STRUCTURE AND ORGANIZATION OF A NOVEL ORGANIC CHEMISTRY COURSE FOR PREPROFESSIONAL STUDENTS

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Three years ago I set out to transform the organic chemistry courses that I teach, Medicinal Chemistry 204–205 (MDCH 204, MDCH 205) by assessing the *needs of the students we teach* and by *assessing and modifying the perceived climate for student learning* as it currently exists in organic chemistry courses. In this effort I worked with Prof. George M. Bodner, a Professor of Chemistry in the Chemical Education Division of the Chemistry Department at Purdue, with two of his graduate students, Richard Bauer and Kirsten Lowrey, and later with my colleague Don Bergstrom, who teaches with me in the Department of Medicinal Chemistry and Molecular Pharmacology. We have attempted to *evaluate what we have done* both through student interviews and carefully constructed course evaluations.

Student Needs

Students need to experience the benefits of a successful study of organic chemistry. Perhaps the most obvious benefit is its content, which is the foundation on which courses in biochemistry, pharmacology, therapeutics, and, ultimately, pharmacy practice itself are ultimately built. But there are other advantages that are less obvious. It presents students with the opportunity to learn (or develop for themselves) new techniques for the mastery of a large body of material. It presents them with opportunities to learn strategies for problem-solving, not in the abstract, but "up-close-and-personal" as they deal with a specific body of material. The types of problems in organic chemistry run the gamut from quantitative problems with a mathematical component to problems with more qualitative answers.

Students need to learn the value of continued reinforcement of earlier material. My colleague Bodner has referred to the "immunization theory of learning." The student version of this theory says, "If I've seen it once, I should never have to see it again." The faculty version of this theory is, "If I've taught it once, I should never have to teach it again." This attitude by *both* faculty and students contravenes an important principle of learning, namely, that continued reinforcement is essential.

Students need to learn that the best problem-solving draws on collective resources as well as individual resources. Imagine if a company were to tell an employee, "Here is a problem. Go into a cubicle and solve it. You can't use any books, you can't use the library, and you can't talk to any of your other experienced colleagues." Such a company would have a bleak future. Yet that is precisely the way students are tested in the typical organic chemistry course and in many other courses as well. The reasons we operate this way are probably (1) we want student grades to be a true reflection of their individual efforts, and (2) we haven't paused to consider any alternative.

Finally, students need to be actively engaged with the material during the class period. The educational literature has suggested that students remember about 20% of what they are told, but 70% of what they discuss. Clearly, student learning can be enhanced by more active student participation.

Climate for Student Learning: Consider Amy

I believe that the climate of the typical course is not optimal for realizing the benefits of a good organic chemistry course. Consider Amy, a fictitious but typical prepharmacy student, who is attempting to negotiate her organic chemistry course. Amy works hard in the course and is the type of student who usually makes an A or a B. Amy has a hard time staying focused on her

professor, who is standing in the quiet, tense, semidarkened room next to the overhead projector from which he delivers carefully prepared, well-organized lectures that cover well the factual knowledge required to pass the next examination. It bothers Amy that her mind wanders, that she occasionally dozes off, and that she doesn't always understand everything the professor says, even after reading the assignment. Neither Amy nor her professor realize that research has shown that students retain only about 20% of what they are told in *any* setting. Amy might like to ask a question now and then, and her professor would probably be glad if a student attempted to broach the semipermeable membrane between him and the class, but for Amy to venture a question in such an atmosphere requires an uncommon degree of precociousness. Amy's professor has not actively encouraged questions perhaps because answering lots of questions takes valuable time and might compromise his covering the syllabus.

Consider also what happens in the examination room. Amy is seated in a quiet room separated from her nearest student colleague by at least one desk. She has studied hard and has prepared well, but is worried, perhaps obsessed, by the idea that she might not be able to get started on one or two questions. No consultation is allowed. Amy's examination consists of a series of multiple-choice questions, and perhaps a few short-answer questions. She perceives that a serious slip in this environment can cost her admission into a professional school.

Finally, consider the evaluation of Amy's performance. Because the course is graded on the curve, her grade depends in some inverse way on the relative success of her classmates.

