ONLINE ORGANIC CHEMISTRY

BY

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DISSERTATION

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ABSTRACT

This is a comprehensive study of the many facets of an entirely online organic chemistry course. Online homework with structure-drawing capabilities was found to be more effective than written homework. Online lecture was found to be just as effective as in-person lecture, and students prefer an online lecture format with shorter Webcasts. Online office hours were found to be effective, and discussion sessions can be placed online as well. A model was created that explains 36.1% of student performance based on GPA, ACT Math score, grade in previous chemistry course, and attendance at various forms of discussion. Online exams have been created which test problem-solving skills and is instantly gradable. In these exams, students can submit answers until time runs out for different numbers of points. These facets were combined effectively to create an entirely online organic chemistry course which students prefer over the in-person alternative. Lastly, there is a vision for where online organic chemistry is going and what can be done to improve education for all.

"I wish to leave the world a better place for me being there." – Dr. James A. Naismith

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CHAPTER 1

INTRODUCTION

1.1 LITERATURE REVIEW OF DISTANCE EDUCATION

The Internet is a force to be reckoned with. Information that used to be confined to library stacks is now available at anyone's fingertips. Anyone anywhere can learn anything — at least in theory. But knowledge is more than just information. Are we living in a world that is information obsessed and knowledge deprived? Transforming information to knowledge — especially for pervasive subjects like organic chemistry — is a challenge for today's information-rich world, especially for chemical educators.

Technology has given us information on-demand. Can technology also assist in the large-scale dissemination of the knowledge that this information has to offer? We have begun to address this question by changing the way organic chemistry instruction is delivered at the University of Illinois at Urbana-Champaign. Finding a way forward is exciting because it moves the world closer to truly realizing the vision of "Chemistry for everyone."[1]

Distance education has existed on record since 1840 in which students were instructed in shorthand correspondence. Although this was the first official course in distance education, some form of distance education has existed ever since the invention of the printing press.[2] It can be argued that telling a student to read a chapter of a book and then discussing what the student has read in a classroom is the earliest form of distance learning. Since 1840, there have been several instances of distance education courses and also entire curricula.

The first study to compare the effectiveness of distance education with that of traditional education was completed by Crump in 1928 in which he found "**no differences in** test scores of college classroom and correspondence study students enrolled in the same subjects."[3] Between Crump's initial study in 1928 and 1999, there have been at least 355 studies that have investigated the differences between distance education and traditional education.[4] These studies have looked a variety of course types from correspondence courses,[5] to radio,[6,7] to using television,[8-10] and the results are clear: the medium for delivery of instructional information is irrelevant, as students perform just as well or sometimes better in courses which use electronic media.

One big drawback to using mail, radio, and television is the lack of interactivity between the student and the vehicle carrying the information, a result of the one-way medium. When the course consists of largely two-way communication as opposed to one-way communication, student outcomes in distance education are more favorable.[11] The issue of interactivity is a central component to active learning which has been shown to boost student performance. According to constructivist theory, students take in information and construct knowledge based on how the new information connects or doesn't connect with existing knowledge.[12] Piaget argues that students learn best when they are themselves at the center of the educational experience and not the teacher. There is also described a more interactive class in which the professor no longer pitches information into passive students but acts as a "guide on the side," allowing students to participate in constructing their own knowledge with their peers.

The fact that students perform better when learning is more active is consistent with Deci's work which states that students with higher levels of intrinsic motivation exhibit higher educational performance and educational happiness.[13] Work by Heider and Bandura corroborates this theory. They state that students with higher intrinsic motivation are more likely to attribute their own success to factors they themselves can control, such as effort and innate intelligence, instead of to external factors like grading rubrics, luck, and quality of professors.[14,15] These intrinsically motivated students are also more likely to work hard to master a subject than to work hard to achieve a grade.[16] These students are more likely to participate in discussions and attend class when attendance isn't required.

Since these motivated students are more likely to succeed and participate actively for their own sake, active learning much better suits these learners. Several studies have shown that active learning leads to higher retention of information.[17] In order to harness the power of active learning in distance education, a different medium must be used that allows for self-discovery and instant-feedback. The Internet provides both.

The Internet allows the distance in distance education to virtually disappear. People across the globe can communicate with one another instantly via text, images, audio, and/or video. The advent of broadband Internet service has allowed for high-volume transmission of large audio and video files at speeds that rival that of face-to-face conversations. For example, the efforts presented in this dissertation have allowed a student in Champaign, Illinois, to interact instantly with a student in Beijing, China, or Lahore, Pakistan. Distance learning can theoretically occur at the same time as a form of active learning, allowing students to learn anywhere in the world.

The U.S. Department of Education completed a meta-study on online learning to look at its efficacy compared with traditional face-to-face learning, and the findings are similar to that of Russell's findings with other forms of distance education: "Students who took all or part of their class online performed better, on average, than those taking the same course through traditional face-to-face instruction."[18] The interesting finding is that students who used any part of their course online outperformed their classmates who had no part of the course online whereas previous findings with distance education found no significant difference. Perhaps students who sign up for online courses already possess higher levels of intrinsic motivation. As Zhao et al. points out, twenty-first century distance education will be vastly different from twentieth century distance education because of the higher interactivity of the Internet as an information medium, so it can be predicted that performance outcomes from distance education will be higher than they had been using different media.[19]

1.2 OVERVIEW OF DISSERTATION

Since information can be obtained on demand using the Internet, it is increasingly clear that the traditional lecture has lost the value that it once had.[20,21] Additionally, in courses like organic chemistry, homework can be submitted and checked with immediate guided feedback using tools like ACE Organic—a web-based interface.[22] ACE Organic allows students to draw organic chemical structures in response to questions. ACE then analyzes the response, and if it is wrong, ACE provides immediate feedback that specifically addresses the error that the student made without giving away the answer. Rapid feedback has many pedagogical values, but above all else it helps to avoid repetition of bad habits.

The most innovative features of ACE are its abilities to analyze multistep mechanisms, including electron-flow arrows of the usual type, and to provide appropriate feedback depending on the nature of the student's error. These open-ended problems are as sophisticated as any problem that an organic chemistry student would encounter on a traditional paper exam.

Coupling ACE with software like Elluminate Live enables interactive sessions where problem solving, critical thinking, and assimilation of material can be achieved. These online tools make it possible to connect students from various global locations or to see complex 3D structures that cannot be viewed on a chalkboard or a piece of paper.[23,24]

In order to test the tools like ACE and Ellumiante Live as learning media, we have created a fully online course for second-semester organic chemistry. The second-semester course in organic chemistry for non-chemistry majors at the University of Illinois at Urbana-Champaign is largely based in physical organic chemistry and covers molecular orbital theory, reaction mechanisms, and an introduction to bioorganic chemistry using the tools from molecular orbital (MO) theory and mechanisms introduced earlier in the course. The online course was first taught in the summer of 2008 to 37 students and again in the fall of 2008 to 181 students. The largest class size was 624 students in the fall of 2009. There was no face-to-face interaction whatsoever between the students and the instructors.

Despite the lack of face time, the course promoted a high degree of interactivity. Students communicated with one another and the instructors both through a synchronous environment for three hours per week using Elluminate Live and through an asynchronous environment using a discussion board on the course website. As instructors, we have found—quite unexpectedly—that one learns about students' performance capabilities on a personal and individual basis just as effectively as in any other setting in which we have taught.

Course content is delivered entirely online in two different formats. In the summer of 2008, students watched Internet-streamed 50-minute lectures archived from the previous semester using Mediasite, a program for capturing audio and video input synchronously with presentation slides. In the fall of 2008, students had the option of either viewing the archived lectures or watching shorter segments streamed in the form of webcasts. For the webcasts, content from the traditional 50-minute lecture was used to create five or six, 6-minute segments, each one covering a specific topic.

Two advantages of the webcasts are ease of cataloging the content and the streamlined presentation. Cutting out distracting phrases such as "um's" and "er's" in one's speech and eliminating classroom distractions give a sharp focus and deliberate intent. The webcasts also contain "Action Items" which include Internet hyperlinks that, with the click of a button, enable the student to learn more about any unfamiliar topic or word. Not only is the boring traditional textbook transformed into animated and hyperlinked content, but also its outrageous cost is replaced with immediate and free information. Students are typically sent to verified Wikipedia articles for definitions and sites with demos, videos, and animations for more complex phenomena. Occasionally, students are intentionally sent to sites with erroneous information and asked, "what's wrong here?" Sending students to review incorrect information teaches the invaluable skill of information filtering and encourages students to become more self-aware of technical content on the Internet.

Examinations are given synchronously using a combination of ACE Organic and Elluminate Live. Students report to a computer lab on campus or to a local library or community college, and there they receive a copy of the exam on paper. Instead of students' recording answers on the paper copy of the exam, the answers are input into ACE Organic. The exam questions are carefully drafted from contemporary chemical literature and designed to test understanding and reasoning abilities. Moreover, the novel features of ACE Organic mean that the exam questions are not restricted to multiple choice, matching, or numerical answers as machine-graded organic exams are (Figure 1.1).

The Elluminate environment puts security checks in place and forces strict time limits to deter potential cheaters. Within this environment, students are allowed to roam freely on the Internet and use whatever textbooks or notes they want, with the exception of blogs, Facebook, Twitter, email, or any site which allows two-way communication or posting answers / questions. This policy of using “anything but a friend; non-friends also apply” tests students under conditions analogous to those of the practicing research chemist. Since chemists peruse textbooks, primary literature, and Internet sites to find information and use computational tools to help solve problems, why should our students undergo an examination procedure any differently?

Another unique aspect of the examination is the grading. Because the exams use ACE Organic, the answers are checked instantly, and students are immediately informed whether their responses are correct or incorrect. Students then have the option to submit a different response in an attempt to gain points, continuing as many times as they would like until they successfully solve the problem or the exam time has expired. For each problem, students receive points only if they find an acceptable solution, and they are scored according to how many attempts it takes them. This grading style is closer to real world problem solving than traditional “partial credit” because students can attempt to solve the problem more than once. It provides immediate corrective feedback, which reinforces learning and acquisition of knowledge.

The intent of an exam problem is to probe whether a student has the ability to solve it, and the new grading system does just that. The traditional “partial credit” grading system enabled students to answer a question just once, and the grader assigned arbitrary point values according to how close the student’s response matched the correct answer. The “partial credit” system was the best method instructors could use for paper exams because students’ knowledge could be probed only once. In the online format, students must diagnose incorrect responses and find solutions, just as any research scientist would do in the laboratory.

Another advantage to the exam format is that instructors are free from the labor-intensive, mistake-ridden practice of old-fashioned hand grading. Moreover, students can be required to retake exams if performance does not meet expectations. Post-exam learning, motivated by offering a fraction of the original credit and the freedom to work collaboratively, has been a huge and unexpected instructional bonus afforded by machine-graded exams. This approach reinforces the learning and application of current fundamental concepts.

These advancements in technology / online instruction have made it possible to teach a highly interactive online organic chemistry course to a class size of up to 700. Detailed assessment of the course components is discussed in the chapters that follow. Our preliminary conclusion is that in terms of learning outcomes and student satisfaction, the trial offerings have been successful. The pilot run in summer 2008 involved students spread throughout the state of Illinois, but there's no reason to limit the geographical boundaries. Anywhere there is an Internet connection, students can logon to learn and get assistance. Discussion sessions have been moderated from hotel lobbies and airport terminals thousands of miles away without missing a beat.

Now that course enrollment is no longer capped to the size of the lecture hall, why stop at 700 students?[25] Since the content is not tied to any one location or professor, it is possible to create a network of professors and students across institutional and national borders all learning together. Transforming colleges and universities from a "pay-for-teaching" to a "pay-for-accreditation" model would facilitate global, mega-student classrooms. Interested learners from all walks of life around the world could get interactive help on-demand. We conducted a preliminary experiment of this sort during the fall 2008 semester. Students of Prof. Dahui Zhao from Peking University in Beijing, China, regularly logged on to our discussion sessions along with students at the University of Illinois at Urbana-Champaign. The students from both universities were able to connect with one another in real-time, and students drew reaction mechanisms for all to see.

As more experts across the globe join in, students will have access to professional chemistry help 24 hours a day, 7 days a week. Anyone who has a question can log into "organic chemistry customer service" and have their questions answered by a trained professional.[26] That's not just information on-demand but knowledge on-demand. These ideas will be discussed in more detail in Chapter 7.

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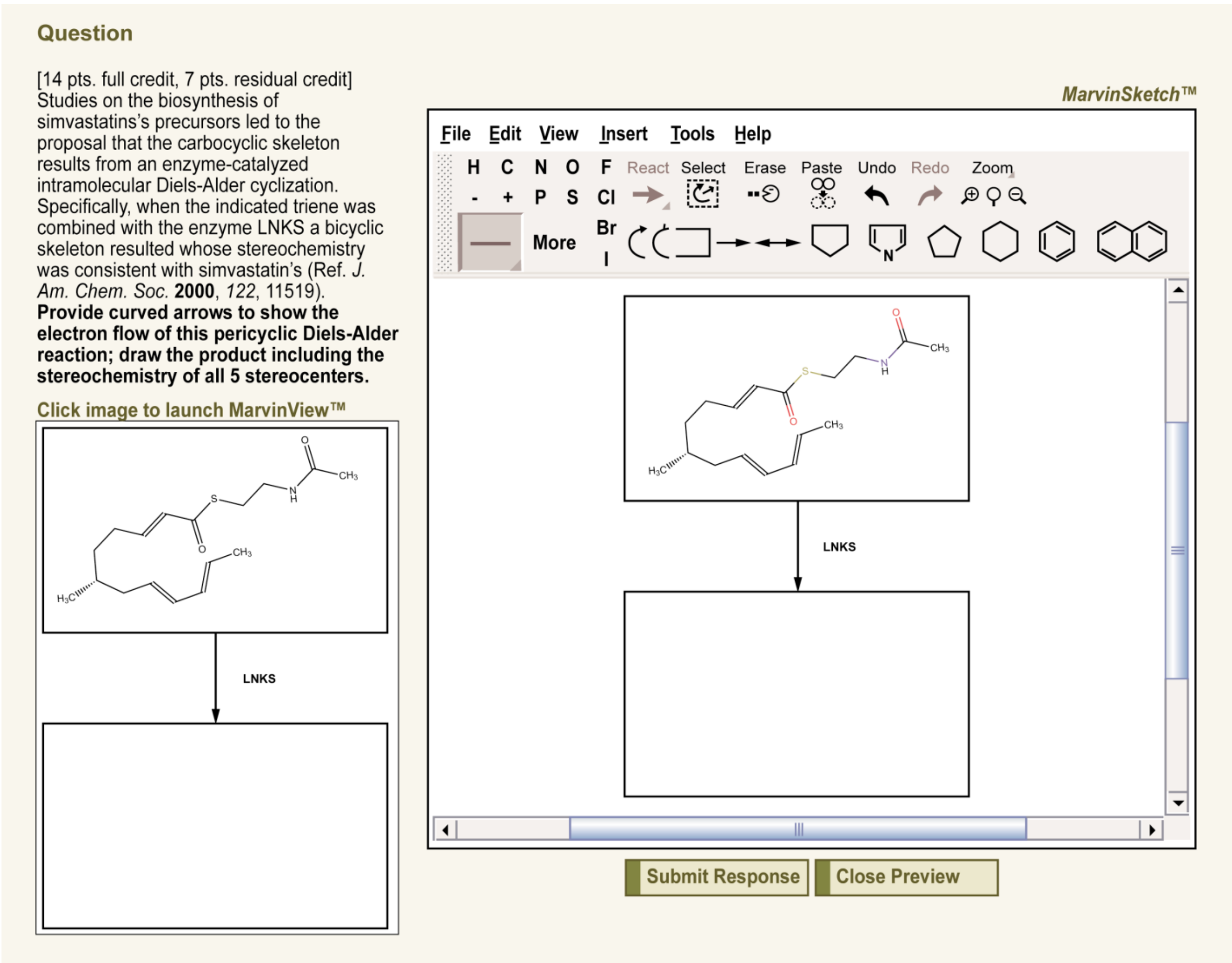
1.4 FIGURES

Figure 1.1 A screenshot of an exam question used in the online course at the University of Illinois at Urbana-Champaign. It illustrates a very simple use of curved arrow notation and (somewhat more challenging) stereochemistry. A link to the literature is included to show the question's relevance to current chemical research.



CHAPTER 2

ONLINE HOMEWORK

2.1 BACKGROUND

Periodic homework assignments provide any course instructor with a method of student evaluation in terms of quantification of the amount and quality of learning by their students. One of the first computer-based tools for delivering chemistry problems was Programmed Logic for Automated Teaching Operations (PLATO), developed by Stanley G. Smith at the University of Illinois at Urbana-Champaign. PLATO had students complete computer-based problems in a computer lab.[1] Since then, many Web-based homework systems for chemistry – such as OWL,[2] LON-CAPA,[3] WebAssign,[4] and ACE Organic[5] – have been developed.

There are several benefits to using online homework systems in the sciences, especially for large lecture courses.[6] In physics courses, an online homework system was compared with a paper-homework system, resulting in the finding that an online method of homework delivery was at least as effective as paper delivery with respect to achievement, but there were significant benefits to practical aspects of the course. It was noted that students who completed the online homework spent on average 80 more minutes on each homework assignment and performed significantly better than students who completed paper homework. Perhaps the extra time allowed the students to perform better, but whatever the reason, students completing online homework spent more time critically thinking about the physics problems and performed better overall. Even if the online homework functioned only to force students to spend more time working on physics problems, the method achieved the goal of better engaging students in the material. Other positive aspects of using the online homework were largely related to time and use of resources. It was noted that one TA was previously hired with the sole purpose of grading paper-based assignments, whereas the computer could complete the task instantly. The resources spent grading assignments by hand could either be cut as a cost savings or transferred to other course activities such as individual help or extended office hours.

Some studies have explored the benefits of having online homework and/or online quizzes for a course, but the findings show that timed online quizzes are not an effective course component. Exam scores did not improve when students were given weekly timed online quizzes as compared to untimed online homework.[7] There was no significant difference between a group of online students who received online quizzes and a group of online students who had no online quizzes.[8] Based on these two studies, graded online quizzes are not used in place of homework.

Traditional pen-and-paper homework assignments are beneficial learning tools that allow students to attempt problems and practice drawing chemical structures. However, being able to put these types of problems online in a similar format would allow for easier submission and would expedite grading. Whereas OWL, LON-CAPA, and WebAssign rely solely on multiple choice questions, the ACE Organic system allows students to draw structures and mechanisms that are evaluated by the program. Incorrect answers are immediately provided with guided feedback based on the type of mistakes made by the student.

The use of guided feedback for individualized instruction has been shown to be effective. Using software to teach tax preparation, Nguyen divided people into two groups: a group with a simple, text-based system and a group with individualized feedback based on specific responses to different tutorial items.[9] Not surprisingly, Nguyen found marked improvement in learning by using the individualized tutorial-based approach. Grant and Courtoreille also found individualized instruction to be beneficial by varying feedback for two groups: one group received a simple “correct” or “incorrect” response while the other group was provided with guided feedback suggesting additional problems on missed items.[10] Once again, the individualized feedback provided a greater enhancement in learning. The ACE Organic system, because it contains such a guided, response-specific feedback capability, was chosen as the online homework system. ACE Organic also allows students to submit free-response structures and mechanisms, two highly crucial aspects to learning organic chemistry.

The ACE system works as follows: structures are input and converted to their respective (x,y,z) coordinates. These coordinates are matched with “evaluators” that determine whether the structure is correct based on these coordinates and instantly judged as correct or incorrect. Students are told whether their answer is correct or incorrect. If correct, they are told to move to a different question. If incorrect, they are given specific feedback programmed into the system by one of the instructors, and the specific feedback is based on the answer provided. For example, if the Markovnikov product is drawn instead of the anti-Markovnikov product, the student may receive feedback similar to the following: “The product you have drawn is the Markovnikov product. Does this reaction employ radicals?” Thus, before distribution of the homework, instructors must provide possible wrong answers (similar to writing a key with partial credit) with corresponding feedback to guide the students to the correct answer.

No study had previously been conducted on the effectiveness of using free-response submissions for an organic chemistry homework system, as no other system has had this capability. Therefore, we conducted two studies to explore the effectiveness of this system. The studies discussed in the following sections aim to answer the question of whether the ACE system provides a better learning experience than written homework.

2.2 PRELIMINARY STUDY

2.2.1 Design of Study

For this study, 144 total students taking first-semester organic chemistry for non-chemistry majors at the University of Illinois at Urbana-Champaign (UIUC), in the summers of 2006 and 2007, were divided into 3 groups. In summer 2006, there were 64 students who took the traditional course with no online lectures available from the current semester and with traditional weekly written homework. This group did not use the ACE homework tool at all (group LN: live lecture, no ACE homework). There were 80 total students (summer 2007) who took the course with ACE. They were divided into two groups: students who attended live lectures and students who watched online recordings of the same live lectures the other group attended. In order to split the two groups accurately, the students were given a survey that asked how often they viewed lectures online and how often they attended live lecture. Forty-seven students reported having viewed over half of the lectures online (group OA: online lecture, with ACE homework), and 33 students reported having viewed over half of the lectures live (group LA, live lecture, with ACE homework). There was no overlap between the two groups.

