Enhanced Student Learning of Chemistry in a Computer Assisted Environment

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Abstract

This study focuses on the implementation of instructional tools (computer assisted instruction, peer tutoring, and instructor-led help sessions) in general and organic chemistry courses, and the evaluation of student outcomes over the past four years and using 1998 as the baseline year when these instructional aids were not utilized. The data show progressive and significant improvement in student performance over the course of the study. The percentage of students receiving a grade of C or better increased from 27% in 1998 to 67 % in 2002 in general chemistry. In organic chemistry the percentage of students receiving C or better increased from 31% in 1998 to 61 % in 2002. Of the students responding to a course survey, most perceive the additional course tools to be beneficial in understanding the subject matter for the course.

Introduction

Over the past decade, reform documents such as the National Science Education Standards have promoted systemic changes to the way science courses are taught in order to provide students with a high quality science education and to enhance student learning. This has been fueled by studies that suggest that the traditional modes of delivery or instruction in science courses are not very effective. While these methods may be effective in covering large amounts of material, they do not ensure that students learn or understand the material. Among the strategies that have been proposed and are being assessed by the scientific community are inquiry based learning (1, 2, 3), cooperative learning (4, 5), active learning (6), critical thinking (7) and classroom assessment (8).

The hierarchal nature of chemistry and the requirement of basic math skills in order to do well have led to the general and organic chemistry courses being viewed as difficult and demanding. As a result, many strategies have been described for increasing retention rate in these courses. Use of peer tutors, active learning, team learning, and grade/performance contracts are some examples. The American Chemical Society and the National Science Foundation proposed a series of guidelines and recommendations aimed at revitalizing the chemistry curriculum in undergraduate institutions (9). Many chemistry educators are utilizing computer-assisted instruction, including the use of Web resources to supplement traditional course instruction (lecture, text, audio-visuals) (10-14). The advantages of the Web format are that it provides a different venue for providing and presenting information, and increases the instructor's ability to present and the students' ability to grasp abstract and difficult concepts. This is achieved primarily through animations, user manipulated representations of chemistry phenomena, and drill and practice tutorials, which provide instant feedback.

Purpose

The purpose of this study was to increase the number of students successfully completing the general and organic chemistry courses without decreasing the course content, by implementing computer-assisted instruction (CAI), peer tutors, and instructor-led help sessions as instructional tools that could be utilized by students to enhance learning. Prior to 1999, these courses were delivered in the traditional lecture format. During 1999-2002, the courses were revised to include computer-

assisted instruction, peer tutors and a weekly instructor led help session. To measure the effectiveness of the added components, the passing rates and students' use of the resources were monitored. For comparison purposes, 1998 was used as a baseline year.

Method

Class Description and Demographics

General Chemistry. The general chemistry course, CHEM 1211, is a study in basic chemistry concepts that include matter, stoichiometry, atomic and molecular structure, solution chemistry and chemical equilibrium. This general chemistry course is the first required for students interested in pursuing degrees in math, biology, chemistry, pre-engineering and technology. The majority of students take this course in their freshman or sophomore year. While students are encouraged to take college algebra prior to taking the general chemistry course, it is not a requirement. The majority of the students (>95%) indicated taking chemistry in high school. Less than 2% had taken Advanced Placement Chemistry. During the period of this study students could take the chemistry course once admitted to the university if no remediation course in mathematics was required. The number of students enrolled in the general chemistry course during the study period ranged from 45 to 59 students with an average class size of 52 ± 7 students.

Organic Chemistry. The organic chemistry course, CHEM 2301, is an introduction to the chemistry of carbon compounds and covers topics such as nucleophilic substitution, electrophilic aromatic substitution, aromaticity, stereochemistry, and spectroscopy. The students enrolled in this course are either Biology or Chemistry majors. Students taking the organic chemistry course must have completed the general chemistry course with a grade of 'C' or better. These students included students who took the general chemistry course in the computer assisted environment as well as students who did not, and to which the computer environment used in this study was unfamiliar. The number of students enrolled in the organic chemistry course during the study period ranged from 29 to 42 students with an average class size of 35 ± 5 students.

Period of Study, Instrumentation and Procedures

The first semester general and organic chemistry classes from Fall Semester 1998 to the Fall Semester 2002 were utilized in this study. The baseline year of the study was 1998. In 1998, the class content was delivered in a strictly lecture format. Development of computer assisted environments in the general and organic chemistry classes began in 1999, with the use of computerized tutorials, drill and practice exercises, a class Web site via WebCT with online class notes, email, bulletin boards, online grade access, animation links, and online quizzes. The same instructor throughout the course of the study taught each course. The textbook and course content covered also remained the same.