The Group-Study Approach

We have endeavored to oversome some of the shortcomings of the typical course environment by implementing a group-study approach within our organic chemistry course in the School of Pharmacy. Obviously, we did not invent the concept of group study, but our implementation of group-study methods in organic chemistry, particularly our examination procedures, may be unique, particularly in the large research university.

Class Organization On the first day of class (Monday), students are told that they are to organize themselves into groups; ideally a group consists of 3–5 students. On the following Friday they turn in their group memberships, and on the following Monday a seating chart is posted. This chart prescribes that students are to seated in group clusters; that is, each group is seated together, with (if possible) some space between groups.

Conduct of Class First and foremost, the premise of this course is that students should learn in class major approaches to problem solving. Thus, the classroom is not used primarily for conveying facts; rather, it used for conveying *process.* The textbook (which I wrote) presents and organizes all necessary facts; spending class time regurgitating the text is viewed as a waste of effort. Although the text also deals with problem-solving tips, students tend to view these hints as "recipes." Further, no text can provide the "give-and-take" that is a common element in essential problem-solving. Students must view problem-solving as a dynamic process.

The second premise of the class is that each student must become *personally involved* with the material during the class period. This is accomplished primarily by in-class problem-solving within the study groups. The scholarly basis of this strategy is that students retain about 20% of what they are told, whereas they retain about 70% of what they discuss in a group. This conclusion is consistent with the ideas of constructivist theory, which has been strongly advocated by Prof. Bodner, namely, that students construct their own knowledge. Consequently, each class consists of dialogs with the instructor and group problem-solving exercises. Each problem is chosen with two goals in mind. First, it illustrates the day's reading. Second, the best problems require application of principles or facts from the previous semester's organic chemistry course, from General Chemistry, or from an earlier part of the present course.

A simple example of this approach is provided by a nomenclature problem. Students were introduced to the principles of construction of a name in the first semester. The only thing new in

the present class is application of these principles to the type of compound that constitutes the major subject of the present unit. The students are given a rather complicated molecule to name. The instructor and teaching assistant walk around the room to see how the groups are doing. If a substantial number are having trouble getting started, the instructor reminds the class of the first step. "What's the first step in constructing a name?" A student answers, "Find the principal group." Instructor: "What groups in this molecule are eligible for citation as principal group?" A student answers. Instructor: "Which group gets precedence?" A student answers. Instructor: "What's next?" Student: "Identify the principal chain." Instructor: "What's the principal chain?" A student identifies the principal chain. Instructor: "How do we number the principal chain?" A student answers. Instructor: "What are the substituents?" A student answers. Instructor: "What are their numbers?" At any point in this process the instructor can gauge whether he has gone far enough and say, "Finish the job." The instructor and TA move around the room to assess student progress. The students are actively involved in their groups. They are talking. The room is noisy. The class is relaxed. The instructor and TA offer individual hints where necessary. Finally, the instructor calls on a group that has the right answer to report, and the instructor probes the student's understanding with questions such as, "How did you know to number the substituents as you did?" Further questions are invited. The *entire* subject of organic nomenclature has been *reviewed* as the students have applied the principles of nomenclature to the present example. This example might take ten to fifteen minutes.

After several such examples, the instructor finishes the class by recapping the *most important points* to emerge from the class.

An interesting thing happens in this type of class. Students sometimes come up with unanticipated and truly sophisticated answers. I have personally experienced an on-the-spot invention of a reagent by a study group who applied the principles learned in class in a proper but unexpected manner. That very reagent was reported in the recent research literature. The instructor who tries this method needs to be ready for such eventualities and must think twice before writing off an unexpected student answer simply because it is not what is presented in the text—even if he wrote the text himself!

A major reservation about the use of this method is the amount of classroom time required for conducting each group activity. The question is, "How can I cover the syllabus?" The answer is that the instructor is under no obligation to cover everything in the day's reading. Ideally, the instructor picks out the kernels, the central points, and uses them where possible to reinforce material learned in earlier classes. The students learn quickly that they are obligated to use the principles and processes discussed in class to read the day's assignment, and they are held responsible for it on examinations. Students have *responsibility for their own learning*, and the goal is for the class exercises to provide them with the tools for outside-of-class learning. This is liberating for the instructor. Even though less material is covered in class, the instructor can feel comfortable exploring fewer subjects in greater depth. The instructor need not fear the effect of student questions on coverage of the syllabus, because there is no obligation to cover the syllabus in the first place.