Both summer semesters lasted 8 weeks and contained the same material taught in the same order. Live lectures were 80 minutes long and occurred four times a week; the online lectures were exact recordings of the video, audio, and powerpoint slides used in the live lectures during the same summer. There was one homework assignment due each week during both of the summer sessions, and the number, type, and difficulty of assigned problems was comparable. During lectures delivered in summer 2006 and summer 2007, every effort was made to use the same methods of explanation and keep the same pace. The number of office hours and review sessions was also held constant, and the amount of time spent helping students was comparable. All exams were written exams taken in person. The students in the LA and OA groups took the same exams, but the LN group took hourly exams with different problem. Although the exams for the LA/OA groups were different than for the LN group, their difficulty was similar, as verified by the use of the same teaching assistant for both summers. Despite the difference in hourly exams, the final exam score distribution can still be used for an accurate and direct comparison because the final exam was exactly the same for all groups. It is highly unlikely that any students were made aware of the content or questions on the final exam, as the exam was never posted on the course website, no students came to view the exam after the summer, and all blank exams, scratch paper, and exam keys were shredded immediately following the posting of the final grades. Furthermore, all graded exams were safely locked away in case any students wanted to view their exam, but no student came to view the exam.

Comparison among groups was based on two scores: the total score in the course and the score on the final exam. As stated above, the final exam was exactly the same for all students and was not released to the students after completion of the course. When the total score was used for comparison, only the scores on the three hour exams and the final were used, such that the three groups could be accurately compared. Since the homework assignments and extra credit possibilities were quite different between the two summers, those scores were removed from the total points comparison.

2.2.2 Results and Discussion

The three groups (LN, LA, OA) were compared using a one-way analysis of variance (ANOVA) and then later compared using a Tukey test to delve deeper into the reasons for significant results. The groups were first compared on the basis of total points for the course (Figure 2.1) and then by the score on the final exam (Figure 2.2). The full results of the ANOVA comparing total points are shown in Table 2.1 with the results of the Tukey test on total points in Table 2.2. The full results of the ANOVA on comparing final exam scores are shown in Table 2.3 with the results of the Tukey test on this analysis in Table 2.4. The ANOVA of total point distribution demonstrated a significant difference among groups, indicating an effect caused either by ACE homework or the online version of the course. A Tukey test was performed to determine if the significant difference comes from ACE and/or the online lecture delivery. These results demonstrated a significant difference between LA and LN; live lecture students performed better with ACE than with traditional written assignments. There was no significant difference between LA and OA. Students watching lectures online were at no significant disadvantage to those students who attended live lectures. In comparing the groups based on final exam score, the same results were found: there was a significant difference between LA and LN, and no significant difference between LA and OA.

The significant difference between LA and LN could have also arisen from factors other than ACE. For example, the teaching effectiveness of the instructor could have improved between the two summers, skewing the scores in favor of LA and OA. Unfortunately, there is no quantitative way to test these possible improvements in teaching ability, but we believe the effect to be smaller than the effect of ACE for the reasons stated in the previous section. Based on these reasons and the data presented above, it appears that ACE Organic was a significant contributor to students' learning organic chemistry.

The insignificant difference between the live and online groups is noteworthy for various reasons. Every attempt to minimize differences between the live (LN, LA) and online lecture groups (OA) was made. In order to offer similar benefits to live office hours, the same number of office hours were available using AOL Instant Messenger. Students could send questions to the instructor and teaching assistant both by text and by sending structures and mechanisms as picture files. All lectures and review sessions were made available online immediately following their conclusion.

One factor that explains why scores from OA were lower, yet not significantly lower, than the scores from LA is the standard deviation. The standard deviation is much higher for OA than for either of the other two groups, and the individual scores show three clusters of students: four students with four of the top seven scores in the class, a group of students hovering around the course average, and a large group of students at the bottom of the class. Further investigation of the top and bottom clusters reveals a difference in relative level of student effort. The top cluster of students watched lectures everyday and completed all homework assignments. The bottom cluster either watched lectures the night before homework was due or did not watch lectures at all, and the students seldom completed homework assignments as evidenced by the low homework scores, and thereby indirectly brought the scores of the online group down. Although there were still students in the live section who either slept through class or failed to complete homework, the number of students in the bottom of the class is much larger for the online section than for the live section. This data indicate a need for higher accountability for students taking online courses. Perhaps the feeling that the course was online or that the instructor was not physically watching the students led them to become lax in completing their work in a timely manner. Whatever the case may be, a tool needs to be developed to mimic the feelings of accountability gained by taking a traditional course to keep students on track. We believe that ACE has the potential to make students even more accountable for their work and knowledge than traditional methods.

Groups OA and LA were not combined to compare against LN, as this combination would result in confounding variables. Groups OA and LA viewed their lectures differently, so combining these groups to compare with a group that only received instruction by one method would provide meaningless results. This same reasoning applies to the lack of combination of LA and LN to compare against OA. Groups LA and LN completed homework assignments in different settings, so any statistical data gathered through combination of these groups would be inconclusive.

Based on this data, there appears to be a marked advantage to using online homework in teaching organic chemistry and no quantitative disadvantage to replacing traditional lectures with online lectures in organic chemistry. Because the sample size for this study was small, though, a larger study involving online homework was conducted, and a separate study was also run involving online lectures. In order to gather more data to compare the live and online groups directly, a larger study in which all students received the same homework assignments was conducted. Similarly, a larger study was also conducted to compare the ACE and no ACE groups directly, holding the style of lecture delivery constant for all students. The online homework study is described in the following section, and more studies conducted on online delivery of lecture material are discussed in Chapter 3.

2.3 LARGER HOMEWORK STUDY

2.3.1 Design of Study

There were 941 total students who took first-semester organic chemistry for non-chemistry majors at the University of Illinois at Urbana-Champaign (UIUC) during the spring of 2007 and 2008 semesters. In spring 2007, there were 483 students who took the course consisting of five traditional written homework assignments and 36 pre-lecture online quizzes which required students to answer brief multiple choice questions about the topics to be discussed in lecture. This group took the course without the ACE system (group NA or "no ACE"). There were 458 students who took the course in the spring of 2008, using ACE for homework and delivery of 36 ACE quizzes that corresponded to material discussed in lecture (group WA or "with ACE"). No students took the course during both semesters, so there was no overlap between the two groups. Students in both semesters were able to receive lecture information only by coming to a traditional live lecture, because online lecture capture was not used in either semester.

Comparison between groups was based on two scores: the total score in the course (3 exams plus final exam) and the score on the final exam. The final exam was exactly the same for all students and was not released to the students after the spring of 2007. When the total score is used as a comparison, only the scores on the three hour exams and the final were used. Since the homework assignments and extra credit possibilities were different between the two semesters, the scores were removed from the total points comparison. Both groups were taught by the same instructor during the spring semester. The spring semester at the University of Illinois at Urbana-Champaign is traditionally the “off” semester in that students in the recommended pre-health / pre-professional tracks take first-semester sophomore organic chemistry in the fall term, not the spring. Choosing spring classes as a study group was important for making a comparison between two semesters of similar types of students so that any comparisons would be accurate.

During lectures, every effort was made to use the same methods of explanation and keep the pace of the course constant. The number of office hours and review sessions was also held constant, and the amount of time spent helping students outside of class was comparable. The difficulty of hourly exams, which were different for each semester, was similar between semesters. Even if the exam difficulties were drastically different, the same final exam was used each semester and this can be used as an accurate basis of comparison. It is highly unlikely that any students were made aware of the content or questions of the final exam because the exam was never posted on the course website, no students came to view their graded exams, and all blank exams, scratch paper, and keys were shredded immediately following the posting of the final grades. Also, all graded exams were safely locked away in case any students wanted to view their exam, although no student asked to do so.

2.3.2 Results and Discussion

The two groups were compared using a one-tailed t-test. The groups were first compared based on the total points for the course (Figure 2.3) and then final exam scores were compared (Figure 2.4). There is a significant difference between the groups (WA and NA) based on total point comparison, so ACE must have some positive effect. Comparison between groups based on the final exam score gave the same results: group WA performed significantly better than group NA. Full data tables for the t-test comparisons of total points and final exam scores are shown in Table 2.5 and Table 2.6, respectively.

The significant difference between the scores of the two groups (WA and NA) could have also arisen from factors other than just ACE Organic. For example, improvements in the instructor's teaching skills may have also led to improved scores in group WA as it was the second group taught. Unfortunately, there is no quantitative way to test improvement in teaching ability, but we believe the effect is probably smaller than the effect of ACE for various reasons, many of which were mentioned in the previous section. Also, spring 2007 was the instructor's fourth semester teaching the material, and spring 2008 was the sixth semester teaching the course, so much of the improvement in teaching quality would probably have occurred during the first three semesters.

An interesting note from this study is that the total number of homework assignments turned in is fewer for the semester in which ACE was used: group NA was required to complete 5 written homework assignments and 36 online quizzes, and group WA completed only 36 online quizzes. One would assume that the more practice students were required to do, the better their exam scores would be; however, the opposite was observed in this case. Two possible explanations for this result are that the written homework assignments themselves were of no pedagogical value and / or that the older, non-ACE online quizzes were not as effective content-wise as the ACE quizzes. It is more likely that the older, non-ACE quizzes are the main culprit; these online quizzes featured several questions in which students were asked to predict the product of a reaction by clicking a multiple-choice box next to the correct product. The questions were designed so that students were required to solve the problem on paper, determine if what they drew was a choice on the screen, and then click the button so that their answer could be graded. This format allows for a high probability of guessing because students do not need to solve the problem in order to submit a gradable answer. In the case of the old online quizzes, there were 4 answer choices, so based on guessing alone, students had a 25% chance of correctly answering the question.

The online quizzes in ACE Organic are open-ended and therefore require students to draw structures directly into the program. The incidence of guessing the correct structure is greatly diminished, and students must put forth more effort and thought in order to receive credit for answering the question correctly. Another advantage of the online homework system is that specific feedback is delivered to the student based on what incorrect answer is submitted. For example, a student who enters the anti-Markovnikov product instead of the Markovnikov product receives guided feedback based on that specific structure submitted, and the student who draws a product with an extra carbon in the response is told to count the carbons. This type of adaptive feedback is similar to what the instructor would say if the student were to answer the question in office hours. The higher exam scores are directly attributed to this increase in required critical thinking and the adaptive feedback contained in the ACE Organic system.

There is a major limitation of the ACE Organic system, and that is security. In the current format for assigning homework, students are all given the same fixed question assignment, so students are able to work on problems with one another freely. Although group work is somewhat beneficial to the learning process, students have been relying too much on others to complete the assignments. For example, when a particular assignment has questions which must be answered in four attempts, students will “pool” their attempts together so that a group of four students now has twelve possible incorrect tries instead of just three for an individual. Also, wonderful ability of MarvinSketch to copy and paste structures easily also allows students to directly copy answers from one account to another. These are certainly issues that need to be addressed in future online homework programs.

Based on these reasons and the data presented above, ACE Organic contributed significantly to the effectiveness of learning organic chemistry. This adaptive learning system is an important first step in creating a "virtual" individual tutor for each student. Every student learns differently, so no student should receive the same one-size-fits-all guidance for their individual difficulties. More discussion on this topic will appear in Chapter 7.

2.4 REFERENCES

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2.5 FIGURES AND TABLES

Figure 2.1 A comparison of performance based on total points for the 3 different groups. Group LA (live lecture, ACE homework) has 33 students; group OA (online lecture, ACE homework) has 47 students; and group LN (live lecture, written homework) has 64 students. The total points are the combinations of three midterms and a final exam with a range of 0-800. The average of each group is given in the graph, and the error bars represent the standard error. There is a significant difference between LA and LN, but no significant difference between LA and OA or between OA and LN.

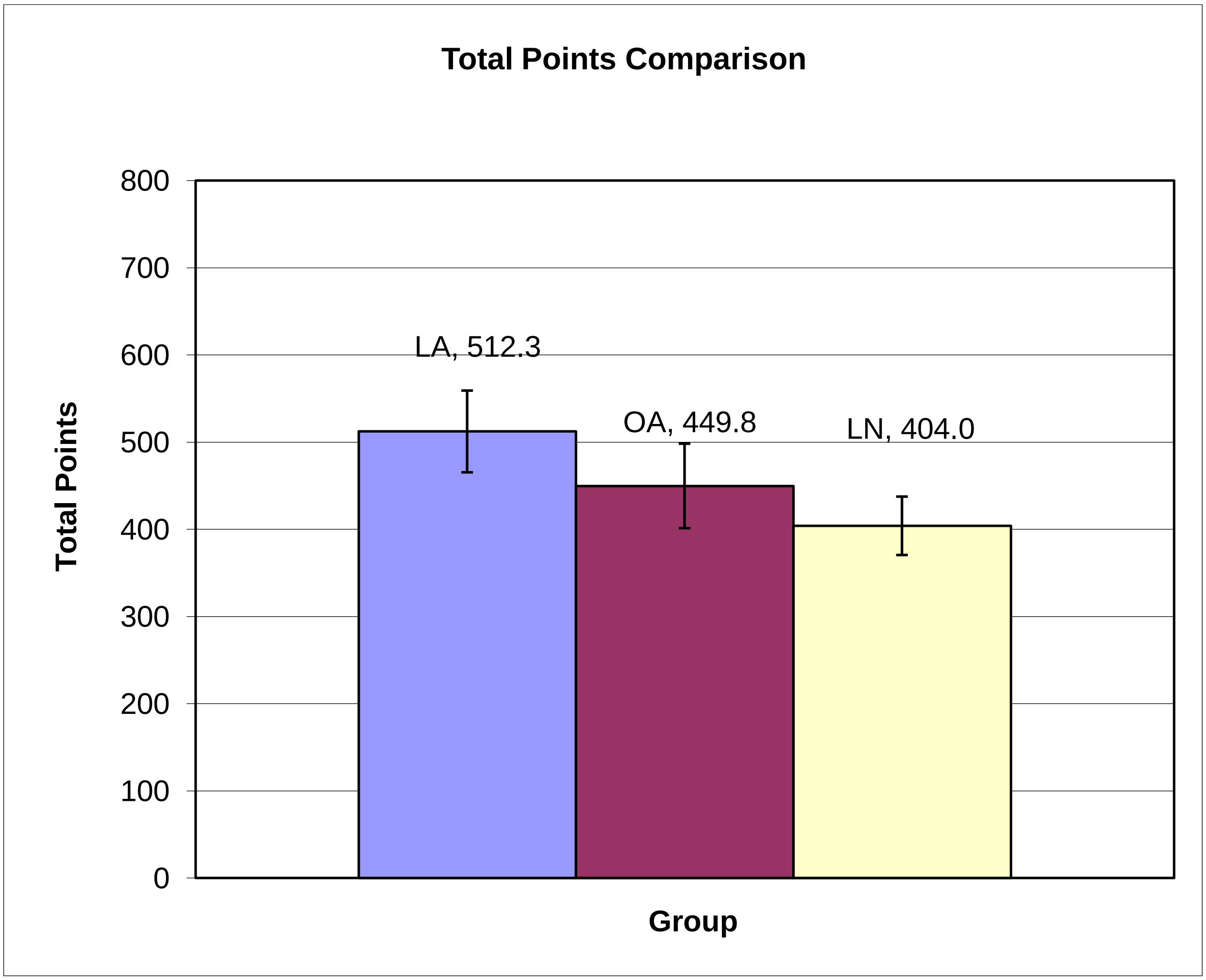

Figure 2.2 A comparison of performance based on the final exam for the 3 different groups. Group LA (live lecture, ACE homework) has 33 students; group OA (online lecture, ACE homework) has 47 students; and group LN (live lecture, written homework) has 64 students. The final exam has a range of 0-300. The average of each group is given in the graph, and the error bars represent the standard error. There is a significant difference between LA and LN, but no significant difference between LA and OA or between OA and LN.

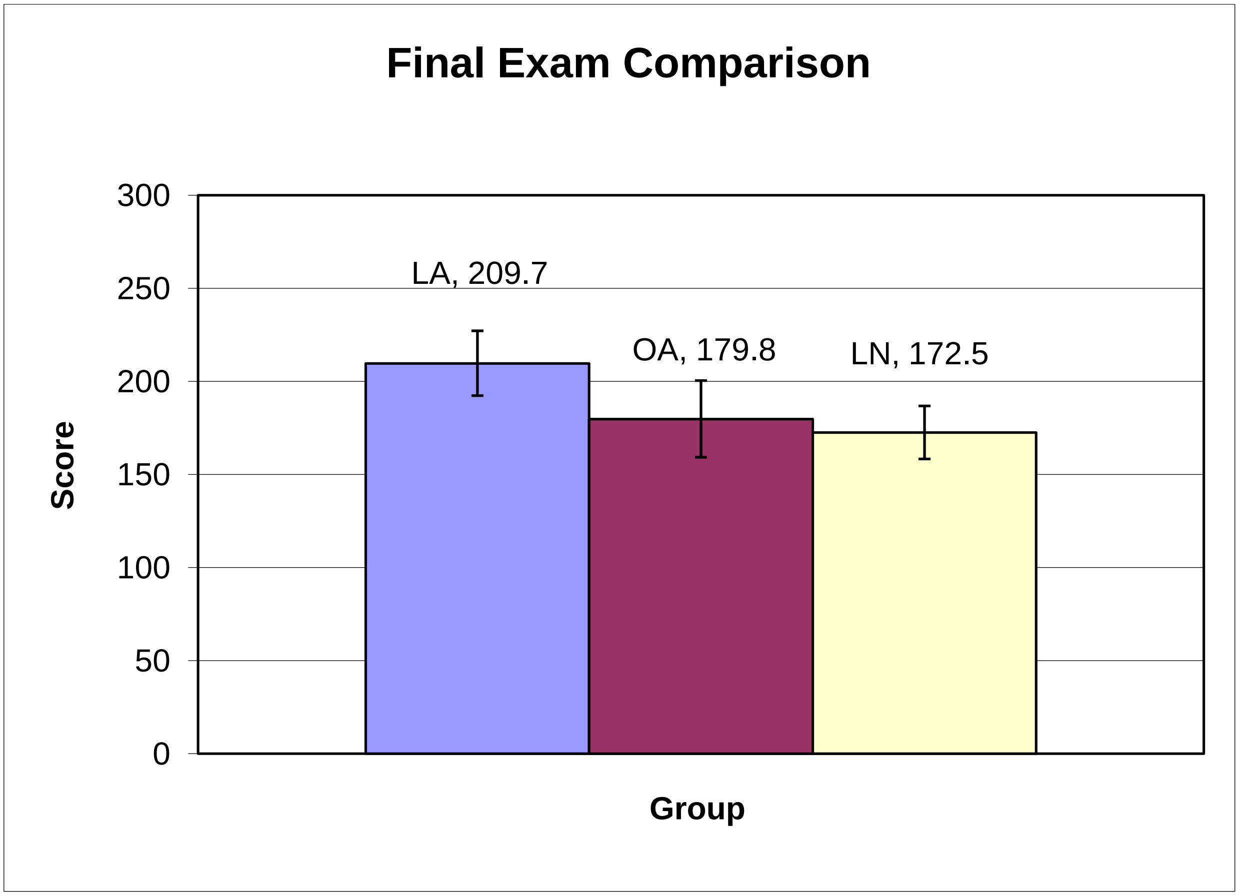

Table 2.1 Full data table on the comparison on total points for the three different groups. The total points for all groups has a range of 0-800.

Group	N	Mean	Std. Dev.
LA	33	512.3	134.7
OA	47	449.8	166.1
LN	64	404.0	134.0
Total	144	443.8	150.5

Table 2.2 Full data table on the Tukey test comparing total points for the three different groups.

Groups in Comparison		Mean Diff.	Sig.
LA	OA	62.5	0.145
LA	LN	108.2	0.002
OA	LN	45.8	0.233

Table 2.3 Full data table on the comparison of final exam scores for the three different groups. The final exam for all groups had a range of 0-300.

Group	N	Mean	Std. Dev.
LA	33	209.7	50.0
OA	47	179.8	70.6
LN	64	172.5	57.0
Total	144	183.4	61.7

Table 2.4 Full data table on the Tukey test comparing final exam scores for the three different groups.

Groups in Comparison		Mean Diff.	Sig.
LA	OA	29.9	0.078
LA	LN	37.2	0.013
OA	LN	7.3	0.805

Figure 2.3 A comparison of performance based on total points for the 2 different groups. Group WA (ACE homework) has 458 students, and group OA (written homework) has 483 students. The total points are the combinations of three midterms and a final exam with a range of 0-600. The average of each group is given in the graph, and the error bars represent the standard error. There is a significant difference between the two groups.

