Organic Chemistry Online: Building Collaborative Learning Communities through Electronic Communication Tools†

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One of the largest problems in teaching chemistry is learning how to teach large lecture classes for undergraduates, where the teacher/student ratio may range from 1:100 to 1:1000. How do we make the large class seem small?

Recent innovations in computer technologies, particularly in computer-mediated communication via the Internet, are being increasingly used as resources to enhance teaching and learning in the college classroom. The number of articles about chemical education resources online published in the *Journal of Chemical Education* in the last few years (*1–8*) alone gives testimony to the increasing interest in these resources. What follows is an account of how one faculty member at the University of Missouri-Columbia has been making innovative use of the resources of the Internet to support the development of small learning communities within a large undergraduate course in organic chemistry.

The Problem

Dramatic increases in student enrollment in higher education in the past 50 years (*9*) have forced many of us to grapple with the problems of how to effectively teach a vast number of students with a wide range of abilities, backgrounds, and academic interests, often in a large, auditorium-style classroom. Confronting such a challenge, the overwhelming number of teachers fall back upon the method they are most familiar with, the lecture (*10*).

The lecture mode of teaching was borrowed from the 19th century model of the German university, a model in which a "scholar" delivered lectures to his students on his research (*10*). Well suited to students who are intrinsically motivated to learn (*11*), this approach suffers greatly in the undergraduate curriculum, particularly in the lower-division courses, where student choices are limited, enrollment is "required for the major", and intrinsic motivation for learning is low. Although the limitations of the large lecture are widely recognized—its lack of emphasis on higher-level thinking, problem solving, and active engagement in learning, and the limited opportunities it provides for student–teacher and student–student interactions—the lecture remains the most frequently used mode of teaching in higher education (*12, 13*).

How do we make these large classes seem small? How do we overcome the impersonal nature of such classes? How do we increase communication both between teacher and student and among students? How do we get students actively involved in learning? How do we make it meaningful, relevant, and engaging for students with a wide range of abilities and a wide range of academic majors and interests? How do we foster the creation of collaborative learning communities within a large undergraduate class? These are the questions that guided the planning and implementation of this teaching innovation.

The Setting

Undergraduate organic chemistry courses at the University of Missouri-Columbia usually enroll some 200 students each semester, typically sophomores with a variety of academic majors, mostly in the natural sciences and engineering. Many are preparing for careers in medicine. Most of the students are there because the courses are required for their majors. Tobias (*14*) tells us that as many as 80 (40%) of them will change majors before graduation, never completing that degree in science or engineering. Few will go on to graduate school, fewer yet to study chemistry. Although teaching assignments for these courses typically rotate among the faculty in the department, it is safe to say that these courses have been taught according to the traditional "chalk and talk" large lecture model by most of the faculty for years.

Yet these courses are taught on a technology-rich campus, dedicated to providing a high level of access to technology to all students and teachers. Every student, upon enrollment, is given a computer account by which he or she can gain access to the Internet. In addition to the personal computers many bring to campus, students have access to some 1000 workstations across campus at 15 public labs, many open 24 hours a day, 7 days a week. Dial-up access to the Internet is available to all faculty, staff, and students. Additional support for faculty wishing to develop and integrate advanced technologies into their teaching is also available on campus.

Computer-Mediated Communication Technologies

A Web site for the course (*15*) was developed as a first step in enhancing students' ability to visualize complex chemical structures and reactions as well as to provide increased opportunities for communication between the teacher and the students (Fig. 1). The site included course essentials such as the syllabus and schedule of class meetings, topics, review sessions, and exams as well as a series of interactive exercises that contained links to a variety of online resources, including animations of reactions. The site also included links to the instructor's Web site (*16*), where students could learn more about him and his research. It contained a list of all students enrolled in the course, with links to their email addresses,

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to provide an avenue for students to contact one another. A class electronic discussion list was also implemented for the instructor to send out class announcements and for students to communicate with one another about problems encountered in their studies. The “portrait in progress” personalized the course site by posting informal photos of the class in action taken by the instructor with a digital camera.