Students are encouraged to maintain their groups by studying and solving problems in groups outside of class. Although there is no effort to enforce this behavior, an incentive is provided by the style of the examinations.

The Examination The most unusual aspect of this course, and probably the most controversial, is the way examinations are conducted. A two-hour evening examination period is required. Students arrange themselves into groups and a copy of the examination is given to each student. *Students openly discuss the examination at will for forty-five minutes.* They can write whatever they want on scratch paper. They are allowed a crib sheet consisting of one handwritten sheet (front and back), but they may make no new entries on the crib during the discussion. Shortly after the examination begins, the room is buzzing with student conversation. Anxiety is sublimated as students get busy tackling the problems together. Students groups are lying about on the floor,

sitting at instructor tables, or clustered in seats about the examination room. Students walk in from the hall thinking this is a good place to study and have to be informed that this is actually an examination. After forty-five minutes, all examinations and all scratch paper are collected and a fresh copy of the examination is given out. The students then write their own answers to the questions.

Weekly (fifteen-minute) quizzes are managed in a similar manner. The students are given the quiz to take home and discuss on a Wednesday. On the following Friday they are given a fresh copy of the quiz, which they work individually in class.

Obviously, the nature of the questions asked on this type of examination must be quite different from those on the short-answer examination. Students are asked to provide not only the answer to each question, but also a clear rationale for how they arrived at it. Little or no credit is given for a correct answer alone. Examinations of this type can be graded by TAs, but careful monitoring of graders by the faculty is required. The rationale for this type of examination is that students who are well-prepared can be "pushed down the correct road" to an answer by the group work, but will not be able to rationalize their answer clearly *unless* they are well prepared. Students may learn something about the subject from their study group *during* the examination. Students may also learn more about the subject matter by *teaching* their fellow group members. Another premise is that study groups that have worked together on problem assignments will work more effectively on the examinations. Individual accountability is retained by asking each student ultimately to complete their own examinations without assistance. We have not opted for a group-grading scheme, or by "triangulation" within groups to assess the relative contributions of group members, although such strategies are used in other courses within the School of Pharmacy. (However, see 1997 Update, below).

Assessment

We are committed to trying to assess whether this technique is effective in augmenting student learning. In the first attempt at using this method, a first-semester class (MDCH 204) was divided into two sections in such a way that the two sections were demographically matched by gender, performance in General Chemistry, and pharmacy status (prepharmacy or pharmacy). Thus, for example, the percentage of female prepharmacy students with "A" grades in general chemistry was the same in both sections. One section (40 students) was taught by the study-group method described here. The other (170 students) was team-taught by two other faculty using the conventional lecture method. Obviously, this was not a perfectly controlled experiment because of the difference in instructors and the difference in section sizes. Nevertheless, the outcome of the experiment was interesting.

Two students who had received "A" grades in General Chemistry opted out of the study-group section on the first day of class, claiming that they did not want their grade to be affected by performance of others. One other student opted into the class when she heard there was a vacancy.

The two sections were given a pre-test about attitudes toward the course. There were no significant differences between the two sections, except that the study-group section showed considerably stronger agreement with the statement, "I expect to read textbook assignments before coming to class." Two graduate students working with Prof. Bodner, Rich Bauer and Kirsten Lowrey, attended every class and conducted extensive ongoing interviews with students during the course of the semester. Every class was videotaped. The results of their research will be presented in their graduate theses and subsequently published.