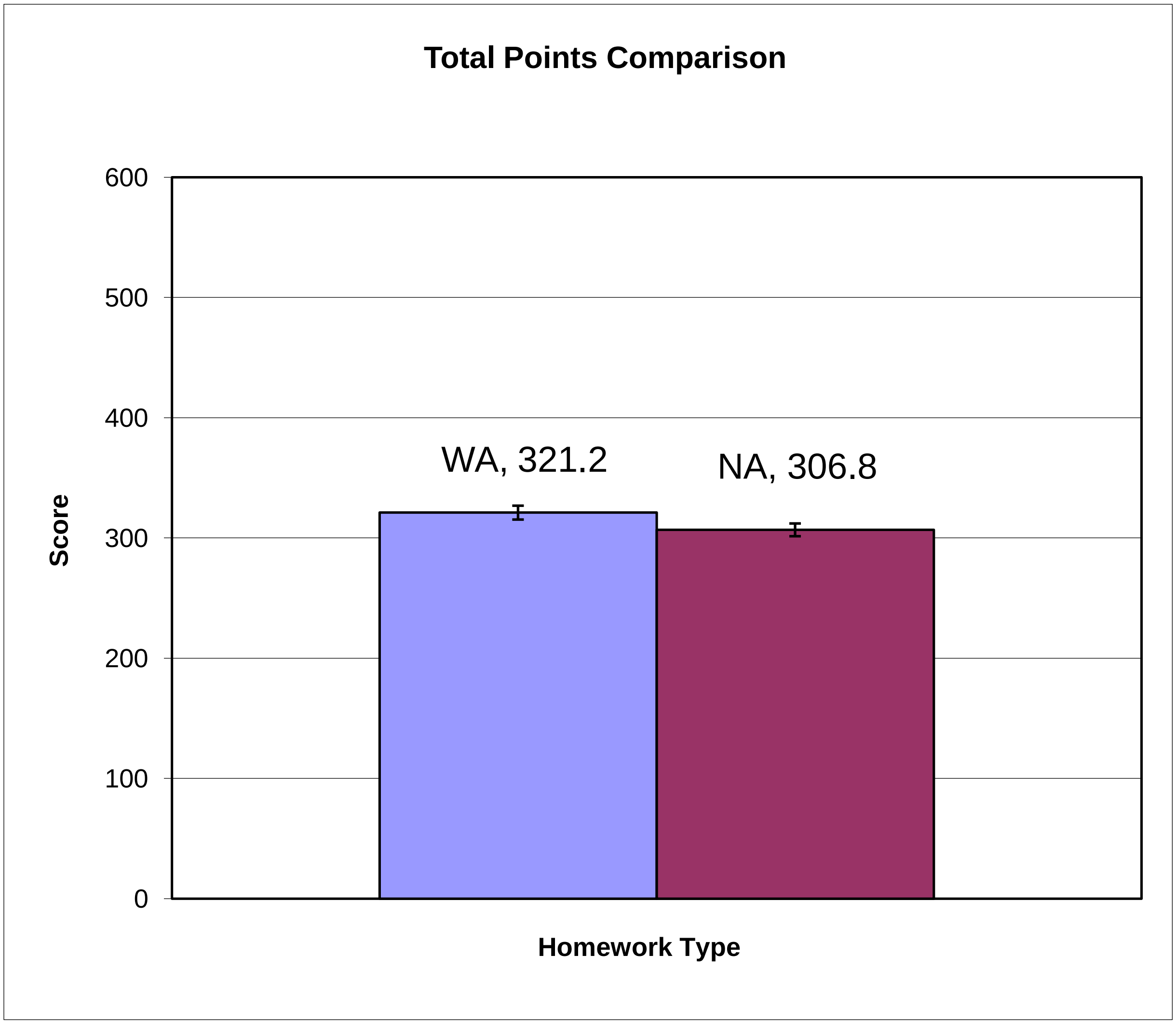

Figure 2.4 A comparison of performance based on the final exam for the 2 different groups. Group WA (ACE homework) has 458 students, and group OA (written homework) has 483 students. The final exam has a range of 0-300. The average of each group is given in the graph, and the error bars represent the standard error. There is a significant difference between the two groups.

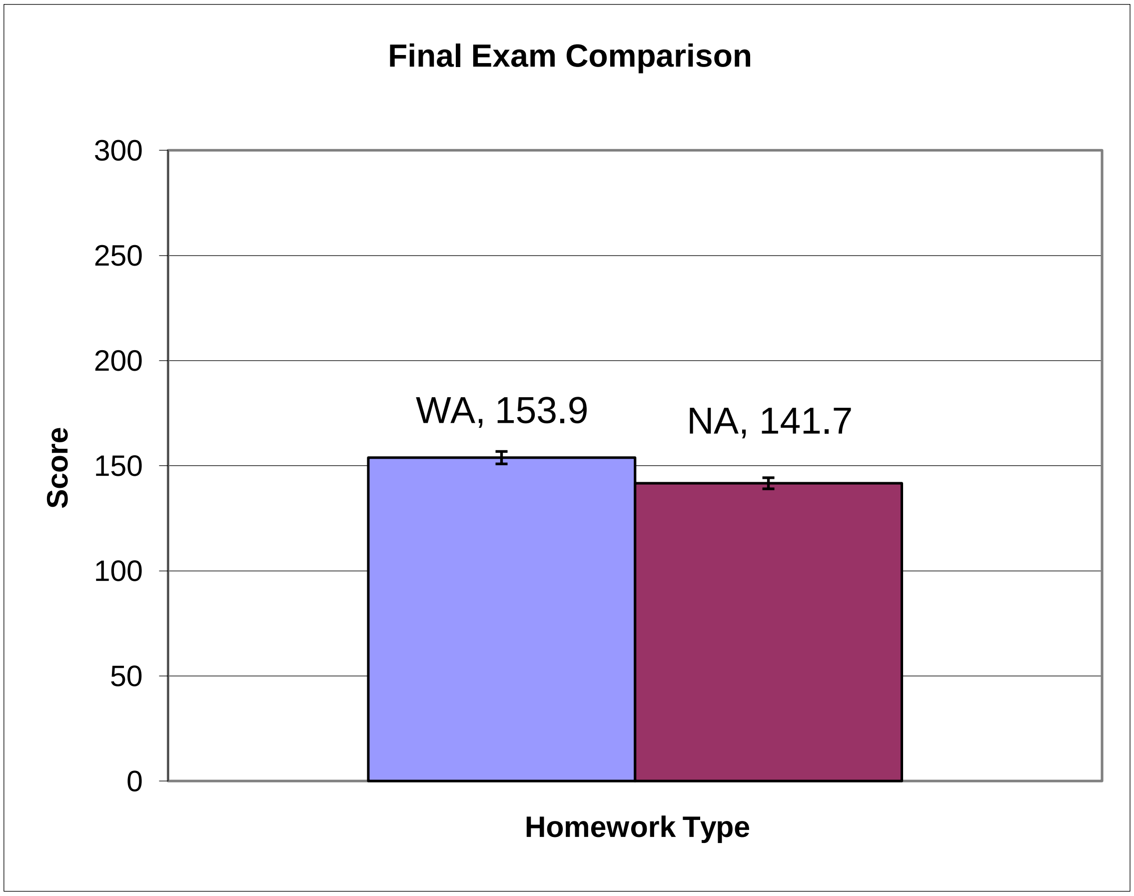

Table 2.5 Full data table on the comparison on total points for the two groups. The total points for each group has a range of 0-600. The difference is significant at the 95% confidence level.

Group	N	Mean	Std. Dev.	Difference	p-value
WA	458	321.2	5.8	14.4	0.034
NA	483	306.8	5.3		
Total	941	313.8	9.1		

Table 2.6 Full data table on the comparison on final exam score for the two groups. The final exam for each group has a range of 0-300. The difference is significant at the 99.9% confidence level.

Group	N	Mean	Std. Dev.	Difference	p-value
WA	458	153.9	3.0	12.2	0.001
NA	483	141.7	2.6		
Total	941	147.6	6.7		

CHAPTER 3

ONLINE LECTURE

3.1 BACKGROUND

One of the primary duties of an instructor is to deliver a lecture so students can learn the material delivered by an expert in the subject. In order for students to access lecture content when they are not physically present, lectures can be placed online in various incarnations. One potential problem with online lectures is whether they can still convey the information as well as an in-person lecture or whether the traditional face-to-face lecture can be improved.

Previous studies have found little to no significant differences in learning outcomes when the delivery of lecture was either online or face-to-face.[1-3] These studies confirm assertions by Clark that the medium is merely the vehicle for the content and should not theoretically affect the learning process.[4,5] These studies all included video-taped lectures of exactly what students in the face-to-face section saw.

With all that the Internet can offer, the media does not have to be a mere one-camera set-up of a traditional lecture. Several studies have shown no significant difference between simple one-way media and one-way media enhanced by more vibrant colors and static pictures.[6-11] In the highly visual life sciences, streaming video has no significant effect on short-term learning but has a significant effect on long-term retention.[12] Students also benefit from visual aids instead of merely narrated Powerpoint slides.[13]

When the media becomes more interactive and the students are given control over their own learning, student outcomes are significantly better than non-interactive media.[14] In a study by Zhang et al., students were randomly placed into one of four groups: traditional face-to-face lecture, online without video, online with non-interactive video, and online with video that could be paused, rewound, and fast-forwarded. Whereas there was no significant difference between the online group without video and the online group with non-interactive video, the online group with interactive video performed significantly better than the three other groups.[15] An earlier study by Zhang also showed a significant improvement in student performance when videos could be randomly viewed in any order, rewound, and fast-forwarded.[16]

In order to create an effective online lecture for organic chemistry, the lectures cannot be simply a one-camera set-up and must include interactive elements. Because no study had previously been performed on comparing face-to-face lectures with simple online lectures in organic chemistry until the small study discussed in Chapter 2, a larger study was necessary to validate the earlier results. Then, the lecture component can be improved with interactivity and with shorter lecture segments as will be discussed in section 3.3.

3.2 LARGE LECTURE STUDY

3.2.1 Design of Study

Although the results from the previous study in Chapter 2 showed no significant difference between the online group and the live group, a larger study needed to be conducted to determine whether the results hold with a larger sample size. There were 567 total students who took first-semester organic chemistry for non-chemistry majors at the University of Illinois at Urbana-Champaign (UIUC) in the fall of 2007. All students took the course with online homework using ACE Organic and had four options for delivery of lecture material: 8am live lecture with Prof. Jeffrey Moore (group 1), 9am live lecture with Dr. Lynne Miller (group 2), online web-streamed lectures of the same 8am live lecture given by Prof. Jeffrey Moore (group 3), or viewing no lectures at all (group 4). Because attendance was not taken in the live lectures and because students in any group could feasibly attend any live lecture or choose not to attend, the students were given a survey and were asked how often they attended either of the two live lectures, how many lectures they viewed online, and how many lectures they neither viewed live nor online.

First, a scatter plot was created which compared the number of lectures viewed online versus the total points in the course (Figure 3.1). Another scatter plot was also created which compared the number of lectures viewed online versus the final exam score (Figure 3.2). Both of these plots show no evidence of correlation, so the students were then pooled into groups. Students who received the majority of their information from Groups 1, 2, 3, or 4 based on the survey were placed in that group for subsequent analysis. Students who did not attain more than 50% of information from one particular group were excluded from the analysis. Group 1 was reported to have 202 students; group 2 was reported to have 100 students; group 3 was reported to have 257 students; group 4 was reported to have 8 students. There was no overlap between the four groups.

The groups were compared based on two scores: the total score in the course and the score on the final exam. Students in all four groups took exactly the same hourly exams and final exam in the same environment, so comparisons among the exam scores are valid. When the total score is used as a comparison, only the scores on the three hourly exams and the final exam were used so that any effects of extra credit opportunities are removed from the analysis.

3.2.2 Results and Discussion

The four groups were compared using a one-way ANOVA and then later compared using a Tukey test to delve deeper into the possible reasons for significance. The groups were first compared based on the total points for the course (Figure 3.3) and then compared by the score on the final exam (Figure 3.4). Comparison among the groups based on total points showed no significant difference at the 95% confidence level, including the group for whom no lecture was viewed. The full data table comparing total points is shown in Table 3.1.

Then, a Tukey test was performed to make sure no two groups had a significant difference with one another when effects of other groups were removed from the statistical analysis. The full results of the Tukey test are shown in Table 3.2. Based on the Tukey test, there was no significant difference at the 95% confidence level between any pairs of the groups, meaning that there was no causal relationship between the delivery of lecture content and the total score in the course.

Comparison between the groups based on the final exam score gave the same results: no significant difference among the four groups and no significant difference between any of the individual pairs of groups at the 95% confidence level. The full data table for the ANOVA calculations for comparing final exam scores is shown in Table 3.3, and the full results for the Tukey test comparing final exam scores is shown in Table 3.4.

These results indicate that the style of lecture delivery has no significant effect on exam scores. Is lecture necessary? These results seem to indicate that the answer is “maybe.” There was no significant difference in exam scores between the students who viewed lecture from the two different lecturers. Students who viewed the online lectures scored no differently from students in either lecture section. In fact, the group of students who viewed no lecture statistically scored no worse than any of the other sections. Although the sample size is only 8 for Group 4, the results are nonetheless intriguing. More research needs to be conducted with a larger sample size regarding the use of any lecture material.

The best comparison to look at is to compare students from Groups 1 and 3 because the only difference for these students was whether the information was seen online or in person with the same lecturer and same script. In both the comparisons of total points and the final exam, the p-values are much smaller than any other comparisons, yet they are not significant at the 95% confidence level. Perhaps there are some reasons why these values are smaller. One explanation is to look at motivation. As was mentioned in Chapter 2, the students in the in-person section had fewer outliers than the students in the online section. The main advantage to an online delivery of material, the ability to watch whenever is convenient, is also the main disadvantage in that it can promote procrastination. In a traditional lecture, the only way to receive information is to follow the regular pace set forth by the lecture schedule, so students are forced to receive information at regular intervals. In an online lecture, When students are given the ability watch lectures online, they are able to procrastinate watching lectures until a marathon session the night before and exam, an unfortunate practice that many students have admitted that they do. However, students who have been able to keep to a schedule while viewing online lectures have performed as well as or better than their classmates who view an in-person lecture. Therefore, it’s not the medium that directly affects learning but rather the unintended psychology of motivation that predominantly dictates learning outcomes. If there were a way to keep students motivated while still allowing for the freedoms given by online delivery of material, then the advantages of online content delivery can be fully realized. More discussion of this topic appears in Chapter 7.

3.2.3 Conclusion

Previous research has indicated that students learn material best by working problems themselves instead of just being told facts.[17-24] These studies further support that the lecture process is outdated and provides little time for students to think critically about the material presented to them. For many students, the critical thinking develops during personal study time, discussion sections, or exams,: all times in which students are making the material their own and reprocessing the information in a way that best suits them. The period of time that is traditionally spent on a passive regurgitation of canned lectures needs to be reallocated to activities in which the student becomes an active learner so that more time can be spent thinking critically about the material instead of having student sit passively to write down whatever words the instructor happens to say.

3.3 WEBCASTS

3.3.1 Introduction

Students of the current “Net Generation” are different students from students of the past. According to Bonamici et al., by the age of 21, these students on average will have spent 10,000 hours playing video games, will have written 200,000 email messages, will have watched 20,000 hours of television, will have spent 10,000 hours on cell phones, and will have spend less than 5,000 hours reading.[25] These students are multi-taskers and become easily bored by expository learning.[26] Because these students can easily find information at their fingertips, they are more likely to question the information that they find instead of accepting information given to them by professors.[27-29] Therefore, the content must not only provide the information necessary in a style that keeps more students' attention but also challenge the students to learn more and develop their critical thinking skills which many "Net Geners" lack.[30-32]

It is clear from the results in the previous section that students do not need to be physically present to obtain information directly from a professor because students can just as easily obtain information from the Internet. Because there was no significant difference between the groups that viewed lecture online and viewed no lecture, it is reasonable to assume that the material in lecture itself can also be found in other locations or in a better format. The time devoted to the lectures in the course was 50 minutes per lecture and 3 lectures per week, and many students lost their attention and desire to learn after the first few minutes. If these lectures were broken up into smaller mini-lectures, the core material could be better presented without being forced to string the information together into one 50-minute block. This section will discuss the creation of shorter "Webcasts" to break up the material in lecture so students can pay more attention to the lectures when viewing them and then learn more of the material presented.

One method of tapping into the attention spans of "Net Geners" is by converting a longer one-camera online lecture into a series of YouTube-style asynchronous "Webcasts." The implementation and efficacy of these "Webcasts" will be discussed in the following sections.

3.3.2 Design of Webcasts and Associated Lessons

In the fall of 2008, several “Webcasts” were created to divide up the material for better information digestion. A typical 50 minute lecture was distilled down into 4 or 5 smaller chunks lasting 5-7 minutes each (coincidentally, 6 minutes is the average time between commercial breaks on American television). At least 15 minutes of “dead air” has been trimmed from the traditional lecture so students don’t have to sit through stutters and sometimes poorly worded explanations. Also, if the instructor happens to make a mistake while recording a Webcast, the Webcast can easily be re-recorded. Because the Webcasts are short and can be re-recorded, instructors can provide clearer for chemical phenomena than are recalled during a lecture, and students can view them at any time. Although creating the Webcasts is time-intensive, they are reusable in many subsequent semesters using simple equipment like a laptop microphone and webcam.

A screenshot of a typical Webcast is shown in Figure 3.5. The page contains the short, edited Webcast at the top of the page along with other actions for students to do should they desire more information. Each Webcast page contains links to concepts covered in the Webcast along with links to course announcements, the course schedule, the discussion board, and the course website. The end of each Webcast contains “Action Items,” which are links to various sites around the Internet for students to gain more insight into the main topic of the Webcast or to a tool on the Internet that can aid in learning that particular topic. For example, in one Webcast, students are sent to the Wikipedia site for “Benzoin Condensation” to view that the arrows present in the mechanism are incorrect. The lesson is for students not to trust all resources fully without critically examining the information.

The Webcasts are bundled together into lessons, an example of which is shown in Figure 3.6. The lesson page contains the over-arching theme for the bundle of Webcasts along with other important items such as the course announcements and links to the discussion board, ACE homework problems, course notes, archived Elluminate discussion sessions, and a Problem of the Day (POTD). Also on the page is a poll for students to choose which topic they'd like to discuss in the online discussions called Which Topic First? (WTF?)

Short Webcasts provide several advantages over traditional lectures. First, each Webcast can be rerecorded as mentioned in the previous paragraph. Each Webcast contains one main topic or one main point, so students can search the Webcast database for a specific topic very easily. If a student has a problem with one particular topic, he/she can re-watch a short explanation of that topic. The student no longer has to attempt to remember which 50-minute recorded lecture contained that topic and navigate to that topic within a longer video. Several Webcasts are solely the instructor working a complex problem along with the student, so students can work a difficult problem along with the professor, and if the student gets lost or needs to go over a point one more time, the student can do so easily by pausing and rewinding either the whole Webcast or just a short part of it.

3.3.3 Student reactions to Webcasts

Since the inception of Webcasts, students have given largely positive feedback on the format. In the spring of 2009, students in second-semester organic chemistry for non-chemistry majors had the choice of viewing either Webcasts, online 50-minute lectures from spring 2008, or watching no lecture at all. Student data was tracked, and students' trends are shown in Figure

3.7. Students overwhelmingly chose to view the Webcasts over the 50-minute lectures. When students were asked in a post-semester survey which style of lecture format they preferred, the majority of students preferred the Webcast format over any other type (Figure 3.8). In this survey, 238 students responded out of 280 enrolled in the course for an 85% response rate.

Because of the success of the Webcast format, first-semester organic chemistry for non-chemistry majors also has Webcasts for its lessons but without associated 50-minute lectures. Studies have yet to be run when students receive only one type of lecture delivery, but it would be logical to perform research in this area.

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3.5 FIGURES AND TABLES

Figure 3.1 Scatter plot of number of online lectures viewed vs. total points in course. The data shows an insignificant correlation between the number of lectures viewed online and the performance in the course.