To determine the readiness of students for the general chemistry course, the American Chemical Society (ACS) Toledo examination was administered at the beginning of each semester. The ACS Toledo Examination tests basic math and chemistry background of students prior to taking a college level chemistry course. The examination comprises of a total of 60 questions in basic math and chemistry. A score of 51% (31 correct responses) is generally used as a cut-off score.

Students were evaluated using objective tests of student knowledge and content (in class exams 40% and final exam 15%), quizzes (15%), assignments (10%), and laboratory exercises (20%). For each year of the study the exams were not identical,

however, the exams covered the same content and had the same format. Questions were generated from the American Chemical Society Test Bank and the test bank for the course text. Students grades were assigned A = 90-100; B = 80-89; C = 70-79, D = 60-69, F = below 60. Pass percentages for the courses were determined from the percentage of student in each course receiving a grade of 'C' or higher.

The number of students who used CAI materials was determined from the WebCT log of student access to the course Web site. Using this log, student use of the course content and the online bulletin board were determined. All students who accessed the home page only were not counted as accessing the course materials, which were on secondary pages.

In addition to objective assessments, a subjective student survey was given to evaluate the course during the 13th week of class. Survey questions are shown in Table 1. The evaluation asked students to rate the class on a variety of items, including the usefulness and ease of use of various components of the course. Most students answer choices involved 'yes' or 'no' response on a 5-point rating scale with 1 indicating *strong agreement*, 3 indicating *neutral* and 5 indicating *strong disagreement*.

Instructor-Led Help Sessions

Each week an instructor-led help session was conducted. This was mandatory for students. These sessions were held during the first hour of each lab section for the general chemistry and organic chemistry classes. Because lab sessions were limited to 24-28 students, this provided a smaller group interaction in each session. The activities consisted of problem solving sessions and computer assisted software. Students were required to work through a series of problems utilizing chemistry software from Falcon. There was immediate feedback and the instructor was available to give additional help if needed. The instructor was present at all times and was able to lend individual assistance to students. After an hour, the students proceeded to the laboratory where they conducted the experiment/lab exercise for that class period.

Table 1.
Student Survey Items

Have you had previous experience with a course that had a Web site?
Have you had previous experience with a course that used WebCT?
How would you rate your expertise with computer technology?
How often did you use the course Web site?
From what location did you most often access the course Web site?
I have found the Web format used in this course preferable to other Web-based courses.
The computer-assisted instructional tools available for the class were valuable and improved my learning.
It is important to have experience using the latest technology applied to my field of study.
Access to my grade information and performance measures such as quizzes, prompted me to take action (such as visiting my instructor or tutor).
Which component of the course was least useful to you?
Which component of the course did you find most beneficial?
I spent too much time learning technology.
In general, I am very satisfied with my overall experience with the course.
If a choice exists, I'd prefer a course with a Web component to one without.
Instructor-led help sessions were helpful in understanding the subject matter.
Peer tutors were helpful in understanding the subject matter.

Peer Tutors

Peer tutors were made available for both courses. The tutors were selected from outstanding students who had recently completed the course and had obtained a B (80-89) or A (90-100) in the general chemistry sequence courses, CHEM 1211 and CHEM 1212. The tutors were available at various hours during the week. Tutors schedules and location were posted and given to students during the 2nd week of class. Students who did poorly on the first exams were encouraged by the instructor to work with a tutor. The use of peer tutors was monitored.

Technology Integration

Technology integration began with the introduction of chemistry software that provided drill and practice exercises in general chemistry and organic chemistry concepts. With the adoption of WebCT by the University System of Georgia, the capabilities of WebCT were utilized to provide a computer-assisted environment in chemistry. The tools used included the following:

Online Course Notes. Notes for each topic covered in the course, were placed on WebCT. Students could access the course Web site at any time to review or print copies of the notes.