Collaborative Group Projects

Educational theory and research have established the benefits of collaborative learning activities for students, as well as the benefits of involving them in authentic learning experiences (*17–20*). A number of articles in recent issues of the *Journal* (*21–27*) attest to the interest in incorporating collaborative learning strategies into the teaching of chemistry. The goal of this project was to build on that knowledge by using new instructional technologies to support and enhance collaborative student group work.

During the course of the semester, students were required to form groups of 5 or 6 and work together in these groups to select topics of research, research the topics online using Internet resources, and write reports of their findings to share with the rest of the class via the course Web site. At each stage along the way, groups were required to report in to the instructor via email, with staged deadlines for group member identification, topic selection, and final reports, so that students could not procrastinate and put off all the work to the end.

Students were not expected to develop their own Web sites, but simply to collaborate in doing the research and write reports following a designated format, so that they could be easily formatted for publication on the course Web site. Each report was to include not only the project title and report of the findings on the topic, with relevant URLs, but also a group name, a listing of group members and email addresses, a description of how the group was formed, how often the group met, and a discussion of group dynamics. The rationale for the collaborative group projects, suggestions for how to organize a group and select a topic, and guidelines for write-up and submission of reports were posted in the course Web site (*28*).

Peer Assessment

To make the group project assignment a more authentic learning experience for the students, peer assessment of the projects was used. Peer assessment has long been used in writing courses and now is emerging as a means of assessing student work in a variety of other fields (*10*, *29*). Research has shown that peer evaluation supports collaborative group work in general and, in writing assignments in particular, it supports a shift in students’ perspective from writing for the teacher to writing for their peers and ultimately for a larger audience. Since these project reports were to be published online for all the world to read, it was appropriate that they be reviewed by their peers.

The instructor performed an initial evaluation of the electronic submissions for completeness. Once projects were completed, he added the coding for publication online. Group members then collaborated in reviewing 5 other group projects and posted a score for each project, based on rubrics outlined in the course Web site. Criteria included visual appeal (of the linked sites), content, suitability for Web publication, relevance to organic chemistry, and the ability of the report to contribute to the reader’s learning (*28*). Each group’s peer review scores and evaluative comments were posted via electronic mail to the instructor, who then coded them for publication on the course Web site (Fig. 2). Final points for the project were an average of the peer review scores of the 5 teams assessing the project report and points assigned by the instructor for scope, completeness, and technical merit.

The Group Projects

The resulting collaborative group projects were, in many ways, astounding (*30*). Thirty-four groups emerged and researched a broad range of topics (Table 1). Initial write-ups were to be submitted by the Friday before spring break and final revisions were to be completed the week after break. However, 14 of the 34 groups elected to submit their reports a week early and were awarded extra credit points. These “early bird award winner” projects were then highlighted at a presentation made in March at the annual Teaching Renewal Conference on campus.

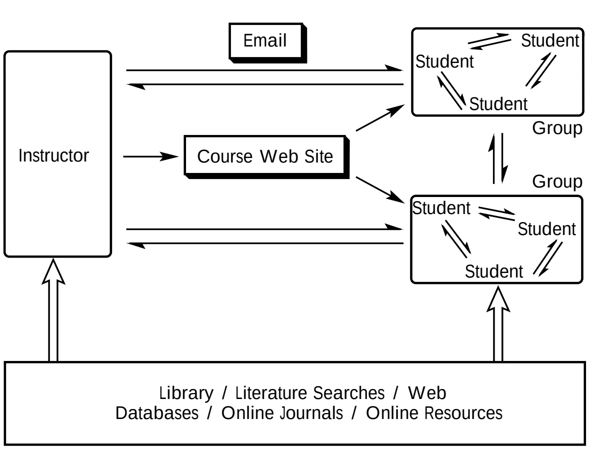

Figure 1. Communication pathways.