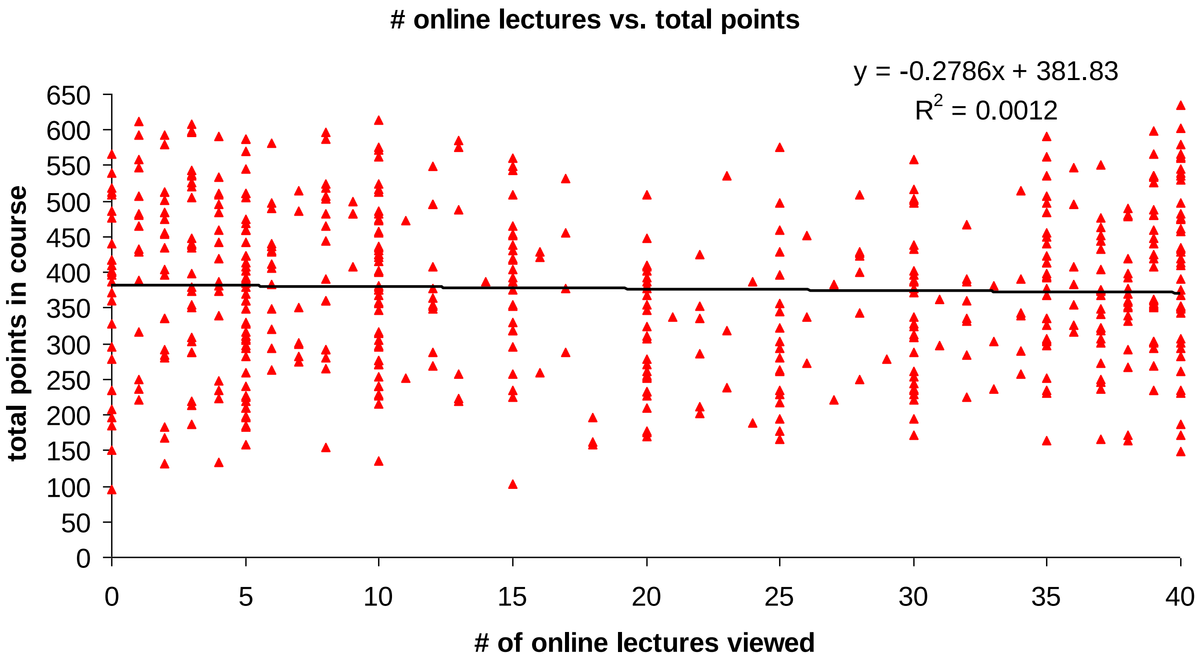


Figure 3.2 Scatter plot of number of online lectures viewed vs. score on final exam. The data shows an insignificant correlation between the number of lectures viewed online and the performance on the final exam.

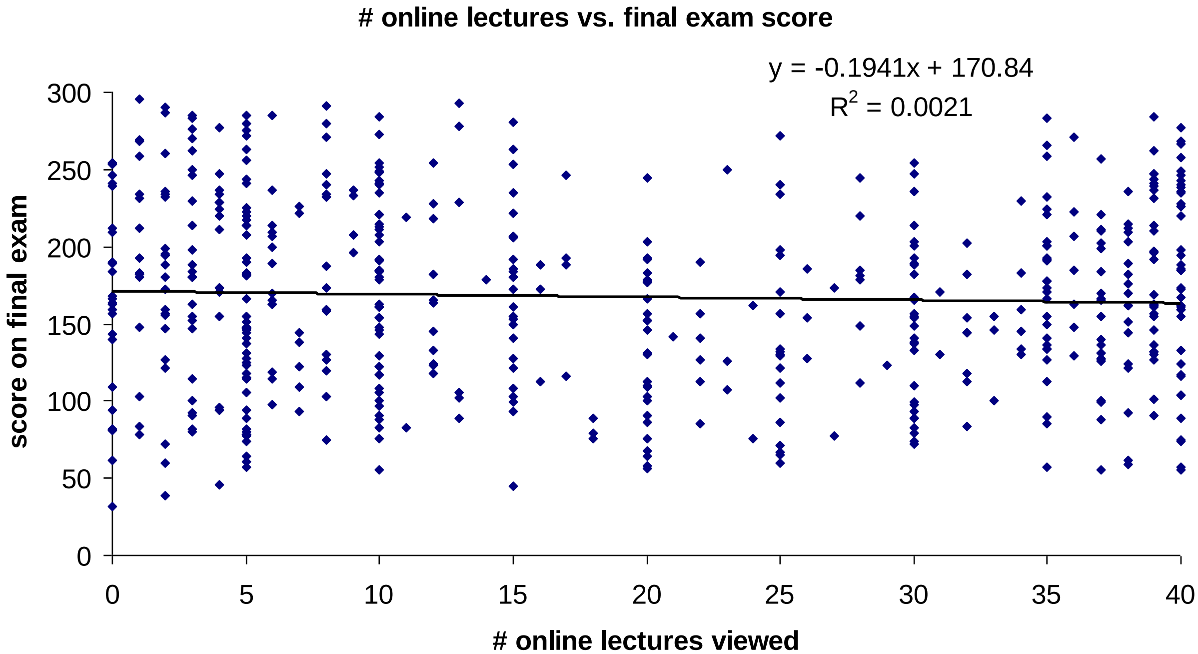


Figure 3.3 Mean score of total points for groups with different delivery of lecture material. Group 1 (live lecture with Prof. Moore) has 202 students; group 2 (live lecture with Dr. Miller) has 100 students; group 3 (online lecture with Prof. Moore) has 257 students; and group 4 (no lecture) has 8 students. The total points are the combinations of three midterms and a final exam with a range of 0-650. The average of each group is given in the graph, and the error bars represent the standard error. There is no significant difference between any of the groups at the 95% confidence level.

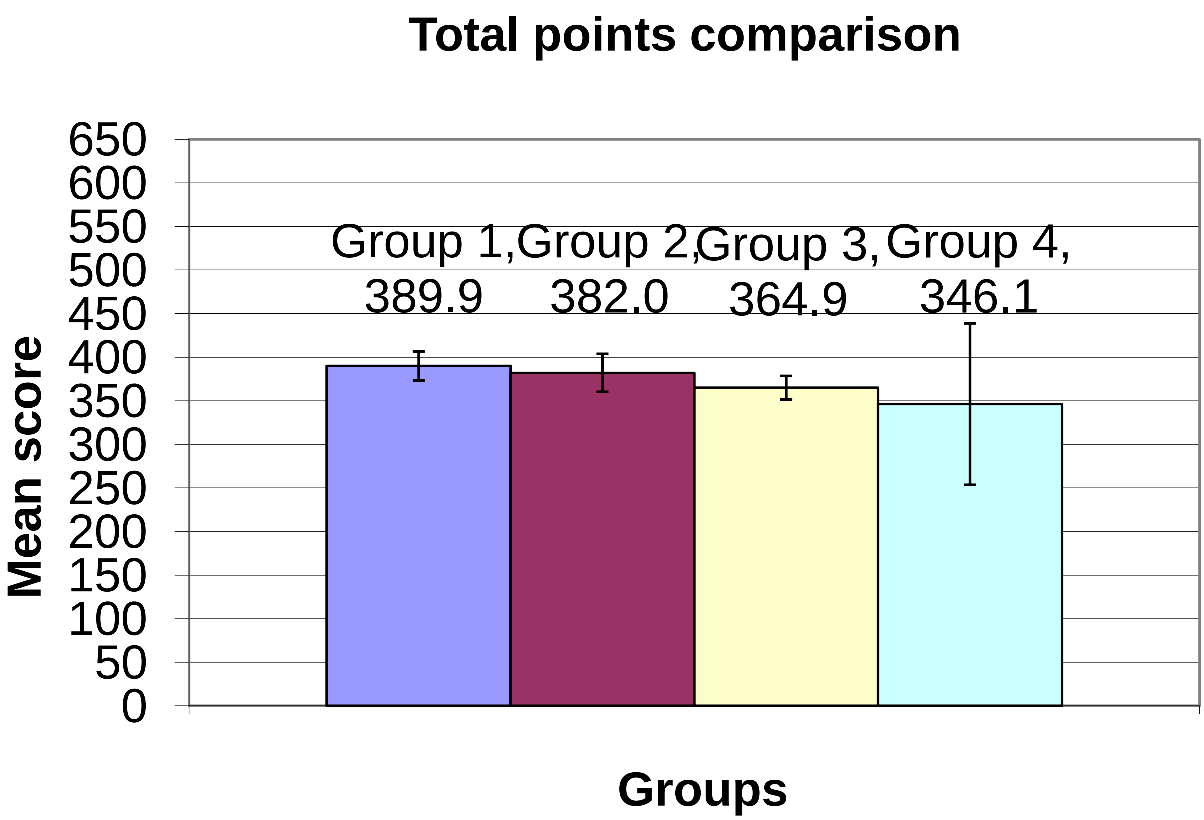


Figure 3.4 Mean score on final exam for groups with different delivery of lecture material. Group 1 (live lecture with Prof. Moore) has 202 students; group 2 (live lecture with Dr. Miller) has 100 students; group 3 (online lecture with Prof. Moore) has 257 students; and group 4 (no lecture) has 8 students. The final exam has a range of 0-300. The average of each group is given in the graph, and the error bars represent the standard error. There is no significant difference between any of the groups at the 95% confidence level.

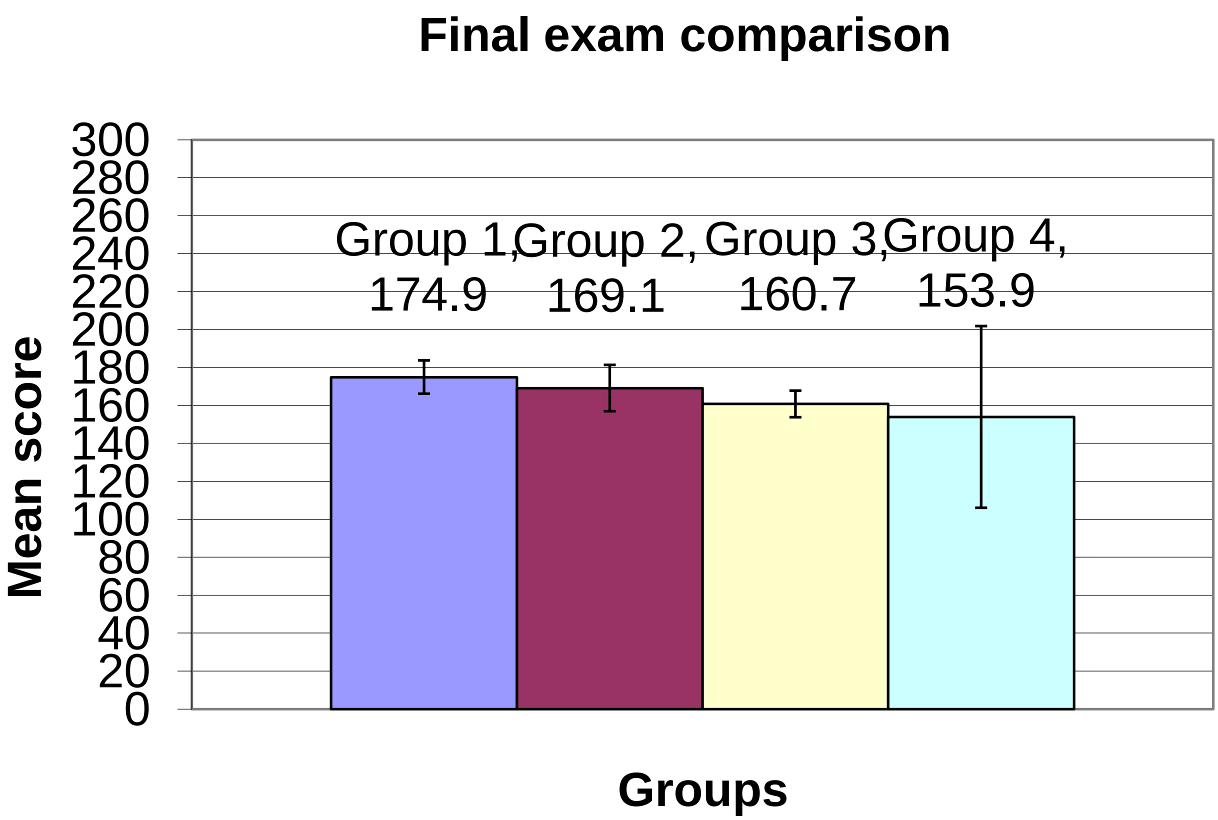


Table 3.1 Full data table on the comparison on total points for the four different groups. The total points for all groups has a range of 0-650. There is no significant difference between any of the groups.

Group	N	Mean	Std. Dev.	p-value
Group 1	202	389.9	118.6	0.095
Group 2	100	382.0	108.8	
Group 3	257	364.9	108.7	
Group 4	8	346.1	130.9	
Total	567	376.5	113.0	

Table 3.2 Full results from the Tukey test comparing total points for the four groups. There is no significant difference between any of the groups.

	p-values for each comparison			
Group #	1	2	3	4
1	x	0.941	0.086	0.704
2		x	0.570	0.822
3			x	0.967
4				x

Table 3.3 Full data table on the comparison on final exam score for the four different groups. The final exam for all groups has a range of 0-300. There is no significant difference between any of the groups.

Group	N	Mean	Std. Dev.	p-value
Group 1	202	174.9	62.3	0.075
Group 2	100	169.1	61.0	
Group 3	257	160.7	56.1	
Group 4	8	153.9	67.7	
Total	567	167.1	59.6	

Table 3.4 Full results from the Tukey test comparing final exam scores for the four different groups. There is no significant difference between any of the groups.

	p-values for each comparison			
Group #	1	2	3	4
1	x	0.856	0.056	0.760
2		x	0.631	0.898
3			x	0.989
4				x

Figure 3.5 A screenshot of a typical Webcast. The Webcast page shows the video alongside action items. The Webcast can also be downloaded by clicking below the video.

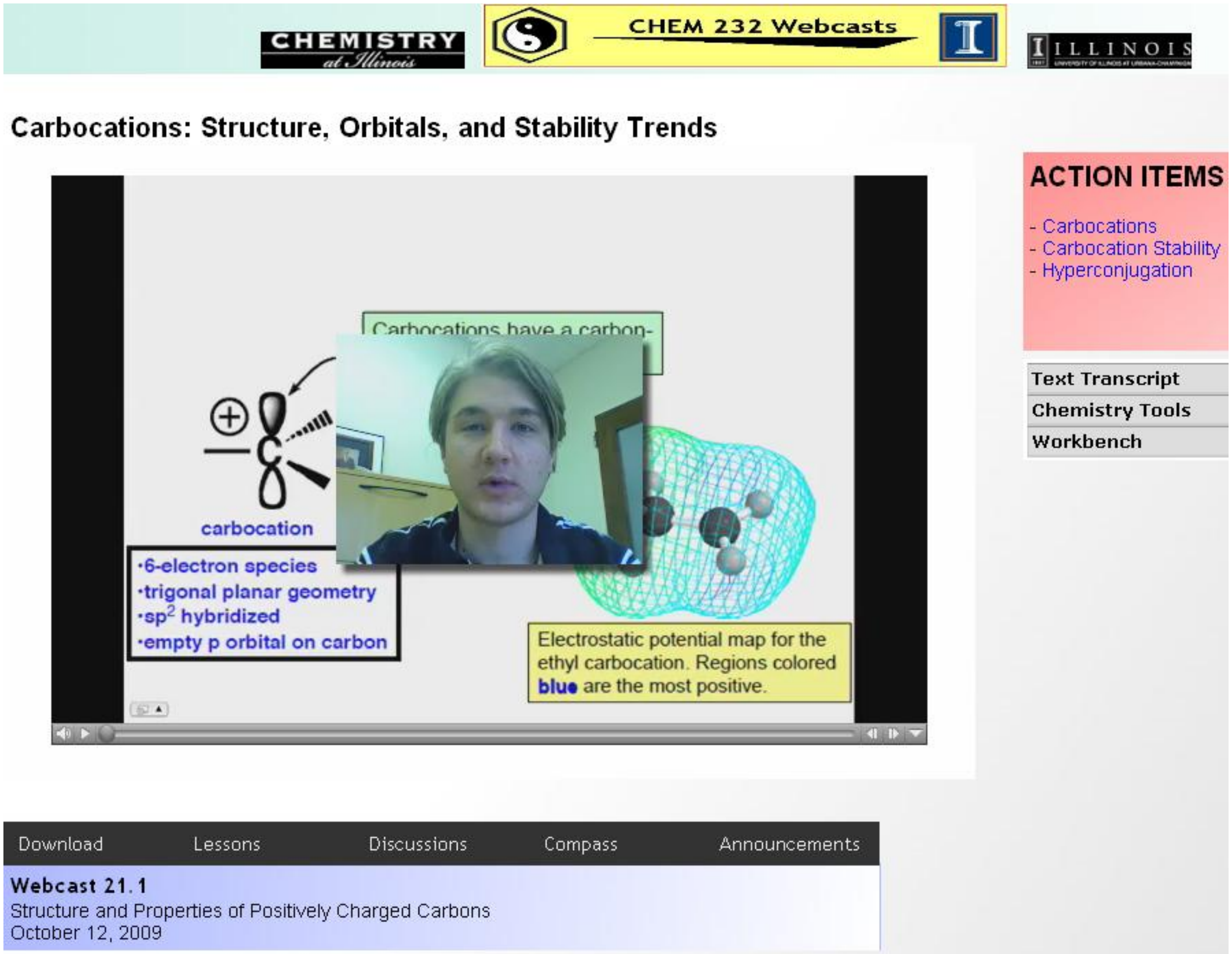


Figure 3.6 A screenshot of a typical Lesson webpage. The lesson webpage contains links to archived discussions, the course announcements, the Webcasts within the lesson, the WTF? Poll, the problem of the day, the discussion board, the course notes, ACE Organic, and a link to subscribe to course announcements via an RSS feed.

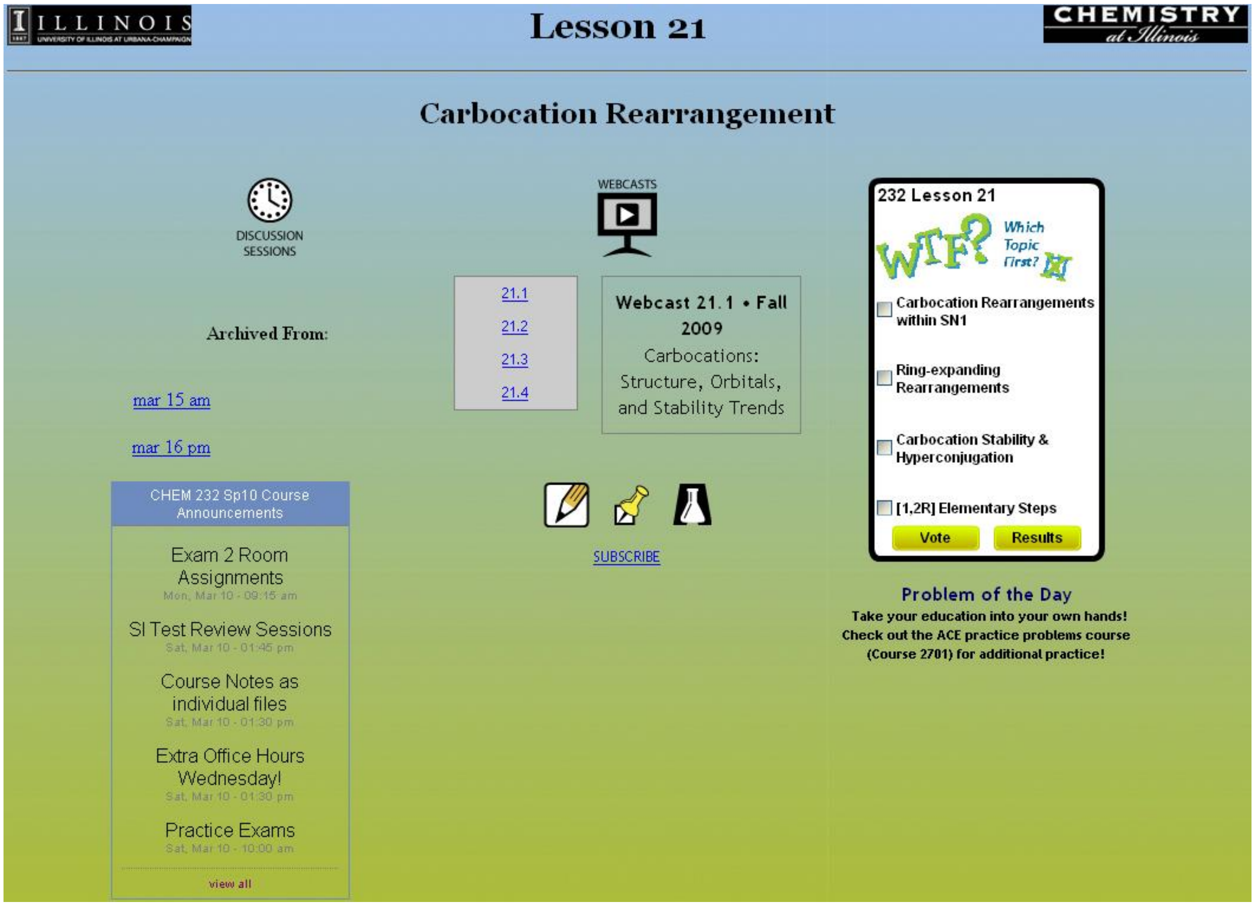


Figure 3.7 Percentage of lecture material viewed by students in spring 2009. Students overwhelmingly chose to watch Webcasts instead of longer 50-minute lectures. The number of students surveyed is 236.