Bulletin board/email. Bulletin board and e-mail were used in several ways:

a) to stimulate student to student communication
b) to stimulate student to instructor communication
c) to facilitate integration of writing across the curriculum in general chemistry. Small writing assignments were given throughout the course. The assignments were based on topics that required students to understand some content as well as for students to gain insight into the applications of chemistry in the real world. Typical topics included applications of chemistry and chemical reactions in the students' life, and exploration of the chemical processes involved in acid rain formation, the green house effect, global warming, and ozone depletion. Students' grades for these assignments were based on content and understanding as well as proper use of English, grammar, and paragraph development.
d) to enhance oral communication skills in organic chemistry. To help students to research and formulate an effective presentation the online bulletin board was used. Each student in the organic chemistry class was required to give an oral presentation at the end of the semester on a particular topic. Students were required to describe, analyze, interpret, and explore the topic as it related to chemistry. During the first 2 weeks of the semester, students were randomly assigned to groups and topics. To prepare for the oral presentation, students were required to post relevant information to the bulletin board on a weekly basis for a period of 8 weeks. Topics included, but were not limited to, chemical warfare agents, artificial sweeteners, digitalis, tamoxifen, okadaic acid, red tides, licopene, Phen-Fen, Chitosan, Viagra, Prozac and DEET.

Quizzes. The quizzes were used as a tool to focus students on the important concepts, and the subject matter that had to be mastered in the course. Students were given a quiz at the end of each topic. The students were given the option of taking the quiz twice, and the average score of the two trials taken. The use of WebCT calculated

questions allowed a variety of questions to be prepared, so that each student attempted a different quiz each time.

Grades online. Grades were posted online and updated immediately after a quiz or exam had been graded. Students were therefore able to obtain grades for all assignments, as well as their average grade in the class at all times during the course by accessing the course Web site.

Animations. Computer projection and animation were utilized in the classroom to enhance lectures that involved concepts that tend to be difficult for students to understand.

Results and Discussion

The mean scores and standard deviations for the ACS Toledo examination for General Chemistry I from 1998 to 2002 are shown in Table 2. The results are slightly below the scores compiled by the ACS Division of Chemical Education (DivChemED) Examination Institute (31 ± 7.12). The mean Toledo score in the base-line year (1998) was 28.6 with a standard deviation of 7.2. When scores are compared for each class during the study period (1999-2002), the results show that the average performance of entering students during the study period was fairly consistent.

Table 2.
Mean ACS Toledo Exam Scores, General Chemistry

	1998	1999	2001	2002
Mean Score	28.6	30.2	25.4	27.7
Standard Deviation	7.17	7.13	7.12	7.09
American Chemical Society Data[1]	31.5 ± 7.12			

[1]Data obtained from the ACS DivCHED Examination Institute Web site, collected in 1998-1999. 2000 data not available

Pass Percentages and Correlations

Students passing the course received grades of 'C' or higher. The results show higher algebraic means for student performance in both general and organic chemistry courses following implementation of course instructional aides in each year of the study (Figures 1 and 2). For general chemistry, a 14 percent increase or greater pass percentage above base year was observed. Except for 2000, the pass percentage increased steadily from 46% in 1999 to 67.8% in 2002. In 2000 the pass percentage of 41 is above the baseline year pass percentage or 27, however, the 2000 pass percentage is five points below the pass percentage in 1999 (46%). The larger number of students involved in the study, $N = 117$ in 2000 compared to $N = 54$ in 1999, may have provided a more statistically significant pass percentage. Pass percentage in organic chemistry increased in each year of the study, from 31% in the baseline year to 61% in 2002.