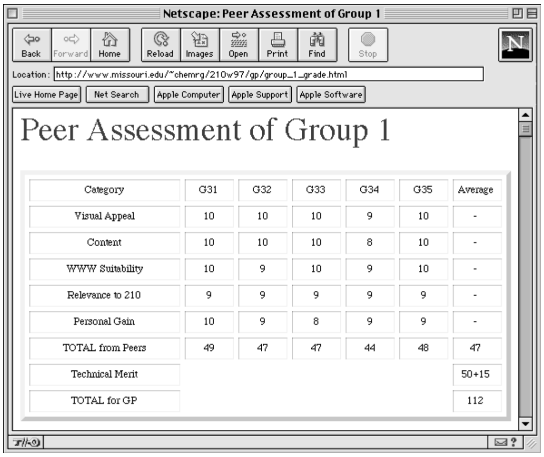

Figure 2. Posted results of peer evaluation of the group project of one of the groups.

Although students were not required to build their own Web sites, more than half of the class (18 of 34 groups) elected to do so, using such advanced authoring features as animated graphics, sound clips, movies, frames, and Java applets. Even more amazing was the project that came to be called the "WebNotes Project" (*31*). Several students had commented on the limitations of obtaining class notes on reserve at the library and on the need for multimedia-enriched class notes on the Web site. Members of three groups initiated the idea of filling that need by building hypermedia class notes, working together in a student multimedia lab on campus.

Evaluation

A need for evaluation of this innovation in the teaching of undergraduate organic chemistry was recognized from the beginning. Poole joined the team during the planning phase for this course as a consultant and evaluator, to provide formative and summative assessment of the course, using both qualitative and quantitative methods. In addition to making suggestions for course design and developing assessment tools, she attended class and took field notes throughout the semester and monitored electronic communications of students on the class list.

Formal student feedback came in two forms: from the groups in the discussion of group process in the project reports, and from individual students, through responses on an end-of-the-semester questionnaire.

Table 1. Group Project Topics

Category [a]	Topic	Frequency
Drugs (6)	LSD	2
	Prozac	1
	Marijuana	1
	Ecstasy (MDMA)	1
	Smart Drugs	1
Food (5)	Olestra	3
	Vitamin C	1
	Simplesse	1
Health (5)	Cystic Fibrosis	1
	Cholesterol	1
	Breast Cancer	1
	AZT and AIDS	2
Hormones (6)	Pheromones	1
	Adrenaline	1
	Atropine	1
	Anabolic Steroids	3
Science (4)	Genetics	1
	DNA	2
	Buckminsterfullerene	1
Society (6)	The Internet: A Tool for Learning Chemistry	1
	Ozone Depletion	2
	Beer	1
	Nuclear Disasters	1
	The Hazards of Hair Dye	1

[a]Number in parentheses is the total number of projects in the category.

Students' group reports on the process of forming their groups and learning how to work together were overwhelmingly positive. Students consistently reported that they would like to do group projects in the future. Benefits they most frequently noted were learning from each other, having a study group to work with on problems and to study with for exams, learning about people from diverse backgrounds, and learning how to work together in teams. The obstacle to group work most frequently noted was finding the time to work together in the same place and at the same time on the projects.

The questionnaire collected demographic information as well as baseline information about computer access and Internet use, information about group formation and process, and ratings of satisfaction with the group projects, peer assessment, and the course in general. Three open-ended questions at the end provided students the opportunity to comment on what they liked best about the course, what they liked least, and what might improve the course in the future.

The typical student in the class was a sophomore (52%) majoring in biology (57.6%). Other majors included biochemistry, engineering, geology, chemistry, nursing, premed, and pre-vet studies. When asked why they enrolled in the course, the consistent response was "it is required for my major". Thus, intrinsic interest in the course was assumed to be low.

At the beginning of the course, 68.8% reported themselves to be regular users of email (daily, weekly, or hourly); only 52% reported themselves to be regular users of the Web. Less than a third (32%) reported that they had access to a computer at home or in their dorm room. The remainder were limited to access in public labs on campus (66%) or elsewhere (2%). Self-reported use of the Internet increased during the course of the semester, and 73% of the class reported regular Web usage at the end of the course.