The first and most gratifying outcome of the class was that for the first time in my career, no students received a "D" or "F" grade. Skeptics will argue that this is to be expected when students can consult with each other during examinations. One of the major criticisms of our approach, and certainly one of major concern, is that the group-study aspect of examinations "spoon-feeds" students and allows lazy students to use others as a crutch. If this were so, we should expect students

who have been through this process to suffer in later courses in which the study-group technique is not used. Accordingly, the small study-group section was integrated into the large section for the second-semester course (MDCH 205), which was taught by the standard lecture and examination technique. Of the students who had been through the study-group course, 34% received "A" grades in MDCH 205; 16% of the other students received "A" grades. There was a higher percentage of "B" grades among the students who were not part of the study-group section. There was one "D" and no "F" grades among the students who had received study-group instruction; there were several "D" and "F" grades among the other students. The students who received study-group instruction scored 27 points higher (out of a total point spread of 220 points, with 400 points possible). The latter result may not be particularly significant, but what can be said with confidence is that we did not harm these students by subjecting them to study-group instruction. (Ms. Lowrey, one of the graduate students on the project, says that the first rule of teaching, as in medicine, should be, "Do no harm.")

The study-group technique was subsequently used in a large section (142 students) of MDCH 205 in the following year. This course was team-taught by both me and Prof. Don Bergstrom, who agreed to try the study-group approach with me. The results were assessed in part by a student evaluation (attached).The students were asked to calculate their expected grade. They were also asked whether they used the study-group method on a regular basis *outside* of class (Question 4). Only 35 students said yes, but among those students the average expected grade was 2.7/4.0; among the remaining students the average expected grade was 2.4/4.0. Asked whether they preferred the study-group method or the traditional method—both of which they had experienced in their organic chemistry instruction—73% of the students who answered "Yes" to Question 4 answered "Agree" or "Strongly Agree"; 60% of the remaining students answered "Agree or "Strongly agree."

What's Next?

Efforts are continuing to improve and refine this approach. We hope to publish a description of our method in the educational literature as soon as the relevant graduate-student theses are completed. The results, where possible, must be tested for statistical significance. A number of questions have arisen that can be potentially answered from existing data, for example, is there a correlation of performance with identity of the study group?

This approach was used in MDCH 205 in Spring 1996 and Spring 1997, in which the enrollment is 175 students in a single section. Assessments will continue. On the basis of our results to date, it appears that this method is well-accepted among students, although it should be mentioned that in each class a few students do *not* like it. Student performance does not appear to suffer, and may improve, when this method is used. Prof. Bodner predicted that the major effect of this type of instruction will be one of "affect;" that is, student attitude will be perceptibly improved. There is no question that this is the case. A much more informal, less tense, more participatory class atmosphere has certainly renewed *my* enthusiasm for teaching this subject.

1997 Update

In 1997, we introduced this method to *first semester* organic chemistry with a few changes. First of all, the instructor formed the study groups with attention to diversity of student abilites (as measured by overall GPA), gender, and race. In general this worked well, although, as might be expected in any system, some groups turned out to be more effective than others.

Second, we opted to give ten in-class, ten-minute quizzes during the course of the semester. These were *not* study-group exercises. This was done in an effort to encourage students to keep up with the material. Interestingly, a number of students in previous classes had suggested this change.

We gave four take-home Study-Group Exercises. Each of these consisted of 4–8 fairly sophisticated problems to be worked out as group exercises. Each group turned in a single paper for each exercise. These accounted for a maximum of 32 points, which could be used for extra credit. However, scores on these exercises were multiplied by a fraction ≤ 1.00 which was derived from *students' assessments of each other's participation in study groups outside of class.* Students could further augment their extra credit by in-class participation, which I monitored on my seating charts. A *maximum* of 40 points extra credit was allowed. This is equal to about one-third of a letter grade. The extra credit actually awarded ranged from 0 to 40 points.

The final examination was *not* a study-group examination. However, students could use the results of this examination to replace *any* or *all* of their individual exam or quiz grades. (This is termed the "Modified Resurrection Grading System." Despite the name, it has no religious implications, although it does offer eternal hope.)

Participation in team-oriented problem solving was a *stated objective* for the course. As noted, students assessed each other's participation on two assessment forms, which are attached. A number of students were remarkably frank in downgrading their fellow group members for lack of participation. The overall assessment results were converted into a fraction that was multiplied by the points obtained in the Study-Group Exercises for each student.

In general, student attitudes in this class were excellent. We are in the process of conducting detailed assessments of the results. Much of these assessments will be based on a student evaluation, which is also enclosed.