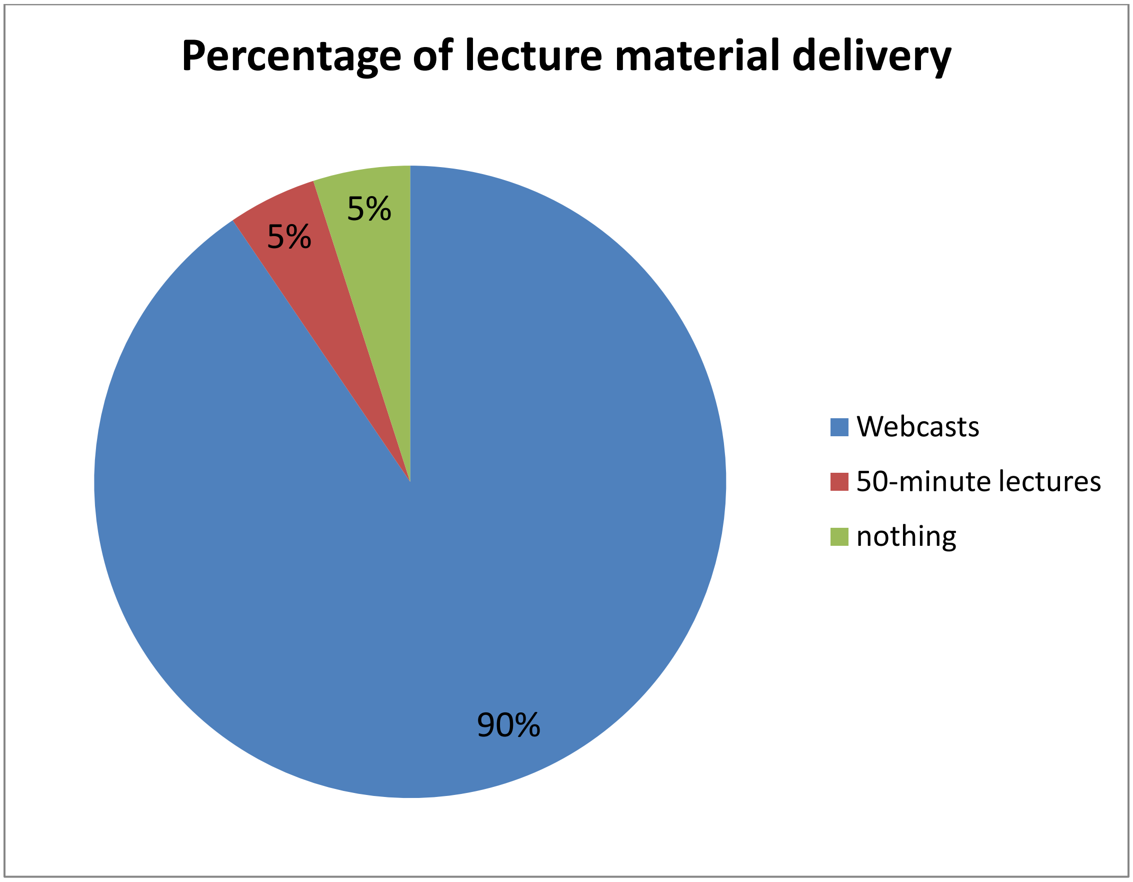
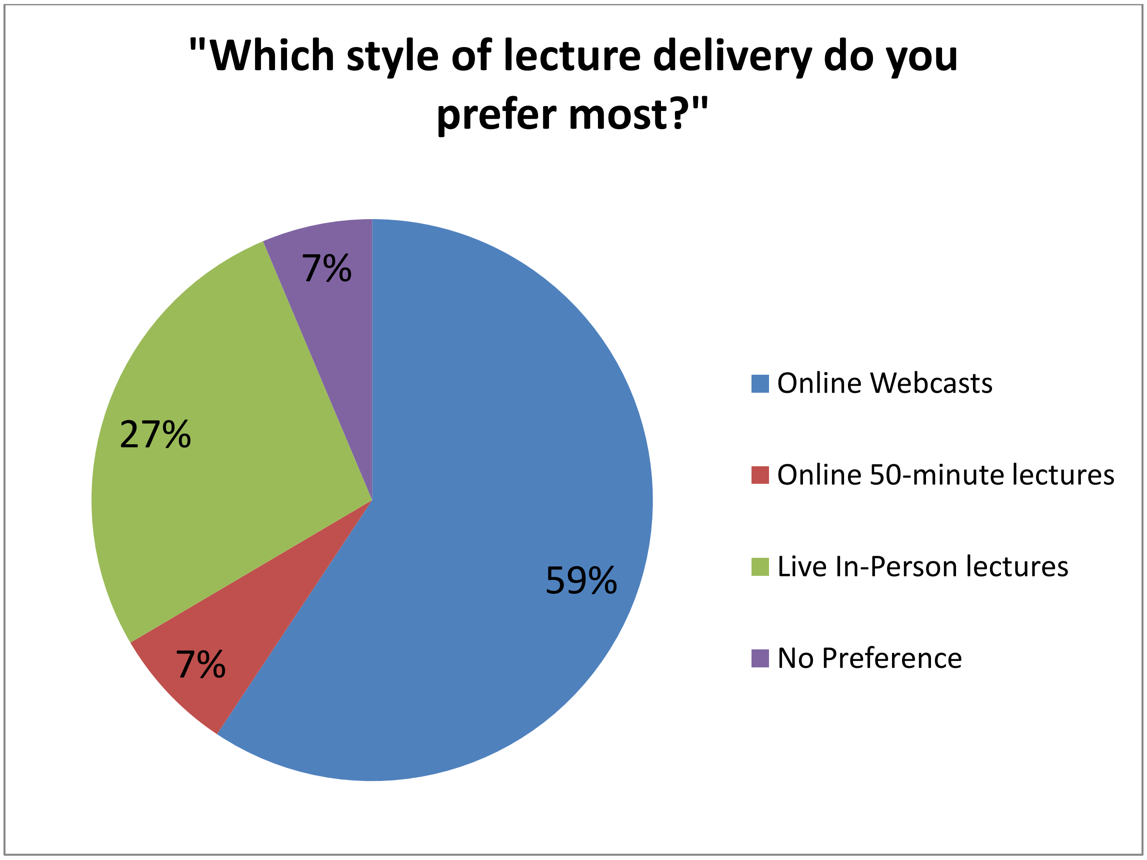


Figure 3.8 Students' preference for lecture delivery in spring 2009. The majority of students preferred to view online Webcasts over online 50-minute lectures and live in-person lectures. The number of students surveyed is 236.



CHAPTER 4

ONLINE OFFICE HOURS AND DISCUSSION

4.1 ONLINE OFFICE HOURS

4.1.1 Introduction

An important aspect of a traditional course is office hours, the time set aside for asking questions of the instructor and teaching assistants. Students often find office hour sessions invaluable when working homework problems or asking questions that they cannot answer themselves. Office hours are also a way to work on problems both with the instructor and with other students so that students can learn by doing in a group atmosphere. Office hour sessions prove even more valuable in large lecture courses that do not have discussion sections with teaching assistants. Providing some interaction between the instructor and student is crucial to raising students' emotional involvement in the material.[1] This raised emotional involvement leads to higher intrinsic motivation for students, which in turn raises student satisfaction with the material.[2,3]

A major challenge in attempting to offer online courses in organic chemistry is to offer an online equivalent of these tutorial sessions so that students can have their questions answered and not feel disconnected from the instructors. Although several online courses offer discussion boards and email contact, these forms of communication are not interactive in real-time and consist of just text with static pictures sometimes attached. Oftentimes, students will not be able to articulate a particular functional group in text and would rather ask their question in a more dynamic way with gesticulations. Although this capability is available in sending pictures with structures and curved arrow notation drawn in, the time delay between the student's forming the question and the answer is variable, and the question is typically answered long after the question has left the student's mind. Real-time online office hours allow for immediate feedback to questions and give students more access to their instructors.

Once the need for online office hour sessions was realized, it was time to find appropriate software that provides a dynamic platform for students to express their thoughts. In 2004, AOL Instant Messenger (AIM) for "online office hours" was used in an attempt to offer immediate online feedback to students in a variety of locations. Based on anecdotal feedback from students, the sessions were a success for students who had to ask only one or two questions and if their questions were largely text-based. Students could ask one or two simple questions without having to travel to campus. These office hours were very popular during a blizzard when classes were cancelled and travel was hazardous. This program fulfilled the requirement of live-chat, but lacked the ability to send picture files in anything other than Microsoft Paint, the ability to answer several questions at once, the ability for students to collaborate with one another during the session, and the ability of students to gesticulate. Seeing the many drawbacks to relying on AIM for online office hours, a new program had to be found that addressed the issues raised above. Although several programs exist to help facilitate communication between people including iChat and Skype, Elluminate Live! was chosen for use in online office hour sessions.

4.1.2 Format of online office hours using Elluminate Live!

It has been shown that Elluminate Live! can be effectively used in teaching biochemistry,[4] so a transition to organic chemistry should be natural because large structures are drawn in both. Elluminate Live! provides students and instructors a variety of different tools that can be used to communicate directly with one another, such as: chatting, whiteboard, audio, video, and live application sharing (Figure 4.1). The application sharing capability allows students and instructors to share any applications open on their desktops so that everyone else in the session can view that person's desktop. An extra feature of desktop sharing is that control of the desktop can be given by an instructor to anyone else in the Elluminate room. This feature is most useful when students are attempting to solve complex online homework problems on ACE Organic with the instructors watching and giving feedback along the way. This desktop sharing combined with audio, chatting, and alternating mouse control makes these online office hour sessions strikingly similar to live office hours. The desktop sharing also allows the instructor and student to use 3D modeling software to view complicated structures, an act which a traditional blackboard cannot accomplish.

Online office hour sessions have two advantages over in-person sessions. Online sessions allow off-campus students to participate, and the online sessions can be recorded so that students with a time conflict can view the material at their leisure. When these office hour sessions debuted in the summer of 2008, students were scattered throughout Illinois and were able to participate from the comfort of their own homes. Instructors also joined sessions from various locations, including airport terminals and hotel lobbies. Anywhere there is internet connection with appropriate bandwidth, anyone can log on and learn. Several students in the summer of 2008 were employed while taking the course, so a large portion of students were unable to attend office hours during the allotted times. A portion of these students, as evidenced by website tracking, viewed the office hour sessions on demand and could easily scroll to the moment where they needed help.

Although the new online office hours have the capability to effect change in learning, the question remained of whether they actually did. Because these office hour sessions were introduced in the summer of 2008 at the same time as other online components, no good control group could be created. In the absence of good quantitative data, qualitative data was gathered in the form of surveys and interviews to judge not only the effectiveness of the online office hour sessions in general but whether they are more or less effective than traditional live office hour sessions.

4.1.3 Design of Study

There were 37 students who took second-semester organic chemistry for non-majors at the University of Illinois at Urbana-Champaign (UIUC) in the summer of 2008. These students took the course which consisted of four different, entirely online components: five 50-minute taped lectures each week from spring 2008, 24 online homework sets on ACE Organic (roughly three per week), 33 50-minute office hour sessions using Elluminate Live! (roughly four per week), and four exams given entirely online (three hourly exams and one final exam). The students were given a survey at semester's end and were asked how often they viewed office hours, their opinions regarding office hours, and their opinions comparing these online office hours to live office hours they have experienced in the past. Thirty-one of the thirty-seven students responded to the survey.

4.1.4 Results and Discussion

The first question asked in the survey asked how many online office hour sessions students attended in real-time to interact with the instructors and with other students. The results (Figure 4.2) corroborate what the instructors knew already from hosting the online office hour sessions: attendance was low. The histogram shows a back-loaded distribution, showing that very few students attended real-time office hours with a median of two sessions per student. This median value of two real-time sessions attended per student is also consistent with the average attendance in office hours of two students out of 37 total students for a 5.7% attendance rate. This attendance rate is anecdotally similar to in-person office hour attendance rates in previous semesters.

Although having roughly two students each office hour session is disconcerting, a big advantage to these office hour sessions is that the sessions can be recorded and viewed at any time. Another question in the survey asked the students how many times they viewed archived office hours. The results (Figure 4.3) show a marked increase in the number of office hour sessions viewed over that of real-time sessions. The distribution is wider, and the median number of sessions viewed is 15 out of 33 (45.5%). This "archived attendance rate" is markedly higher than any previous office hour attendance rate. This rate includes several students who attended no real-time office hours because of work or other class conflicts but viewed every archived office hour session. The median number of total sessions viewed either in real-time or archived (Figure 4.4) is raised to 21 sessions out of 33 (63.7%). This added flexibility in material delivery allowed more students to receive guidance in the course material that would not have been available otherwise.

The higher attendance rate is certainly encouraging, but the point is moot if this extra time was not beneficial to students' learning. Students were first asked whether they found the online office hour sessions informative and a good way of learning course material. The results indicate that students found the online office hour sessions effective and informative (Figure 4.5). The average response was a 4.26 +/- 0.15 (Strongly agree = 5, Strongly disagree = 1). It is clear from this response that students believe online office hours were effective and aided in their learning of the material.

Not only are online office hours beneficial to students, but they are also at least equivalent to the in-person alternative. Students were asked to compare their experiences in online office hours with their experiences in live office hours in other courses they have taken. The results are mixed (Figure 4.6). The average response was a 3.17 +/- 0.23 (Online much better than live = 5, Live much better than online = 1). Clearly, students had mixed feelings about the effectiveness of the office hour sessions online versus in person. In the survey, students were asked to elaborate on their answer. Their responses can provide insight into the strengths and weaknesses of this online office hour set-up.

First, the major strengths of the course can be identified by looking at the open-ended responses from students who ranked the online system as better than live office hours. A typical response from the 20% of students who said that online office hour sessions were much better than live office hour sessions was: "I felt that you could address many more questions and work through them much better. It was a good tool to learn as a group. I also feel like it gives classes like orgo chem and other enormous sized classes a chance to have more one on one time." This student mentions how a larger number of questions could be addressed in the online format versus the live format and how the questions could be answered better. Of the 6 students who responded that online office hour sessions were much better than live sessions, 4 of the 6 mentioned the use of technology in answering questions and explaining concepts and in that the sessions could be replayed at a time other than the designated live time. Two of the 6 students mentioned that the online office hour sessions were their “favorite part of the course.”

A typical response of the students (17%) who mentioned that online office hours were somewhat better than live office hours is given here: “Office hours for normal classes often go unused. It is VERY helpful to be part of working through problems and hearing others' questions. Also, it is convenient and a trusty reference!” This student valued both the ability to reference the archived sessions while studying and the ability to work problems alongside other students in the course this student may not have met otherwise. All 5 of the students who gave this response mentioned how they liked the ability to replay sessions at their convenience and how technology was used to answer the questions discussed in the sessions.

A common response from the group of students (30%) who responded that online office hours were comparable to live office hours shows that many students still enjoyed the sessions: “I thought it was a fun atmosphere and it was a good way to have all of your questions answered and see exactly what you are doing wrong.” Of the 9 students who responded this way, 7 of 9 mentioned good aspects of the sessions similar to the response above and the positive responses about technology and replay. Seven also responded that they wished they had attended more sessions. Two of the 9 responses included a suggestion for improvement in that the instructors' responses were too long-winded. This is a valid point but is not related to whether the office hours were online or live.

Looking at the responses from those who ranked the online method as inferior to the in person equivalent can reveal some of the weaknesses of this method. A typical response from the group of students (27%) who responded that online office hour sessions were somewhat worse than live office hour sessions showcases similar points made by other students: “My schedule did not permit me to attend live office hours. I felt occasionally too much time was spent on certain problems, but overall it was a great tool for this online course. Without it, I wouldn't have passed.” This student mentions how the sessions directly conflicted with work; however, viewing the sessions at a later date was crucial to passing the course. Of the 8 students who responded this way, 5 of 8 mentioned that explanations took too long, and 2 of 8 mentioned technical difficulties. The technical difficulties mentioned by these students were issues with bandwidth and that the students kept getting logged out of the system because their internet could not handle the heavy traffic. This concern is a legitimate one that now arises when using online office hours instead of live office hours because bandwidth is never a problem in live office hours. The corresponding issue in live office hours occurs when the room gets too crowded, but then, students can just relocate to a larger room. This issue certainly needs to be addressed.

The explanations from the 2 students (7%) who mentioned that online office hours were much worse than live office hours were most intriguing. One student responded with the following: “I find in person office hours are so much more effective, as you can actually ask a detailed question without the technology delay…. That in person communication helps out, at least for me. A prof/TA can tell if you're really not getting the answer rather than just placating them by saying ‘I think I understand.’” This student was a non-traditional student who was admittedly unfamiliar with internet technology. This student also attended only 1 online office hour session in real-time, and viewed only 2 sessions archived. The student raises a valid point about the technology delay, and one method to overcome the delay is for students to use microphones to ask their questions instead of the chat box. Throughout the summer session, only twice did students use a microphone to ask their questions. One way to mimic the live office hour session is to ask and answer questions using voices instead of relying solely on text. The uses of microphones and webcams are improvements recommended in the future.

The other student gave an interesting response: “Well the problem is that I could not watch the live versions of the office hours due to a job, but then when watching the recorded version of one, some stuff that I was confused on was not covered nor was I able to ask. However, I only did try it once so other days might have been better.” This student has a valid frustration, in that the questions the student had were not answered because of a time conflict. To attempt to remedy this problem, before every office hour session, an online poll was set up asking students “Which Topic First?” (WTF?). This method allowed students to prioritize topics discussed in office hours even if they could not attend. If a student desired discussion on a topic, all the student had to do was to type the question or topic into the “Comments” section of the daily WTF? poll, and the instructors would discuss the question or topic in the next session. Unfortunately, response was surprisingly low for most of the WTF? polls with an average of 4 responses out of 37 students per session (11%).

Based on these findings from the office hour surveys, many students used the online office hours as a valuable resource whenever they needed to. Although students who participated in the sessions in real-time reported to have gained more from their use, those who could not attend still found the sessions at least as valuable as live office hour sessions. It is clear that online office hour sessions are viable options for discussing organic chemistry and give students in large lecture courses a chance to have their voices heard.

4.2 ONLINE DISCUSSIONS

4.2.1 Introduction

Discussion sections are also an important medium for students to communicate with an instructor. Live discussions have been a major component of education for some time. With the advent of the Internet and online education, the challenge is to see whether discussion sessions can be conducted effectively online. Online discussion sessions have been shown to be either just as effective as in-person discussions or more effective. Poirier and Feldman compared students who were in a face-to-face discussion but used an asynchronous discussion board with students who were in online discussion, and the students in the online discussion group outperformed the students in the face-to-face section on exams.[5] Campbell et al. also noticed the same results when comparing students who participated in face-to-face discussions and online discussions.[6] Research has shown that there is a great potential for learning in online discussion sessions. It is important to identify what aspects of organic chemisty discussion sessions can be translated to or enhanced by holding them online.

Group work can be one of the most valuable characteristics of a discussion section. Group work provides students with the opportunity to teach and learn from their peers. Teaching reinforces the information they have learned, and learning from peers can give students a fresh perspective on a topic. When students are split into groups, the groups themselves can be moderated either by the instructor, by TAs, or by the groups themselves. In online discussions, previous studies have given mixed results about which moderating style provides the greatest learning outcomes. Bernard and Lundgren-Cayrol show that a course which is largely based on collaborative projects benefits from minimal moderation by the instructor.[7] Another study during a pediatric clinical rotation showed that the group using a course instructor as a moderator performed significantly worse on exams than the group with students moderating themselves.[8] However, when the content being discussed involved either statistics or problem-solving, the group moderated by the instructor performed significantly better than the group moderated solely by peers.

The main conclusion to draw from these studies is that simple, collaborative tasks are better moderated by the students themselves, and tasks involving analytical skills are better moderated by someone with advanced knowledge of the subject. From anecdotal evidence from years of leading discussion sessions, not having a knowledgeable moderator nearby causes the students to stray off task or become silent when students in a group are all unaware of how to start a problem. It is for this reason that the online discussion sessions were run similar to Process Oriented Guided Inquiry Learning (POGIL).[9]

POGIL replaces lectures with an interactive, self-discovery approach that can potentially be applied to online discussion sessions. Students independently work in small groups to discuss problems on unfamiliar lesson material. Current POGIL studies demonstrate that smaller group discussions make learning more inviting and achieve higher academic success than traditional lecturing methods. As a result, students develop strong critical thinking and problem solving skills from working on discussion problems without attending lecture. Prior to a POGIL discussion, students are assumed to have no knowledge of the discussion material. Instructors assign four different "roles" for each group member including the manager, recorder, reflector, and presenter which students alternate roles during the semester. Unlike traditional lecturers, a POGIL instructor becomes a "facilitator" who assists students solving discussion problems.[10] Facilitators ask questions to reinforce concepts and guide students through a three step process known as the "exploration," "concept invention," and "application" phases. Students actively participate in small groups to interpret concepts in discussion problems (Exploration Phase). Facilitators encourage independent discovery for the student to answer a discussion question (Concept Invention). Interaction with other peers allow the student to verbalize and practice conceptual skills learned in discussion (Application Process).