However, only a few reported that they had learned to use the Internet to find group members or to overcome the problem of finding time to work together. The majority reported that they found their group members face-to-face (83%) rather than online (17%). Predominantly sophomores (52%) in similar degree programs, most (69%) reported that they already knew each other from previous classes. Once the group was formed, the majority continued to meet face-to-face rather than to use email to communicate about their group work. Only 39% reported "occasionally" using email to communicate about their projects.

Groups reported working an average of 12 hours together on the project over the course of 4 weeks. Some reported spending as few as 2–4 hours on the project; others reported more than 50 hours of work. They met in a variety of settings—in dorm rooms, computer labs, and group members' homes, as well as in local restaurants and coffee houses. Quite a few of the reports on group dynamics included comments on the benefits of group work beyond the work on the project, for learning from each other and studying for exams. Ratings on the end-of-semester questionnaire demonstrated that students felt that members of their group, for the most part, regularly attended group meetings, were equally committed to the project, and shared equally in the work of the project (see Table 2). Students were enthusiastic about using peer assessment for their projects and agreed that they would like to do group projects and use peer assessment in other classes. However, despite enthusiastic anticipation of continuing to work together reported in project write-ups at midsemester, by the end of term, students reported their groups were less likely to continue to study together and socialize together.

An overwhelming majority (91%) of students reported the use of the Internet resources for the class beneficial for their learning. Those few who reported it was not beneficial acknowledged that the greatest barrier for them was finding access to the online resources because they did not have a computer at home. In response to an open-ended question on what they liked best about the class, comments about the use of the Internet, the enthusiasm of the instructor, and the benefits of the group projects were the three most frequently cited themes. Listed below are some sample comments on the end-of-semester questionnaire in response to the question "What did you like best about this class?"

> The teacher's enthusiasm and attempt to use the latest innovations for learning.
>
> I liked the project because it allowed students to work together and to get to know each other as well as requiring strong participation in the class.
>
> Group projects were fun and a fair opportunity for improving your grade, while sticking with the course.
>
> The teacher and working in groups, especially. It gave me a group of people to turn to when I needed help.

Students reported that use of the Internet and the engagement in group projects improved the course. Examination of enrollment figures from the last four semesters that this instructor taught the course showed that student attrition rates dropped from 9% in FS91 to 3% in WS97 (Table 3). Only one of the five students who withdrew from the course did so before the group projects were completed, so student attrition had no significant impact on the group work. While the overall course grades indicate an improvement from 58.4% in FS91 to 63.6% in WS97 (Table 3), much of the increase in WS97 is due to the high group project averages. The most positive indication of increased student learning in these numbers is the positive trend in exam scores during WS97.

Table 2. Evaluation of Collaborative Group Work

Variable	Mean Score[a]
All the members of our group attended all group meetings	2.27
All the members of our group shared equally in the work of the project	2.27
All the members of our group were equally committed to the project	2.14
Members of out group shared a common set of beliefs and interests	2.09
Our group developed certain rituals at our meetings	2.54
Our group continues to meet to study together	2.81
Our group continues to meet to socialize together	2.80
I believe the peer assessment of the group projects was fair	2.03
I would like to do group projects in my other classes	2.28
I would like to have peer assessment in my other classes	2.42
I would like to take a class like this again	2.65

[a]Statements are rated on a 4-point Likert-type scale: 1 = strongly agree to 4 = strongly disagree.

Table 3. Attrition Rates and Test Grades

	Semester			
	FS91	WS92	FS92	WS97
Attrition	9	6	8	3
Grade				
Exam #1	73.7	65.7	63.9	52.5
Exam #2	74.6	49.4	48.2	68.1
Exam #3	49.1	62.5	49.6	69.6
Exam #4	50.3	51.2	–	–
Group Project	–	–	–	101.3
Final Exam	46.4	58.7	39.4	44.5
Total Course	59.9	58.4	52.2	63.6

NOTE: All numbers are percentages.