Figure 1.
General Chemistry Pass Frequency

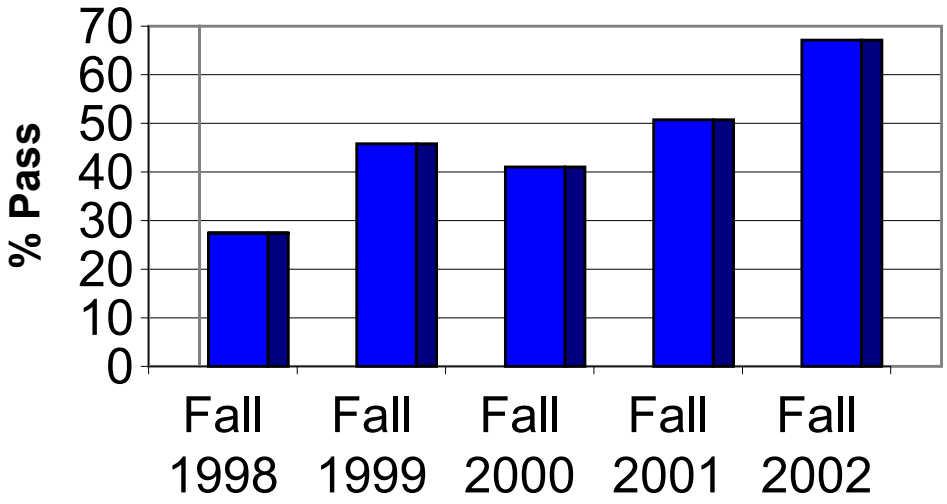
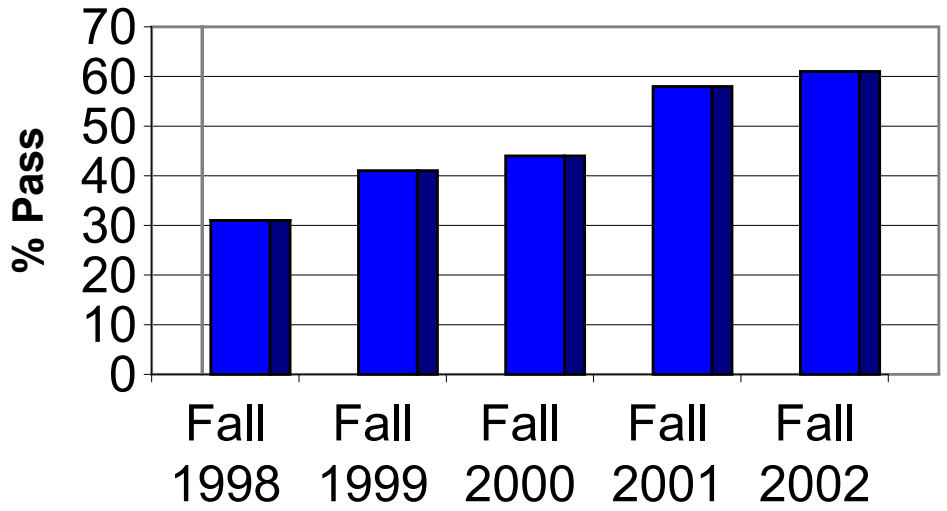


Figure 2.
Organic Chemistry Pass Frequency



In the general and organic chemistry courses the frequency of usage of the course Web site was determined. When this was compared to students grades, in both general and organic chemistry courses, the pass percentage was higher for students that utilized the Web site compared to those students who did not use the Web site

regularly, that is, less than three times a week, (Tables 3 and 4). In 2001 and 2002, the correlation of Web site usage to course grade is significant for general chemistry at the 95% confidence level, (p = 0.019 in 2001 and p = 0.002 in 2002). For organic chemistry, p = 0.109 in 2001 and p = 0.263 in 2002, at the 95% confidence interval, indicating that the correlation was not significant for this course (Table 5).

Table 3.
Utilization of CAI in General Chemistry I[1]

	1998	1999	2000	2001	2002
	$N^1 = 90$	$N = 54$	$N = 117$	$N = 43$	$N = 55$
Number of students utilizing CAI[2]	0	5	64	27	50
Pass rate for students utilizing CAI	-	ND	61	67	72
Pass rate for students not utilizing CAI	-	ND	7.5	31	20
Class Pass %	27	46	41	51	67

[1]The large variation in N values (N = 43 to N = 117) for this course reflects the fact that the instructor taught an additional general chemistry section in 2001
[2]Students utilizing CAI an average of three times per week or more.
ND - Not Determined

Table 4.
Utilization of CAI in Organic Chemistry I

	1998	1999	2000	2001	2002
	$N = 32$	$N = 29$	$N = 32$	$N = 42$	$N = 38$
Number of students utilizing CAI[1]	0	6	30	39	35
Pass rate for students utilizing CAI	-	ND	47	59	66
Pass rate for students not utilizing CAI	-	ND	0	0	0
Class Pass rate	31	41	44	58	61

[1]Students utilizing CAI an average of three times per week or more
ND - Not Determined

Table 5.
Correlations of Grades to Use of CAI

Course	Pearson Correlation Coefficient	*p*	*N*
Fall 2001			
General Chemistry I	0.343	0.019	43
Organic Chemistry I	0.217	0.109	42
Fall 2002			
General Chemistry I	0.397	0.002	51
Organic Chemistry I	0.112	0.263	34
Significance level = 0.05			