Similar to POGIL is PLTL, another common pedagogy in science education that could be useful in designing online discussion formats. PLTL, or Peer-Led Team Learning, supplements lectures given in lecture halls.[11] In a PLTL workshop, each group has six to eight students per group, and meets in a weekly two-hour discussion on challenging problems written by undergraduates who had mastered the material in a previous semester. This undergraduate student leader also functions as a facilitator in these sessions. Past studies show that the PLTL method improved retention of material, exam performance, and a better attitude toward the course. In PLTL, group sizes vary between six to eight students, though the overall class size is not limited to a particular number. With the guidance of a peer leader, the workshop creates a supportive student environment, allowing participants freedom to explore ideas and challenging concepts during the discussion session.[12] Peer leaders do not carry an answer key but only provide helpful hints for problem solving.[13] Similar to POGIL, peer leaders assume the role of a facilitator and only assist students in problem solving when they experience difficulty. Leaders act as mentors rather than instructors.

Recently, the University of Illinois enhanced online education with Elluminate Live, synchronous discussion sessions that occur in real time with a moderator and other organic chemistry students. Elluminate simulates a discussion environment normally observed in a live classroom, maximizing a student’s learning opportunities across large distances. To connect all Elluminate users in the virtual environment, the names of all participants are listed in a column labeled “participants”. In a two-way voice over system, the use of headsets and web cameras enhance communication among all members.[14] Elluminate simulates a virtual discussion board and provides application sharing viewed simultaneously between users. Drawing tools provide users the ability to share information during the real-time discussion. Presented below is a study on the effectiveness of how a particular student discussion environment impacts overall student performance. Comparing a virtual, online environment using Elluminate Live with a live, classroom environment, this study concentrates in improving higher-learning methods supported by distance education, redefining the way students discuss organic chemistry problems in Chemical Education.

4.2.2 Design of study

In the fall of 2009, 602 students took first-semester organic chemistry for non-chemistry majors at the University of Illinois at Urbana-Champaign (UIUC). This research is part of IRB# 09445. At the beginning of the semester, students took an optional survey asking about their class standing, major, and ACT Math scores. Both types of discussions met three times a week for fifty minutes. Students attending either in-person or online discussions worked in small groups of about four to eight students on discussion problems provided in a organic chemistry workbook. For in-person discussions, the professor lectured for roughly fifteen minutes and divided students into small groups to work on discussion problems. Facilitators guided groups who struggled with a particular problem. The lecture hall regrouped to review key points expected to be understood from the discussion period. Similarly, moderators facilitated online discussions in Elluminate Live, a virtual classroom that used headsets, microphones, and chat boxes to discuss organic chemistry problems. Moderators used web cameras to communicate with students and enhance the virtual classroom experience. One of the moderators lectured for roughly fifteen minutes, placed six to eight students in virtual rooms, and gave them time to discuss problems. Students viewed discussion problems on a virtual discussion board and used drawing tools to communicate during the problem solving process. Moderators moved between rooms and guided students through problems as followed by the POGIL system. Near the end of the session, moderators brought students back to the main room to discuss important concepts they learned from the discussion problems.

The effectiveness of student discussion and a student's grasp of discussion material were evaluated in both in-person and online environments. To minimize subjectivity and inconsistent evaluation between the two discussion environments, a general evaluation rubric was created to appropriately score each student. The rubric consisted of three categories pertaining to an element of an effective discussion. Category A focused on the level of student engagement in learning and the student's own motivation to learn in a discussion section. Category B evaluated a student's comprehension of material and ability to recall concepts. Last, Category C assessed the types of questions a student asked and the question's degree of relevance to the discussion. Each student scored between 1 and 5 on a Likert scale in each category, where "5" was the maximum and "1" was the minimum. A student who received a "5" in Category A showed a high level of productivity when working on problems in his discussion workbook and appeared to be engaged in his workbook. For Category B, a score of "5" was given to a student who gave an accurate, relevant comment such as "a racemic mixture has equal quantities of both enantiomers." Lastly, a student given a "5" for Category C asked intellectual and relevant questions at least once during the discussion. An example asked by a student includes, "Why does this particular dissociation of an electrophile (D_E) step have electrons entering an empty p-orbital?"

The evaluation rubric and scoring system was used in in-person and online discussion sessions. Each in-person session began with a brief summary of important concepts. Regularly, there were roughly 80 students in an in-person discussion, and each was required to turn in a sheet of paper with their name and the number on their seat. Students observed during discussion were documented with the appropriate scores in a seating chart, corresponding to the correct seat occupied by the student. There were two student evaluators who collected the data.Evaluated student scores and their seat number was manually matched and entered into a digital spreadsheet.

Each online session began with an overview of the lesson. Moderators used the remainder of the hour to have students work through practice problems in separate rooms. Evaluators in the online discussion observed student discussions under the name "Inactive." The two evaluators attended all online discussion sessions (separately) and on average between twenty and eighty students per session were evaluated. Evaluators moved between rooms and assessed student discussion based on evaluation rubric in real time. The evaluated student was documented with their appropriate score into a digital spreadsheet after the discussion.

4.2.3 Results and discussion

The first inquiry is whether the different types of discussion give different learning outcomes. Students were tracked to see how many times they attended one of the following discussion types: 1) in-person discussion, 2) online discussion in real-time, 3) PLTL style SI sessions, 4) in-person Merit sessions, and 5) online discussion asynchronously. The students were then evaluated based on their total score for the course. A multiple linear regression was run on these five independent variables, and all variables were found to be significant in helping predict the total score in the course (dependent variable) with the exception of the number of archived discussions viewed (Table 4.1). Therefore, the archived discussions were removed from the regression, and the analysis was re-run. The new model now has all components significant (Table 4.2).

Even though all of these variables are significant in the multiple linear regression analysis, the model itself has an adjusted R^2 value of 0.076. This value shows that just these components may be useful in predicting a student's performance, but do not adequately predict the performance on their own. Other factors play a much larger role in addition to the ones shown in the analysis. This analysis also suggests that there is no significant difference in student performance between the online and in-person discussions, as the correlation coefficients for both are very similar. No other conclusions can be drawn about the other variables from this analysis alone.

The second question is whether student activity in discussion plays a significant factor in their learning outcomes. The hypothesis is that more active students perform better than less active students, and that attending and being inactive will have no effect on student performance. A multiple linear regression was performed on the three engagement variables, and only one variable gave a significant result – "B" (Table 4.3). Therefore, "A" and "C" were removed from the analysis, and a simple linear regression was run on just "B" and total points (Table 4.4). This regression shows that the student's average "B" score raises his/her total points in the course by 25.00 times what that "B" score is. Based on this analysis, there was no significant effect in performance based on whether the student seemed engaged in the material (A) or whether the student asked good questions (C). Although the coefficients are negative for these two engagement variables, the results are not significant. These are not surprising findings because students who do not seem interested in the discussion may see no need to discuss the material because they already understand it. Also, students who ask more questions could very well be students who do not have a good grasp of the material, so their scores could be lower than students who do not ask questions to their group. Certainly, more work needs to be done on this topic.

There was a significant effect in student performance based on engagement variable “B” in that students who made more insightful comments during group work performed better than students who made no comments. However, the adjusted R^2 is only 0.061. This is not a surprising finding because students who provide more pertinent comments during discussion probably have a better grasp of the material. This analysis shows that more needs to be measured instead of just whether questions are asked or whether student appears engrossed in the material.

The third question that was investigated was whether the student’s GPA, ACT Math score, or grade in General Chemistry II had an impact in predicting performance. The hypothesis is that they should. A multiple linear regression analysis was run to develop a model for predicting total points based on these three variables (Table 4.5). All of the variables were found to be significant. These three variables explain the data 5 times better than the previous two models as evidenced by the adjusted R^2 value of 0.339. 33.9% of the final score can be predicted by the knowledge and ability level that students enter the course with and are unrelated to anything specifically done by outside influences during the course.

The fourth question investigated is whether SI attendance or Merit on its own is necessary. Students consistently comment on the value of SI sessions and Merit sessions, so the effect of these sessions was investigated. A simple linear regression analysis (SLR) was performed to investigate the performance improvement from attending each SI session (Table 4.6). Also, a two-sample t-test was run to compare students who attended at least one SI session with students who did not attend any (Table 4.7). Another two-sample t-test was run to compare students who attended Merit with students who did not (Table 4.8).

For the SLR on number of SI sessions attended, the results were found to be significant with an adjusted R^2 of 0.026. Each SI session that was attended provided a roughly 6.54 point improvement in total points. Based on the analysis as well, attending at least one SI session significantly improves a student's score. Therefore, attending SI sessions is a significant factor in improving learning outcomes, but attending SI does not tell the full story.

The analysis on Merit attendance shows that Merit is not a significant factor in improving student performance on its own. This result comes with a caveat in that the Merit TAs are not bad. The error lies with the students and what is expected of them. Anecdotally, students who attend a Merit section tend only to attend Merit and do nothing else, including seek help from the instructor or any other resource. What the students need to do is to seek extra help and not rely on Merit to teach them everything, as it clearly will not. Another error is in the format of a Merit session. Merit sessions only meet once a week, and the sessions do not include computer work. Because all exams and homework are completed online, the students should be exposed to more practice online instead of on paper. To make the Merit sessions more effective, sessions need to be twice a week and involve computer work.

The fifth question investigated is whether there is some model that encompasses everything that has been discussed to accurately predict a student's overall performance. The initial model includes 1) total in-person discussions attended, 2) total online discussions attended in real-time, 3) total online discussions viewed archived, 4) GPA, 5) grade in Gen Chem II, 6) ACT Math score, 7) number of SI sessions attended, and 8) whether the student was enrolled Merit. The initial model was run using all the above variables, but not all were significant and the following were removed: viewed archived discussions and the number of SI sessions attended (Table 4.9). Therefore, the model was re-run after these insignificant variables were removed from the model (Table 4.10). Based on a previous analysis, viewing archived discussions was shown to be ineffective at raising learning outcomes, so it was no surprise that this variable was insignificant. The number of SI sessions attended being insignificant was somewhat shocking, but the reason can be seen in the color-coded variable correlation table (Table 4.11). SI attendance is highly correlated with attendance at in-person discussions sessions, so these two variables are confounded. By removing one of the confounding variables, a better model can be obtained. This overall model explains 36.1% of the data, thereby leaving much of the story untold. Other factors are at play in predicting student performance that need to be determined. Perhaps working practice problems, time spent on the asynchronous discussion board, quality of interaction, and studying over the course of the semester instead of just the night before could be significant factors. More studies need to be conducted to know for sure.

4.2.4 Conclusions

The conclusions that can be made about discussion sessions are that active students perform better than inactive students, and some form of a POGIL or PLTL discussion leads to small but significant improvements in student performance. Also, there is no significant difference in performance for students who attended a discussion in-person or online. Students can participate wherever they happen to be with an internet connection, and communication in any form leads to improved learning of the material.

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4.4 FIGURES AND TABLES

Figure 4.1 Screenshot of online office hour session

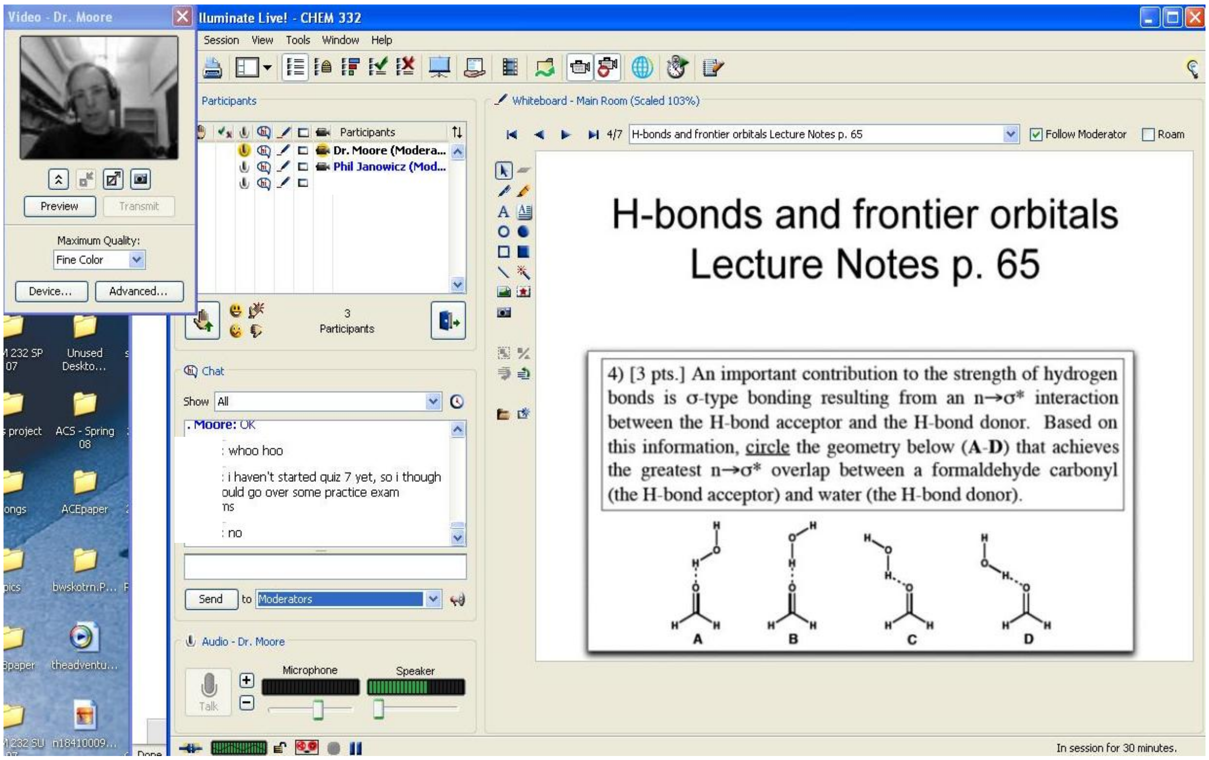

Figure 4.2 Frequency of students in summer 2008 who attended online office hours in real-time (median = 2 sessions). Attendance during office hours was light with not too many students attending in real-time. This class had 37 students.

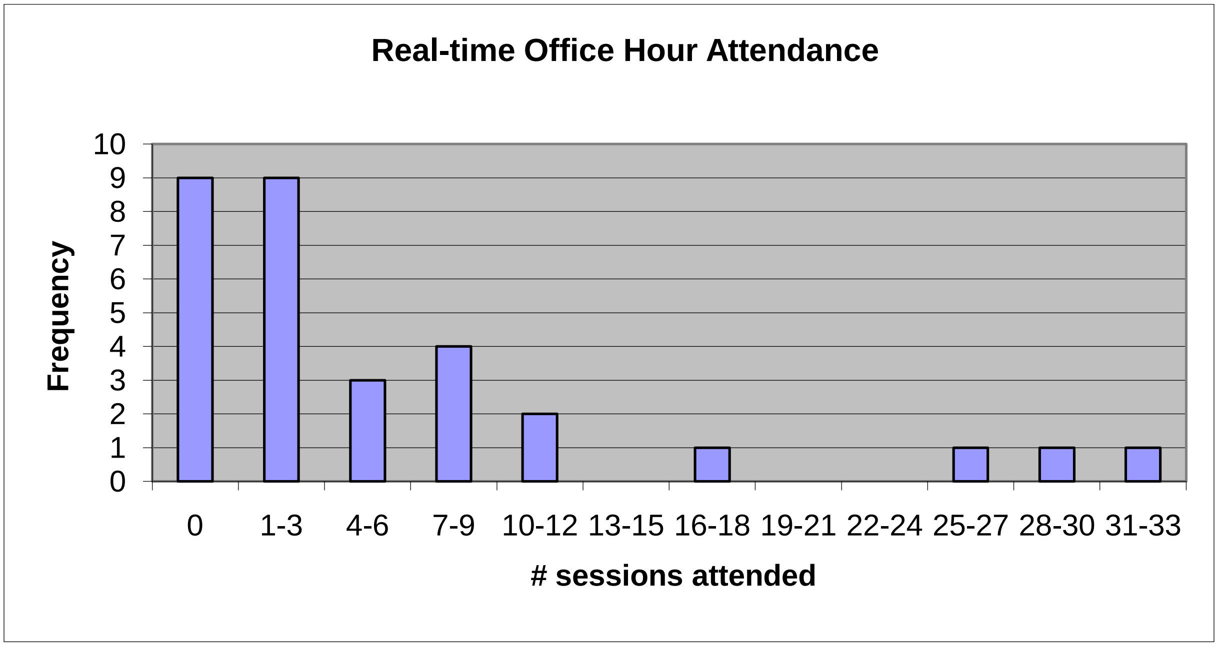

Figure 4.3 Frequency of students viewing archived online office hours in summer 2008. (median = 15 sessions) Students viewed more archived sessions than they attended in real-time. This class had 37 students.

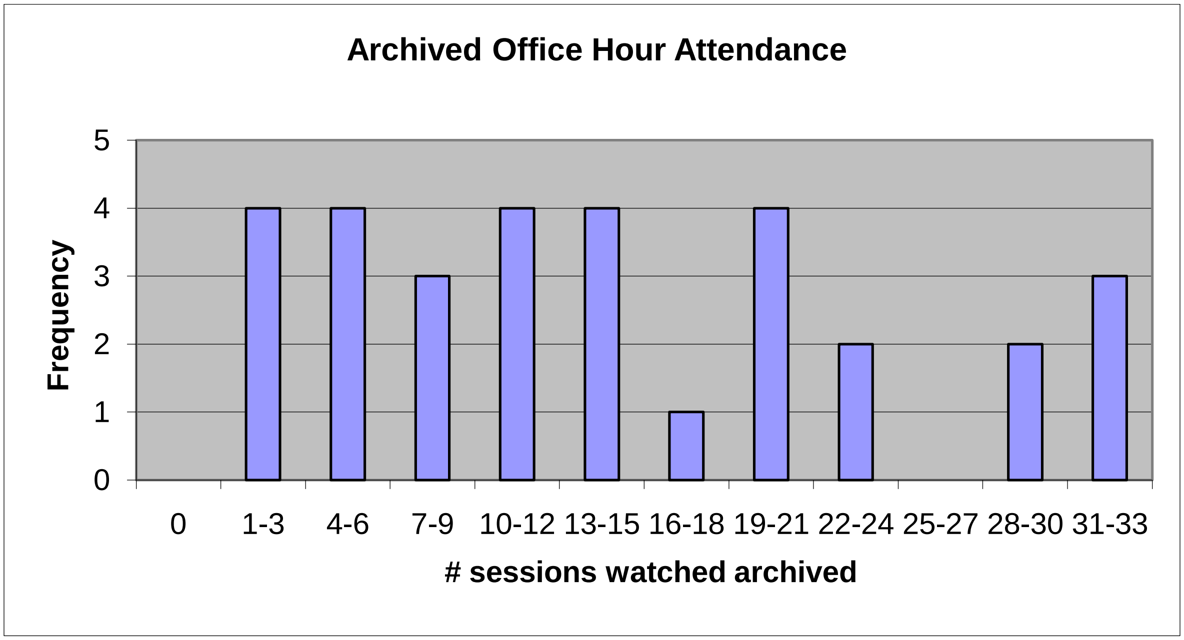

Figure 4.4 Frequency of students viewing online office hours in summer 2008 either archived or in real-time (median = 21 sessions). When the real-time attendance and archived views are combined, the average student viewed 21 sessions with 9 students attending or viewing between 31 and 33 sessions.

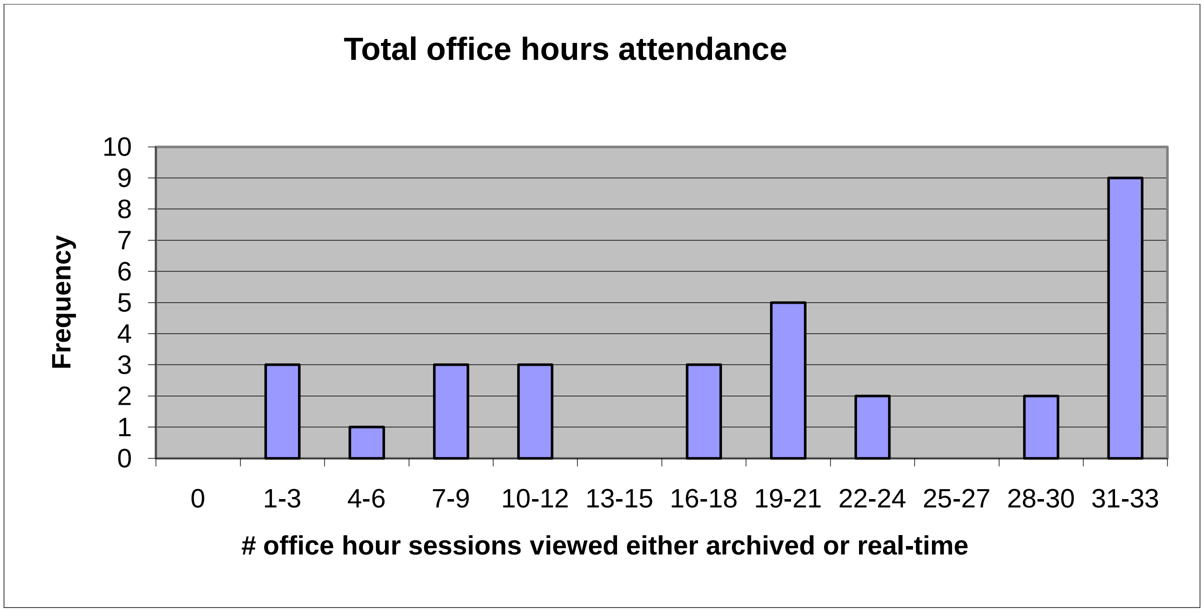

Figure 4.5 Responses to effectiveness of online office hours in summer 2008. Students found the online office hours to be effective.

