time and to finish working on their problem.

Also pass out group functioning forms at this time (if necessary, about every 2 - 3 weeks). (Note: Another common teaching error is to provide too little time for students to process the quality of their cooperation. Students do not learn from experiences that they do not reflect on. If the groups are to function better next time, members must receive feedback, reflect on how their actions may be more effective, and plan how to be even more skillful during the next lab or discussion session.)

When you were an undergraduate, your instructor probably did not stop you to have a class discussion at the end of the period. Doing this is one of the hardest things you will have to do as a TA. You may be tempted to let students keep working so that they can get as much done as possible, or to let them go home early so that they like you better. However, research has shown that students do not learn from their experiences unless they have the chance to process their information. One good way to do this is by comparing their results with the whole class.

Most students do not want to stop, and may try to keep working. If it is necessary, to make your students stop working you can warn them that you will not accept their paper if they keep working. You are in charge of the class, and if you make it clear that you want the students to stop, they will.

7. Select one person from each group to put their results on the board.

Typically, the checker/recorder in each group is not selected. In the beginning of the course, select students who are obviously interested, enthusiastic, and articulate. Later in the course, it is sometimes effective to occasionally select a student who has not participated in the discussion as much as you would like. This reinforces the fact that *all* group members need to know and be able to explain what their group did.

8. Lead a class discussion of these results.

A whole-class discussion is commonly used to help students consolidate their ideas and make sense out of what they have been doing. Discussions serve several purposes:

- to summarize what students have learned;
- to help students find out what other students learned from the same problem;
- to produce discrepancies which stimulate further discussion, thinking, or investigations.

These discussions should always be based on the groups, with individuals only acting as representatives of a group. This avoids putting one student "on the spot." The trick is to conduct a discussion about the results without (a) **telling** the students the "right" answer or becoming the final "authority" for the right answers, and (b) without focusing on the "wrong" results of one group and making them feel stupid or resentful. To avoid these pitfalls, you could try starting with general, open-ended questions such as:

- How are these results the same?
- How are these results different?

Then you can become more specific:

- What could be some reasons for them to be different?
- Are the differences important?

Always encourage an individual to get help from other group members if he or she is "stuck."

Encourage groups to talk to each other by redirecting the discussion back to the groups. For example, when a group reports their answer, ask the rest of the class to comment: "What do the rest of you think about that?" This helps avoid the problem of you becoming the final "authority" for the right answer.

9. If necessary, lead a class discussion about the group functioning.

Discussing group functioning occasionally is essential. Students need to hear difficulties other groups are having, discuss different ways to solve these difficulties, and receive feedback from you.

- Randomly call on one member of from each group to report either
  - one way they interacted well together, or
  - one difficulty they encountered working together, or
  - one way they could interact better next time.
- Add your own feedback from observing your groups (e.g., "I noticed that many groups are coming to an agreement too quickly, without considering all the possibilities. What might you do in your groups to avoid this?")

10. Pass out the solution.

Passing out the solution is important to the students. They need to see good examples of solutions to improve their own problem solving skills. Again, it is important to pass them out as the last thing you do, or the students will ignore anything that you say after you have passed them out. You cannot possibly be more interesting than the solutions.

Group Roles

In your discussion and laboratory sections for this course, you will be working in **cooperative** groups to solve written and experimental problems. To help you learn the material and work together effectively, each group member will be assigned a specific role. Your responsibilities for each role is defined on the chart below.

ACTIONS	WHAT IT SOUNDS LIKE
MANAGER DIRECT THE SEQUENCE OF STEPS. KEEP YOUR GROUP "ON-TRACK." MAKE SURE EVERYONE IN YOUR GROUP PARTICIPATES. WATCH THE TIME SPENT ON EACH STEP.	*"LET'S COME BACK TO THIS LATER IF WE HAVE TIME."* *"WE NEED TO MOVE ON TO THE NEXT STEP."* *"CHRIS, WHAT DO YOU THINK ABOUT THIS IDEA?"*
RECORDER/CHECKER ACT AS A SCRIBE FOR YOUR GROUP. CHECK FOR UNDERSTANDING OF ALL MEMBERS. MAKE SURE ALL MEMBERS OF YOUR GROUP AGREE ON PLANS AND ACTIONS. MAKE SURE NAMES ARE ON GROUP PRODUCTS.	*"DO WE ALL UNDERSTAND THIS DIAGRAM?"* *"EXPLAIN WHY YOU THINK THAT."* *"ARE WE IN AGREEMENT ON THIS?"*
SKEPTIC HELP YOUR GROUP AVOID COMING TO AGREEMENT TOO QUICKLY. MAKE SURE ALL POSSIBILITIES ARE EXPLORED. SUGGEST ALTERNATIVE IDEAS.	*"WHAT OTHER POSSIBILITIES ARE THERE?"* *"LET'S TRY TO LOOK AT THIS ANOTHER WAY."* *"I'M NOT SURE WE'RE ON THE RIGHT TRACK."*
ENERGIZER/SUMMARIZER ENERGIZE YOUR GROUP WHEN MOTIVATION IS LOW • BY SUGGESTING A NEW IDEA; • THROUGH HUMOR; OR • BY BEING ENTHUSIASTIC. SUMMARIZE (RESTATE) YOUR GROUP'S DISCUSSION AND CONCLUSIONS.	*"WE CAN DO THIS!"* *"THAT'S A GREAT IDEA!"* *"SO HERE'S WHAT WE'VE DECIDED . . ."*

Course: ______
Section: ______

Manager: ________________________.
Recorder/Checker: ________________________.
Skeptic: ________________________.
Energizer/Summarizer: ________________________.