Students' Attitudes

CHEM 1211, Fall 2001. Twenty-eight students returned surveys (Table 6). When questioned on the online component of the course, on a scale of 1(*strongly agree*) to 5(*strongly disagree*) student results were positive. Students found the computer assisted instructional tools improved their learning (Mean = 1.94); access to their grade information and performance measures such as quizzes prompted them to take action (Mean = 1.96); and found the WebCT format preferable to other Web based courses (Mean = 2.11) (50% had experience with other Web-based courses). When asked if too much time was spent in learning the technology, the mean score was 3.59 (1 = *strongly agree* and 5 = *strongly disagree*). This indicated a neutral to slight disagreement that too much time was taken learning the technology. This may be attributed to the fact that students needed to input some time and effort in getting familiar with and navigating the online materials, but that students already had familiarity with using computers. The fact that 75% of the students indicated that they preferred a class with a Web-based component to one without showed that learning to use the technology did not distract from the advantages of having the computer environment as a part of the course.

Table 6.
Student Survey Responses, General Chemistry

Statement	Mean Response	
	Fall 2001 *N* = 28	Fall 2002 *N* = 38
I have found the Web format used in this course preferable to other Web-based courses.	2.11	2.05
The computer-assisted instructional tools available, for the class, were valuable and improved my learning.	1.94	1.82
It is important to have experience using the latest technology applied to my field of study.	1.65	1.34
Access to my grade information and performance measures such as quizzes, prompted me to take action (such as visiting my instructor or tutor).	1.96	1.42
I spent too much time learning technology.	3.59	4.11
In general, I am very satisfied with my overall experience with the course.	1.74	1.45
Instructor-led help sessions were helpful in understanding the subject matter.	3.45	1.50
Peer tutors were helpful in understanding the subject matter.	3.42	2.84
Above questions were rated on a scale of 1 (strongly agree) to 5 (strongly disagree)		
I have had previous experience with a Web-based course.	50%	53%
If a choice exists, I'd prefer a class with a Web component to one without.	75%	84%

Students indicated that the most useful components of the course were the class notes (50%) and grades online (39%), in 2001. The least useful components for this course were e-mail/bulletin (32%) and calendar (43%). This can be attributed to the fact that these tools were used mainly for back-up announcements and to provide information already provided in class. The attendance policy at the university is enforced and most students attend classes regularly and are aware of announcements made in-class.

Fall 2002. Thirty-eight surveys were returned. All evaluation categories improved compared to 2001 surveys. Students chose having grades online (42.1 %) and class notes (36.8%) as the most useful aspects of the Web site. Online quizzes were reported

to be most useful by 18.4 % of students. Table 7 shows the utilization of tutors in both organic chemistry and general chemistry was consistently low throughout the course of this study. While students agreed that tutors were useful, very few saw tutors at least one per week. Most students saw tutors less than 5 times throughout the semester in each year of this study. When asked, the majority of students indicated that other obligations (mainly jobs) made it difficult to interact with the tutor, or that they tried to work through the course materials on their own. Most of the students who saw a tutor at least once per week passed the course (Table 7), though the sample pool for this data is small due to the poor utilization of this service and may not be statistically significant.

Students found the CAI materials (Mean = 1.94) more useful than the peer tutoring (Mean = 3.45) or the instructor-led help session (Mean = 3.43).

Table 7.
Utilization of Peer Tutors

	1998	1999	2000	2001	2002
CHEM 1211 - *General Chemistry I*	*N* = 90	*N* = 54	*N* = 117	*N* = 43	*N* = 55
Number of students utilizing tutors	-	9	16	4	6
Pass % for students utilizing tutors	-	ND	63	80	83
CHEM 2301 - *Organic Chemistry 1*	*N* = 32	*N* = 29	*N* = 32	*N* = 42	*N* = 38
Number of students utilizing tutors	-	8	13	17	10
Pass % for students utilizing tutors	-	ND	75	86	90

Although there was no statistical correlation of computer usage to student performance, for organic chemistry, the survey responses indicated that students perceive the online resources to be beneficial.

One of the most important lessons learned was that the use of the course materials on a voluntary basis resulted in poor utilization of resources, even when students were doing poorly in the class. Maximum utilization resulted when the instructor provided specific activities and assignments that required students to use resources.

It is evident that the varied classroom environment helped students' learning. The number of students completing the courses successfully increased and the student surveys certainly show that students perceive that the tools enhanced their learning. Integrating the additional instructional modes, as done in this study, exposed students to different ways of learning the subject matter, an important consideration since different methods of course delivery may have different effectiveness.

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