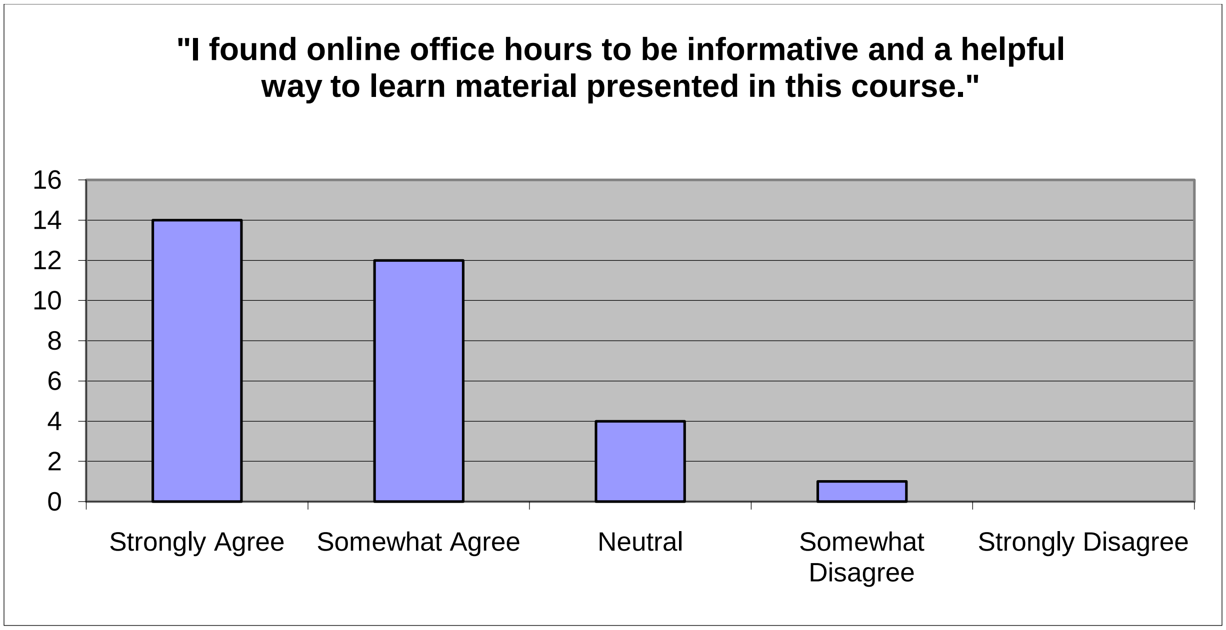

Figure 4.6 Responses to comparison of online office hours to in-person office hours in summer 2008. Students on average found the online office hours to be comparable to in-person office hours.

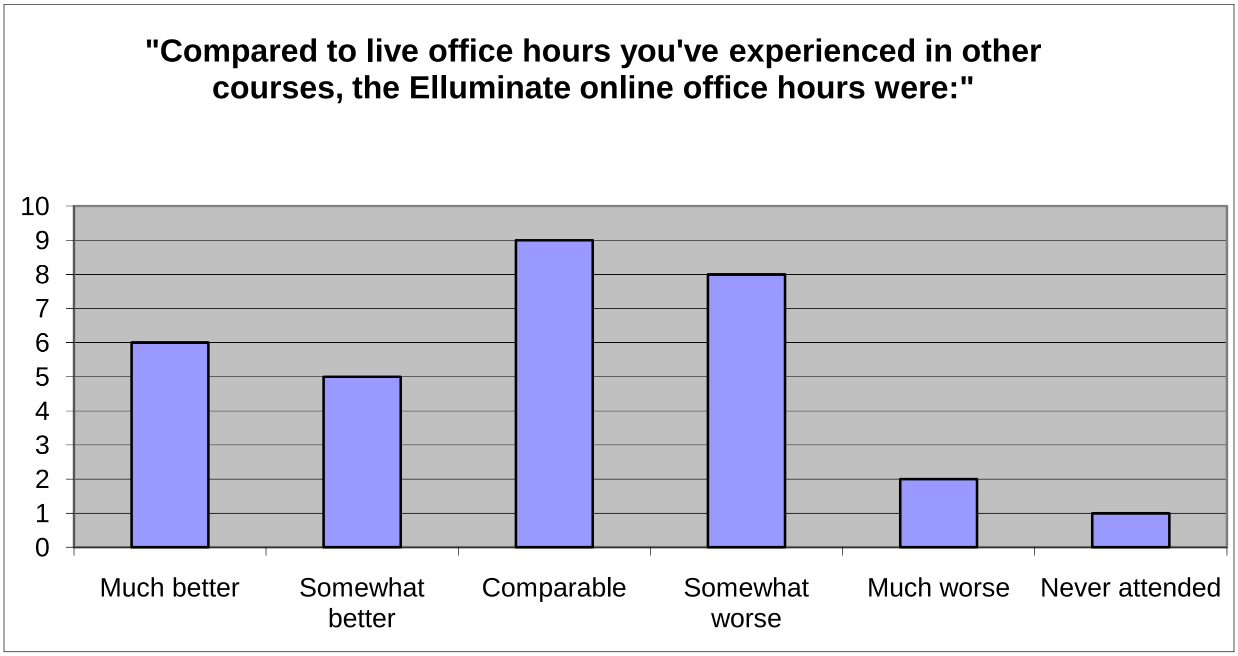

Table 4.1 ANOVA and Multiple Linear Regression (MLR) analysis on attendance at different forms of discussion. Note that there were 35 live discussions, 35 online discussions, 35 archived discussions, and 14 SI sessions. Merit attendance is a binary variable. Total archived discussions viewed was found to be an insignificant variable, so it was removed from the model, and the model was re-calculated.

ANOVA / MLR	*Coefficients*	*Standard Error*	*P-value*		
Intercept	681.28	8.22	1.2E-306		
Total Archived	1.61	1.10	0.146	Adjusted R Square	0.078
Total Live Discussions Attended	4.41	1.55	0.005	Observations	539
Total Online Discussions Attended	3.34	0.82	5.2E-05	*Significance F*	2.77E-09
Merit Sessions Attended (binary)	31.92	16.03	0.047		
SI Sessions Attended	4.19	1.75	0.017		

Table 4.2 ANOVA and Multiple Linear Regression (MLR) analysis on attendance at different forms of discussion after removal of insignificant variables. Note that there were 35 live discussions, 35 online discussions, and 14 SI sessions. Merit attendance is a binary variable. This model shows that students start with a base total point score of 685.03, and they gain 4.15 points for each live discussion attended, 3.81 points for each online discussion attended, and 4.34 points for each SI session attended. If students are in Merit, they receive 33.63 points added to their score.

ANOVA / MLR	*Coefficients*	*Standard Error*	*P-value*		
Intercept	685.03	7.81	0		
Total Live Discussions Attended	4.15	1.54	0.007	Adjusted R Square	0.076
Total Online Discussions Attended	3.81	0.75	5.62E-07	Observations	539
Merit Sessions Attended (binary)	33.63	16.00	0.036	*Significance F*	1.98E-09
SI Sessions Attended	4.34	1.75	0.013		

Table 4.3 ANOVA and MLR of the three different engagement evaluators. Based on the analysis, the "A" and "C" evaluators are not significant predictors of performance.

ANOVA / MLR	*Coefficients*	*Standard Error*	*P-value*		
Intercept	694.03	19.47	1.484E-96	Adjusted R Square	0.054
Averaged "A" Evaluation	-4.47	11.94	0.708	Observations	238
Averaged "B" Evaluation	30.01	12.95	0.021	*Significance F*	0.001
Averaged "C" Evaluation	-0.96	8.16	0.907		

Table 4.4 Simple Linear Regression of the only significant engagement evaluator "B." The results show that the more engaged students appear in solving the discussion problems, the greater their performance in the course. The "B" evaluation is able to explain 6.1% of the variance in the data.

Simple Linear Regression	*Coefficients*	*Standard Error*	*P-value*	Adjusted R Square	0.061
Intercept	691.88	18.77	6.86E-100	Observations	238
Averaged "B" Evaluation	25.00	6.16	6.76E-05	*Significance F*	6.76E-05

Table 4.5 ANOVA and MLR on the effects of ACT Math score, GPA, and grade in Gen Chem II in predicting performance. ACT Math score is a range between 0-36; GPA is between 0.00-4.00; grade in Gen Chem II is a binary variable with no overlap between grade choices. The abilities the students have when they enter the course accounts for 33.9% of the variance in the data.

ANOVA/MLR	*Coefficients*	*Standard Error*	*P-value*		
Intercept	-115.16	90.63	0.204	Adjusted R Square	0.339
ACT Score	6.07	1.35	8.09E-06	Observations	492
GPA	113.68	14.67	5.59E-14	*Significance F*	2.3E-41
A+	326.05	79.38	4.71E-05		
A	282.50	76.28	2.37E-04		
A-	286.71	77.06	2.22E-04		
B+	292.90	75.69	1.24E-04		
B	268.47	75.25	3.96E-04		
B-	234.74	76.93	2.40E-03		
C+	262.49	75.34	5.39E-04		
C	245.02	75.29	1.22E-03		
C-	272.85	78.65	5.70E-04		
D+	177.51	85.05	3.74E-02		
D	0	0	1		

Table 4.6 Simple Linear Regression (SLR) performed on number of SI sessions versus total points in the course. The number of SI sessions attended is significant and has an increase of 6.54 points per session attended. SI attendance accounts for 2.6% of the variance in the data.

SLR	*Coefficients*	*Standard Error*	*P-value*	Adjusted R Square	0.026
Intercept	711.27	6.31	0	Observations	539
SI Sessions	6.54	1.68	1.08E-04	*Significance F*	1.08E-04

Table 4.7 Two-sample t-test comparing students who have attended at least one SI session with students who have not attended any SI sessions. Results are significant with >99.999% confidence.

t-test	*NO SI*	*SI*
Mean	704.40	750.75
Observations	317	222
P(T<=t) one-tail	8.62E-06	

Table 4.8 Two-sample t-test comparing students who attended Merit with students who did not. Results are not significant at the 95% confidence level.

t-test	*No Merit*	*Merit*
Mean	719.84	748.39
Observations	470	69
P(T<=t) one-tail	0.052	

Table 4.9 ANOVA and MLR performed on all facets of the course. A score of D+ or D is not significant, and neither is the number of SI sessions attended. These variables were removed from the analysis, and the analysis was run again. The reason the number of SI sessions attended was not significant is that it is positively correlated with the number of live discussions attended, so removal of one of these variables makes for a better model.

ANOVA / MLR	*Coefficients*	*Standard Error*	*P-value*		
Intercept	-19.02	63.90	0.766	Adjusted R Square	0.363
A+ or A	152.93	40.36	1.71E-04	Observations	492
A-	161.09	41.91	1.38E-04	*Significance F*	7.64E-44
B+	167.08	39.61	2.95E-05		
B	142.40	38.90	2.79E-04		
B-	110.63	42.07	8.81E-03		
C+	135.64	39.16	5.81E-04		
C	118.03	39.12	2.69E-03		
C-	149.51	44.98	9.56E-04		
D+ or D	0.00	0.00	1		
ACT Score	7.38	1.35	7.67E-08		
GPA	103.40	14.61	5.29E-12		
Total Live Discussions Attended	3.28	1.36	1.66E-02		
Total Online Discussions Attended	2.45	0.65	1.85E-04		
Merit Sessions Attended	36.16	13.76	8.87E-03		
SI Sessions Attended	2.25	1.57	0.153		

Table 4.10 ANOVA and MLR performed on all significant facets of the course. This model explains 36.1% of the variance in the data. Note that there were 35 live discussions, 35 online discussions, and 14 SI sessions. Merit attendance is a binary variable.

ANOVA / MLR	*Coefficients*	*Standard Error*	*P-value*		
Intercept	-19.42	63.97	0.762	Adjusted R Square	0.361
A+ or A	155.17	40.37	1.38E-04	Observations	492
A-	163.40	41.93	1.11E-04	*Significance F*	2.75E-44
B+	168.78	39.63	2.48E-05		
B	143.85	38.93	2.45E-04		
B-	112.29	42.10	7.90E-03		
C+	136.37	39.20	5.50E-04		
C	120.11	39.14	2.27E-03		
C-	151.27	45.01	8.40E-04		
ACT Score	7.14	1.34	1.61E-07		
GPA	105.83	14.53	1.34E-12		
Total Live Discussions Attended	3.91	1.29	2.58E-03		
Total Online Discussions Attended	2.54	0.65	9.55E-05		
Merit Sessions Attended	35.69	13.77	9.85E-03		

Table 4.11 Correlation table for course components in fall 2009. Green corresponds to positive correlation; red corresponds to negative correlation; yellow corresponds to mild or no correlation. The table shows that students who attended live discussion also attended SI sessions but did not attend online discussion. Students who attended SI sessions also have higher GPAs. A higher ACT Math score correlates to a higher GPA but negatively correlates to attendance at live sessions. A higher GPA, however, correlates positively to all forms of attendance, especially SI sessions.

	ACT Score	*GPA*	*Total Archived*	*Total Live Discussions Attended*	*Total Online Discussions Attended*	*Merit Sessions Attended*	*SI Sessions Attended*
ACT Score	1						
GPA	0.197	1					
Total Archived	-0.012	0.122	1				
Total Live Discussions Attended	-0.098	0.139	-0.173	1			
Total Online Discussions Attended	0.025	0.147	0.427	-0.158	1		
Merit Sessions Attended	-0.089	0.036	0.072	-0.070	-0.012	1	
SI Sessions Attended	-0.100	0.192	0.062	0.346	0.077	-0.034	1

CHAPTER 5

ONLINE EXAMINATIONS

5.1 INTRODUCTION

The most difficult part of converting traditional courses to online courses was the exam. Life science courses have had online exams administered successfully in the past regardless of whether the lecture was in an online or face-to-face format. Scoville and Buskirk split students in a medical histology course learning microscopy into four groups: 1) face-to-face lecture and an in-person practicum, 2) face-to-face lecture and an online practicum, 3) online lecture and an in-person practicum, and 4) online lecture and an online practicum. There was no significant difference between any of these groups.[1]

Traditional examinations in organic chemistry involve a myriad of question types: chemical structure drawing, mechanism drawing, conformer/chair drawing, labeling atoms, labeling functional groups, and planning syntheses. Many attempts to put organic chemistry exams online have either transferred every question to a multiple choice format or are essentially not online exams. Completely "online" courses currently available at Oregon State University, Drexel University, and North Carolina State University (NC State) do not have valid online exams. Oregon State has students travel to a proctoring site to take a written exam which is subsequently mailed back to Oregon State for grading.[2] This procedure has a two-week turnaround from taking the exam to receiving a grade, and then the exam is never returned. NC State employs a similar format to Oregon State except the written exams are faxed to NC State for grading.[3] The exams are also never returned to the students. The grading and feedback systems are so disconnected from the thought processes involved in completing the exams that it is difficult to perceive that any knowledge is truly gained from the process of completing the exams. Students are certainly not learning from their own mistakes because their exams are never returned nor can they view their results.

At Drexel University, the exams are completely online, but they are all multiple-choice and ask definition questions such as, "Which of the following is an example of a Claisen condensation?"[4] Rudimentary definition and surface-level questions such as the one mentioned above are far from proper measures of organic chemistry assessment because that knowledge does not demonstrate the problem-solving capabilities necessary for a successful organic chemist. A major problem with many of the current online organic chemistry systems is that they are largely multiple-choice based systems in which structures, mechanisms, stereochemistry, and syntheses are diluted to conform to the inherent constraints of multiple-choice questions. It is difficult to ask pertinent organic chemistry questions involving structure drawing, mechanism drawing, stereochemistry, and synthesis through a multiple choice format. A strong online assessment for organic chemistry should allow students to submit structures and mechanisms. This allows students to demonstrate that they know the details of the structures and chemical reactivity of organic molecules. Also, the false positive rate (i.e., guessing or Type I error) is much lower for structure drawing and mechanism drawing than for multiple choice because basic knowledge of organic chemistry must be known in order to submit any feasible answer. Ideally, the lower the Type I error is, the more robust the assessment.

Merely subjecting students to multiple-choice organic chemistry exams does not tap into the learning potential of the students of the Net Generation. As Barnes et al. notes, "While appealing to the media proficiencies of Net Generation students can yield the short-term advantages of increased student engagement, such a shift often caters to those students who seek to complete work with a minimum of effort. The dilemma in this case arises from pedagogical strategies that effectively conflate knowledge with mere information management while failing to tap into the positive potential of the Net Geners' orientation towards learning."[5]

In order to successfully probe the problem-solving capabilities of our students, we needed a medium for students to draw structures, mechanisms, and syntheses and have them be gradable instantly online. The instant grading is necessary because of the TA resources available for grading. A viable online assessment technique exists in the ACE Organic system which is used for homework and is discussed in Chapter 2. The program comes packaged with MarvinSketch to input chemical structures. MarvinSketch also has several tools that allow students to calculate the pKa of protons in a molecule, calculate ^{1}H NMR shifts, and minimize structures and display them in 3D. This 3D capability allows students to view any structure in 3D and rotate/zoom it however they see fit. Therefore, every student is equipped with an electronic molecular model kit that can be accessed promptly with the click of a button.

ACE Organic also contains the necessary features for quality online exams: instant grading and instant feedback. Structures can be input and are converted to their (x,y,z) coordinates. These coordinates are matched with evaluators that judge whether the structure is correct based on these coordinates, and the answer is instantly judged as either correct or incorrect upon submission. Students are told whether they are right or wrong (ROW feedback), but no other feedback is given. The reason students are not given additional feedback during the exam is that the guided feedback would be different for each student who inputs specific incorrect answers. The exam is a time for students to demonstrate what they know and whether they can troubleshoot their errors autonomously without the guidance of a human or digital instructor. Since the instructor is not present to give specific guidance on content to the students during the exam, the program should not either.

This chapter will discuss the first implementation of the online exam system as well as improvements and student reactions to the different versions of exams.

5.2 INITIAL ONLINE EXAMS

5.2.1 Introduction

In the summer of 2008, the traditional written exams for second-semester sophomore organic chemistry for non-chemistry majors were replaced by online exams using answer submission, grading, and ROW feedback as mentioned previously. This class had 37 students. Because this type of exam is novel and the point allocation is radically different from previous exams, no accurate quantitative comparison can be made with any previous semesters. Therefore, qualitative surveys were given at the end of the semester to gauge student perceptions.

5.2.2 Format of Exams

A series of questions were set up in ACE Organic, and students were given multiple attempts to answer the questions with ROW feedback. ROW feedback was given solely because this format mimics what students are accustomed to in a traditional exam setting, but there is no reason why feedback could not be added in the future should it be deemed both helpful and valid.

In the summer of 2008, points were allocated for each question based on two factors: the given maximum point value and the number of attempts each student took to answer the question correctly. Students were instructed to answer every question in as few attempts as possible and were told the grading scheme in the syllabus. Regardless of the number of attempts, students were given half the value of the maximum point value on the problem if a correct answer was submitted. The other half of the points was dependent on the number of attempts. Each incorrect attempt reduced the score by one point until half of the maximum points was subtracted.

For example, suppose a question worth 10 points is answered correctly on the 1st attempt. The total points earned for this response is 10 — 5 points for getting the correct answer and an additional 5 points for getting the correct answer with no miscues. If a question worth 10 points is answered correctly on the 4th attempt (i.e., three incorrect submissions were made before correctly answering the question) then the total points earned for this response is 7 — 5 points for getting the correct answer and an additional 2 points for getting the correct answer after three miscues. A third example is if a question worth 10 points is answered correctly on the 6th attempt. The total points earned for this response is 5 points — 5 points for getting the correct answer and 0 additional points for getting the correct answer after five miscues. Finally, a question worth 10 points is answered correctly on the 14th attempt, and a total of 5 points is earned for this response — 5 points for getting the correct answer and 0 additional points for using too many attempts to answer the question to earn additional points.

5.2.3 Security

Similar to the event of administering written exams, security measures must be taken to prevent cheating on online exams. One measure taken was that the exam was split into two parts: a part printed on paper containing the exam questions and a part posted online with the answer choices. This method was used in case a student was able to hack into the online question server or if a student somehow procured a copy of the paper exam. Either way, students need both components to make any sense of the exam. Also, the added benefit is that students who still desire written exams/papers in front of them to draw on are supplied with scratch paper.

When the exams are taken online, students can feasibly take exams wherever there is Internet access. In the summer of 2008, students took the three midterm exams and final exam from various locations throughout the state of Illinois. Although it was possible for students to take the examinations from their own home computers, there was no way to validate a student's identity while taking the exam. To combat this potential security threat, students were required to find proctor locations. Students used the IllinoisOnline network to find local libraries and community colleges for students to travel to for exam purposes. At the proctoring location, students had to show an appropriate ID to be allowed to take the exam.