GROUP FUNCTIONING EVALUATION

In your group take a few minutes to discuss and answer these questions about this particular cooperative learning experience. Focus your discussion on the **process** -- what you experienced, felt and thought while doing the activity.

1. What are **three** ways you did well in functioning as a cooperative group?

2. What problems did you have interacting as a cooperative group?

3. What is a **specific action** that would help you function and interact *even better* next time?

Typical Objections To Cooperative Group Discussion Sections

Typical "Objections" to Cooperative Group Discussion Sections	**How Would You Reply?**	**Analogous Objections in Traditional Recitations**
#1. Instructor can not always be there to stop alternative conceptions from being reinforced in a group.	There is actually less chance of alternative conceptions being maintained in groups because of the interaction between students. The instructor can usually observe the evidence of alternative conceptions by listening to the group discussion or looking at their group solution as it is being constructed.	*Instructors can not get inside students' minds to see if they are forming alternative conceptions.*
#2. Some groups get done before others, so there is a lot of wasted time.	Yes, so be prepared with something for them to do -- either an extension to the problem or have them go to the board and start their solutions.	*Some students already know how to solve the problem that is being done on the board. So there is a lot of wasted time.*
#3. Some students do not contribute -- they "hitch hike" their way through the problem.	This is a sign of a dysfunctional group. You need to intervene.	*Some students do not ask questions, have not prepared, or are not thinking about the material.*
#4. There is no time to answer student's questions about the homework or the lecture.	There are other times available for this: office hours, review sessions, maybe even in lab.	*You are only answering one student's question, so you don't address the concerns of the other students in the class.*
#5. It takes more time to teach with cooperative groups, so less material can be covered.	True. The intention is to better teach a firm understanding of the fundamental concepts upon which to build later applications.	*The amount covered depends only on how fast the instructor can speak or write. It does not require real time intellectual engagement of the students.*

Typical "Objections" to Cooperative Group Discussion Sections	**How Would You Reply?**	**Analogous Objections in Traditional Recitations**
#6. Cooperative groups hold back the best students, and the weaker students can "freeload."	The research indicates that cooperative groups seem to help **all** students because the best students get to "teach" and the weaker students get peer coaching. See Heller, Keith and Anderson (1992) and Johnson and Johnson (1989)in the reading packet.	*Traditionally the weaker students get left behind and the best students are bored.*
#7. Often groups are dysfunctional.	Most groups function reasonably well from the outset, although careful intervention and group processing will make them function better. For the approx. 20% of groups that are dysfunctional, you should intervene. No instructional method will reach all students.	*The research indicates that traditional instruction tends to only teach to about the top 20% - 25% of the class. (see Wandersee, J.H., Mintzes, J.J., & Novak, J.D. (1994). Research on alternative conceptions in science. In D.L. Gabel (Ed.), Handbook of Research in Science Teaching and Learning, New York: Macmillan)*
#8. Cooperative grouping is not teaching because anyone can do it. You just stand around and watch.	Observing cooperative groups working allows you to diagnose how the students are thinking and coach them to overcome their conceptual difficulty (when the others students in the group can not). Cooperative groups are egalitarian and respectful (i.e., student-centered) by nature	*Lecturing is not teaching because you are concentrating on what **you** say and do instead of concentrating on what your students think.* *Recitations are egotistical and authoritarian (i.e., teacher-centered) by nature.*
#9. Cooperative group work is authoritarian because it forces everyone to work together even if they don't like to.	Cooperative groups respect the different ways that students think. They allow students the opportunity of validating their thought process or getting the precise instruction they need.	*Traditional recitations are authoritarian because everyone must interact only with the instructor and must think like them to follow their solutions.*

Typical "Objections" to Cooperative Group Discussion Sections	**How Would You Reply?**	**Analogous Objections in Traditional Recitations**
#10. Students hate to play group roles.	In effective groups, the roles occur naturally and shift among the students. Role playing is a technique to get dysfunctional groups working together. Roles help students who have not learned to work together in teams develop that capability. Be patient. The roles do work, but for some students, it takes time for them to sink in.	*Students are bored by being forced to play the role of listener*
#11. Students do not want to work in groups because they believe that they learn better on their own.	Learning is a complicated process. To learn something correctly, it is usually necessary for most people to "bounce" their ideas off someone else. For most students, learning is a combination of individual reflection and group interaction. After they get used to it, most students prefer to work in groups. Unfortunately, many students have not developed the simple skills necessary for really effective group work. Practice, especially with roles, will hone these skills. Empathize with those that are uncomfortable, but keep them working in groups. Teamwork is a powerful learning tool and a necessary component for succeeding in the modern world.	*Students do not want to go to a recitation section that rarely addresses their problem in understanding the concepts. Questions of other students are either so "advanced" that they can't follow or so "simple" that they are bored.*