Discussion

One of the surprises using online resources to support collaborative group work in this class was the high level of motivation and initiative demonstrated by the groups who developed their own Web sites, particularly those who initiated the WebNotes project, going above and beyond what was required for the course. The vast difference in project reports set up some tension and confusion in the peer assessment process. Although the criterion of "visual appeal" was intended to be an assessment of the sites selected as links in the report, it became interpreted by many as an evaluation of the Web site the students developed and therefore seemed to give undue advantage to those who could develop their own sites. Indeed, peer review scores for those groups who had developed their own Web sites were significantly higher ($p < .01$) than for groups who submitted the standard text-based report. In the future, as students' knowledge of Web authoring and resources supporting this kind of work on campus increase, all reports will be required to be submitted in the form of Web sites.

Those who devoted more hours on the project may have devoted more of their time to developing the technology for their report than to researching their topic. While it is desirable that all the students devote more time to the project in the future, it would be better if they would devote that time to learning how to work and study together and to doing additional research and critical review of the information they gather. In future classes, students will be encouraged to devote more time to the project not only by increasing the portion of the course grade based on the project, but also by requiring group formation earlier in the semester and completion of projects later in the semester, lengthening the time groups will work together. Students may also be required to submit a text report of their research before they begin the Web site.

In addition, the project goal will be redefined to one in which students will be required to formulate a researchable question and seek an answer for it, rather than simply research a topic. They also will be required to use traditional print media and other electronic resources, such as CAS (Chemical Abstracts Service) online, electronic databases (e.g., protein database) as resources for their research.

Despite the higher grades this semester, students remained concerned about grades. At midterm, when they submitted their project reports, students frequently commented on the benefits of collaborative group work with the emphasis on learning from each other. Comments on the difficulty of the exams on the end-of-semester questionnaire showed that, by the end of the term, they had once again succumbed to concerns about points and grades. Part of this tension may arise from course grades that were based both on collaborative and competitive work. The collaborative group projects were evaluated according to an absolute grading scale and pre-established criteria and counted for 1/6 of the overall course.

The remainder of points assessed for the semester were based on a series of written exams that were graded according to norm-referenced standards. Grading on a curve is known to encourage competition and discourage cooperation (*27*). The competitive environment may have undermined the validity and reliability of the peer review process. This competitive environment may even diminish the benefits of the collaborative work on the group projects.

Changing the grading for the entire course to criterion-referenced grades on an absolute scale, of course, will go only part way in changing the expectations of students raised in a competitive culture who are more accustomed to competing for points, for grades, for honors, for jobs, and for seats in a competitive graduate program than to collaborating to help each other learn. We can take small steps, though, in changing their expectations through increasingly involving them in collaborative group work that is evaluated through criterion-referenced assessments.

Students made less use of Internet resources for their collaborative work than anticipated. Despite the unexpectedly high skill level of Web authoring demonstrated in class and the availability of a class electronic discussion list and a list of all student email addresses on the course Web site, students made little use of the Internet for communication with their peers. The list was predominantly used by the instructor for broadcast messages to the students. Students reported that they accomplished most of their group work through face-to-face communication rather than via email. These changes, too, will take time, as students become more familiar with the resources of the Internet and begin to appropriate these tools to support collaborative work, both in school and beyond.

Development of the course Web site, posting student group project reports, and calculating and posting peer review scores on the Web were time-consuming tasks. Shifting the responsibility of project report write-ups for the Web to the students in future semesters will not only ease tensions for the students that arose over the vast differences in student reports, but it will make continuation of collaborative group work in large undergraduate courses more feasible. Continuation of the use of peer review of group projects and the development of an automated Web tool for calculating and posting scores will also make it possible to continue teaching in this way. Continued refinement of evaluation tools will help us better understand how the use of collaborative work and Internet resources affect student learning. The use of such collaborative group work finally proves to be not only pedagogically sound, but also economical on campuses where large undergraduate courses and high student/teacher ratios continue.

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