Another aspect of the online exams is that students were allowed open access to their resources (books, notes, and Internet) but no help from another person. The policy was called the "everything but a friend policy: non-friends also apply." However, students could roam the Internet — another potential security risk. Students were specifically told not to contact other people either by IM, blogging, Twitter, or even Facebook statuses, but there was no way to restrict access of the Internet to all sites without allowing students to use the Internet as a resource. An effort to prevent this type of "disallowed help" was to monitor every student's desktop remotely using the application sharing feature in Elluminate Live!, the same program used for online office hours (see Chapter 4). Students were moved to their own private rooms in Elluminate Live! so that they could neither communicate with one another nor view each others' desktop screens. If a moderator (proctor) wanted to view a specific student's desktop, the moderator simply needed to move into the student's private room. Then the moderator could monitor the student taking the exam without interfering with the student's thought processes. If problems happened to arise on a student's computer, the student could communicate directly with the online moderator through Elluminate Live! by using the "hand-raising" feature to get the moderator's attention and then ask a question in the chatbox. If a problem arose at the testing center such as Internet failure or computer crashes, the on-site proctor alerted the moderators of the problem via phone, and the student was allowed extra time to compensate for the time lost during the glitch.

Exams were allotted 2 hours, and time was kept for all students simultaneously with a universal clock displayed via Elluminate Live!. Extra time allotments for glitches and other unforeseen issues were added on for individual students, and the students were informed of their time through the chatbox and by the timer present on the screen (Figure 5.1). Typically, around one percent of students would have glitches, almost all of which were from students not following instructions.

5.2.4 Results and Discussion

It was judged that comparison of exam scores between the different exam formats would give meaningless data. Therefore, qualitative surveys were given to students during the summer of 2008. First, students were asked to rate the format of the online exams (Figure 5.2). Thirty-one of thirty-seven students responded to the survey, and the responses were largely positive. The average response was a 3.87 +/- 0.14 (Excellent = 5, Very Poor = 1). Over half the students who responded rated the exam format as "good."

Although the exam format was rated positively by students, a true measure of success is the comparison of the online exam format to the traditional written exam format. The students were then asked to compare the online exam to written exams (Figure 5.3). The results of this survey were mixed with an average of 3.13 +/- 0.17 (Online exams much better than written exams = 5, Written exams much better than online exams = 1). Students rated the online exams as not significantly different from paper exams.

Students were also asked to comment freely on their perceptions of the online exams, and their responses are interesting. The most common response on how online exams are better than written exams was the ROW feedback. One student remarked that he liked the instant feedback, "because you got to know if you were right or wrong, and it gave you a chance to do it over again with partial credit." Another student added the following: "Given the tough nature of chemistry tests, I was very relieved to be able to know whether I got the problem right or wrong. That way, I could try a different approach if I knew I did it incorrectly the first time." Conversely, a subset of students also felt that the instant feedback was detrimental to their testing taking process. One student wrote the following: "I'm not a very good test taker, so I do like knowing if I got a question right, but I also get discouraged and easily frustrated when I see I got a question wrong." Another student noted that "being able to see if your answer is correct can do dramatic things to your confidence (both positive and negative depending on the outcome)."

These results seem to indicate that a disparity exists between student confidence levels while taking exams. Since the survey results were anonymous, there is no way to correlate the student's perceived confidence level with the student's grade or with other student characteristics, so any further discussion on this subject would be pure speculation. However, it is known, that the student who mentioned feeling frustrated when told that a question was answered incorrectly admitted to being "not a very good test taker." It is possible that the highest-performing students would not have their confidence fluctuate by seeing an incorrect answer, but further studies would have to be done on the subject to confirm or disprove this notion.

The second most common response from the survey describing how online exams were better than written exams was being able to surf the Internet. For example, one student noted the following positive aspects: "being able to look up the research paper the question is based off of; ability to look up lecture notes and Bruice pages corresponding to the questions; ability to open SHMO or Jmol and get further insight." Ten of the thirty-one responses mentioned positive appreciation for using the Internet as a resource and the ability to bring notes and flashcards into the exam with them. The examinations probed the students' ability to think and not their ability to memorize, and the students responded positively to this change.

By far, the most common complaint from students is echoed in the following comment: "NO PARTIAL CREDIT!! With as many mechanism problems as we had to do, it was tough not having partial credit (not the multiple submissions type), but the type that you get for drawing most of the structure and arrows correctly but maybe missing one or two things....on a test as difficult as an ORGO test, I think this type of partial credit is a must." This student, along with 21 of the 31 who responded, was very adamant about not receiving "partial credit" on the exams. At least this student along with 3 others acknowledged the fact that the attempt-based grading was some form of partial credit. However, 17 students were either unaware of this fact or did not state this in the survey. One student noted the following: "I can get partial credit on written exams if my work is close to a right answer unlike the online exams." The type of "partial credit" this student is referring to on written exams does not adequately gauge the students' ability to solve problems and troubleshoot.

On written exams, students are given one opportunity to answer a question before submitting the answer for evaluation. When the exam question is graded, the grader must see how closely the answer on the exam matches the answer on the key. If the match is not perfect, the grader must then decide how close the answer was based on previously established rubrics. The student is then awarded some arbitrary number of points, and the problem is now an afterthought barring a regrade request. This method of assigning partial credit looks at only a snapshot of the students' thought process and cannot accurately gauge the students' problem solving abilities. If the student possesses the problem solving abilities necessary to solve the problem, then the student should be allowed to demonstrate them. One method is by using ROW feedback and informing the student that the first attempt is incorrect and thereby allowing the student to learn from his/her mistake and attempt to solve the problem again another way. If the student is unable to solve the problem given as many attempts as necessary, then the student never initially learned the material and lacks the ability to learn the material during an exam setting. If these skills are not demonstrated, then no student should receive credit for possessing skills that are not there. The old method of "partial credit" was necessary when students could not be asked to solve the problem in a different way, and the graders had to infer what the students may have been thinking based on the first and only submitted answer. Now that students' thought can be further probed, the old method of partial credit is moot.

Viewing of the student's desktop was initially used as a security measure to make sure no online communication / conversations were taking place, but it was soon discovered that vast insight could be gained into a student's thought process. Moderators could watch students build molecules, search Google and Wikipedia, answer randomly in true/false questions, and answer mechanism questions to see the most common errors made in real-time. This ability has the potential to reshape both assessment techniques and the material presented to the students during lectures and problem solving sessions. If educators can better see how students solve problems, then both assessment and teaching techniques can be improved to correct some of the incorrect problem solving methods employed by students. Educators can also gain insight to the effectiveness of their teaching strategies by watching a student attempt to solve a problem, in real-time, that is remarkably similar to one discussed during lecture. An assumption made by many educators is that the material mentioned many times in lecture is learned, but, as we discovered, this assumption is false.

For example, students had to complete an assignment in which they used the Simple Hückel Molecular Orbital Calculator (SHMO) to look at π-systems of heterocycles. Because students were required to use this tool when completing a homework assignment and because they were specifically told that a few questions would involve using SHMO, it was assumed that nearly all students would at least have the tools to solve the problem even if the problem solving abilities were not present. However, 36% of the students in the summer of 2008 were unable to use SHMO properly. Students were adding atoms that were not in the correct hybridization state, as specifically asked in the question. One student asked a moderator how to use SHMO, and when no assistance was given, the student proceeded to read the online instruction manual. It was certainly the mistake of the instructor to assume that all knowledge presented in class was absorbed by the students, but it was fascinating to see during a live session.

5.3 IMPROVEMENTS TO ONLINE EXAMS

5.3.1 Residual Points

Online exams are being used in second-semester organic chemistry at the University of Illinois at Urbana-Champaign, but the enrollment is much larger than during the summer session. Also, the grading procedure needed minor modifications as students were able to easily guess and receive points. These issues of scale-up and the grading procedures had to be addressed for larger classes.

The first change was the grading procedure. Instead of arbitrarily setting the value for a correct answer at half the total points, the value was changed to a variable number based on the difficulty and type of question. Questions now have both a maximum point value and a number of "residual points." For example, a question is worth 5 points and is given 2 points of "residual credit." If a student submits an answer only once and gets it right on the first try, the student gets the full 5 points. If the student gets the question correct in 2 attempts, the student receives 4 points. If the student answers the question correctly in 3 attempts, the student receives 3 points. If the student answers the question correctly in 4 attempts, the student receives 2 points. At this point, the "residual points" are used in that every subsequent attempt does not decrease the points scored if the student answers the question correctly. Therefore, if the student answers the question correctly in 5 attempts, the student still receives 2 points. The same applies if the student takes a large number of attempts to answer the question correctly. Just as before, if the student does not answer the question correctly, the student receives 0 points, regardless of the number of attempts.

The number of residual points per question is varied so that some questions that do end up being either multiple-choice or extended true/false questions are not given any residual credit; leading to a decrease in the incidence of a Type I error. Higher difficulty-level questions, such as multi-step mechanisms and 3D conformer questions, are given larger residual point values. These questions are much more conceptual and more difficult to answer such that getting the question correct, even after many attempts, can be achieved only if the student has indeed learned the concepts either initially or by working through the question during the exam itself.

The change in grading procedure effected a change in the distribution of grades on the first exam in the fall of 2008 (Figure 5.4). The lowest score on exam 1 with the original method of scoring was 41 out of 100, and the average was a 63.5. Also, the distribution of exam scores was heavily skewed toward the bottom end with much clustering. Conversely, the lowest score on exam 1 with the "residual points" scoring method was 11 out of 100, and the average was a 47.0, a statistically significant drop of 16.5 points. Although the distribution of this exam is also skewed toward the bottom end, the level of clustering has diminished, leading to a better distribution of scores. This wider distribution gives merit to the validity of the revised grading assessment.

5.3.2 Consolidation of exam questions and submission

One common complaint from students was the separation of the questions and answers (one on paper and one online). Students complained that they either have to write the answer choices on paper to be able to read them with the questions or that they get frustrated looking down at the paper and then back at the screen. At first, this separation was for security reasons, but after having tested the exam procedures and the security features of the programs used, it is highly unlikely for a security breach to occur without the knowledge of the instructors. Therefore, in later semesters, students received both the questions in ACE Organic along with the answer choices and blanks so that everything is together, and the answer choices for non-structure drawing questions were placed on the paper copy so that time is not wasted copying. We have opted for this at the small risk in security compromise.

It is not necessary for the paper copies of the exam to be present anymore as they create a new security hazard in that students have double the opportunities to copy down information from the exam to give to their friends. Therefore, in spring 2010 for first-semester organic chemistry for non-chemistry majors, students were no longer given paper copies of the exam. When students were asked to give feedback on the exam format in a similar way to exams in previous semesters, no student mentioned that a paper copy of the exam would have been helpful on either of the first two exams. Therefore, printing the exams was no longer necessary, and the cost of photocopying could be cut from the budget.

5.3.3 Problems from scale-up

In the many incarnations of online examination scale-up, there have been a few challenges. The exams still take a total of 5 minutes from the end of the exam to grade and upload to the course management system, and there is adequate bandwidth to proctor the increased number of students. Whereas during the summer session, a 7:1 student:proctor ratio was used, the ratio jumped to 23:1 in fall 2008. The old method of having every student in the same Elluminate Live! session was too hectic to hold over 100 students. To relieve some of the tension associated with looking after so many students, the total number of students in each session was split into groups of no more than 30 students and placed into different Elluminate Live! sessions. Each session was run by one online proctor, and students were still kept in private rooms to prevent communication among students. This arrangement worked well for the class size of 199 in the fall of 2008, but this arrangement had to be altered when the class size grew even larger.

In spring 2009, the class size grew to 320 students, and the biggest limitation was the number of available computers on campus for administering exams. Because only 90 computers were available, the exam had to be split into four different time periods spanning two days. The added time periods certainly increased the security risk of the exam's leaking to students in a later time period. There was not ample time to create completely different exams, and any new exam would not be able to be accurately compared to an old exam without an external metric. For example, a student who scored an 80% on one exam could not be accurately compared with a student who scored a 60% on another exam. It was for the time constraints and also the accuracy that extra exams were not created.

In order to help combat the security risk, more computers were used to administer exams in the fall of 2009. The class size grew to 700 students, and 400 computers were available. Based on the limitation of available computers, exams could now be put back into two time slots on the same day, thereby reducing the security risk. The new limiting factor, however, was the server capacity that housed ACE Organic. It was discovered that the previous server capacity of 5000 concurrent users in spring 2009 had been reduced to 120 concurrent users with no lagging in the server and 150 concurrent users with significant lagging in the server. Unfortunately, this limitation was discovered less than 24 hours before the first exam, so the students were subjected to several different exam formats in fall 2009. Exam 1 was a traditional paper exam with arbitrary partial credit; Exam 2 was a combination of a take-home exam and a mini-exam run on ACE Organic which had 26 different exams; Exam 3 was a scantron exam similar to the ACS Organic exam; the final exam was the same final exam on ACE Organic split into 6 different time periods of no more than 120 students.

Because the students were subjected to three different types of exam format – paper, ACE, and scantron – students were asked in a post-survey which exam format they preferred. No other study had been run in which the students were all subjected to all of the exam formats, so this is the first valid comparison of student opinions. Students were asked to rank the exam formats from best to worst, and the results can be seen in Table 5.1. The averages of the choices among the students with error bars are shown in Figure 5.5.

Students overwhelmingly preferred the ACE Organic format over paper exams or scantron formats. When students were asked to comment on their choices, the reasons for choosing became clearer. Students who liked the ACE exams enjoyed being able to answer multiple times and easily draw structures and mechanisms. Students who preferred the paper exams liked being able to draw freely and liked being able to get some credit for drawing something. Students who preferred the scantron exams liked the fact that they could guess and still receive points. Judging from the comments, students who did not have a firm grip on organic chemistry preferred some exam format that allowed them to receive points even when their knowledge of the subject was not present.

When the students were asked what they did not like about the formats, the comments had a similar tone to comments from summer 2008. Students who did not like the ACE exams did not like that they could not get points for being close to the right answer and did not like drawing structures on the computer. Students who did not like the paper exams did not like having to redraw structures by hand and be able to put down only one answer. Students who did not like the scantron exams commented that the exam was "too tricky" in that they wanted to answer more than one choice for each question but could only answer one. The trend is that students did not like being potentially tricked, wanted to be able to put down several answer choices, and once again wanted to get points when they did not know the full answer. Based on these comments, it is clear that student perceptions of the online exam are good, and the previous comments about lack of "partial credit" are more related to wanting free points.

In spring 2010, exams are still being capped at 120 students per exam session, but the total enrollment is 462 students. Therefore, only 4 exam times are necessary for all the students to take the exam. In the future, this server capacity should not be a problem if exams could be run from a working server or were changed entirely to a computerized adaptive format. More discussion on this aspect of online courses will appear in Chapter 7.

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5.5 FIGURES AND TABLES

Figure 5.1 Screenshot of a student taking an online exam in summer 2008

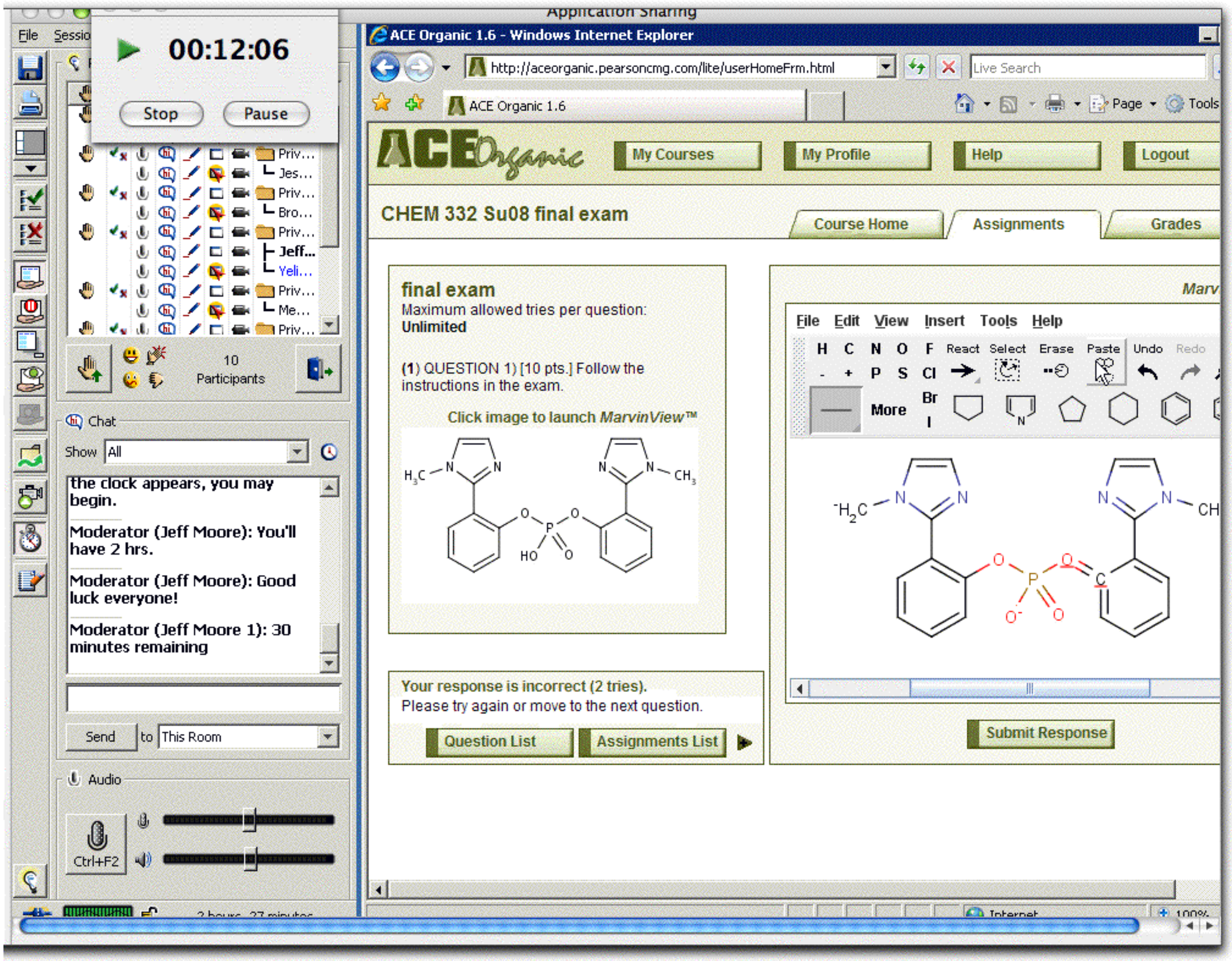


Figure 5.2 Student perceptions on exam format in summer 2008. Students rated the online exam format as good on average.

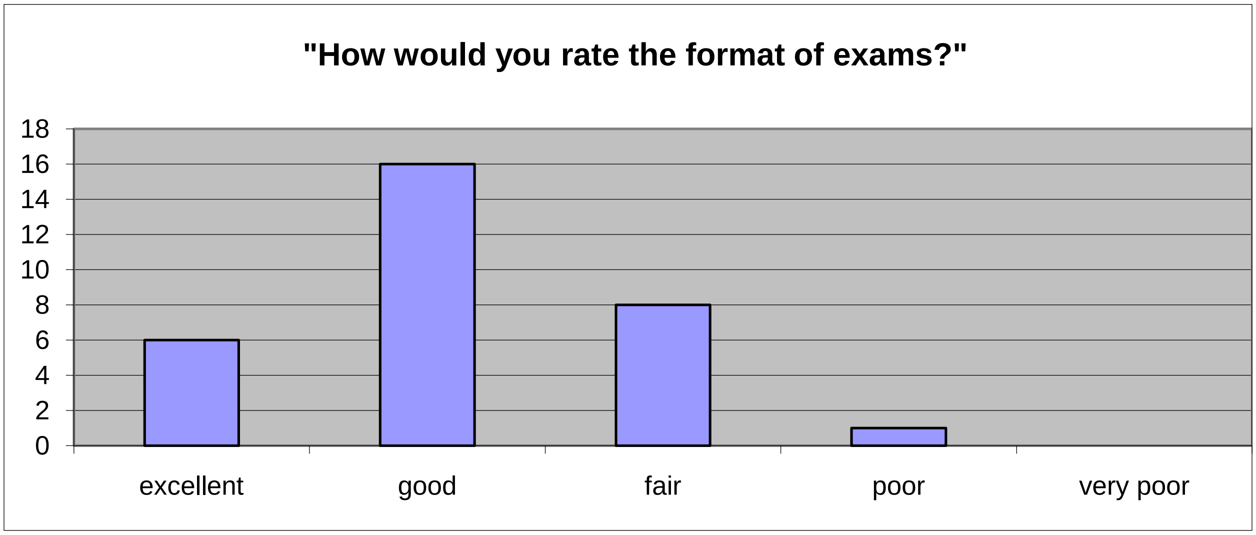


Figure 5.3 Student perceptions comparing online exams to written exams in summer 2008. Students on average rated online exams as comparable to written exams.

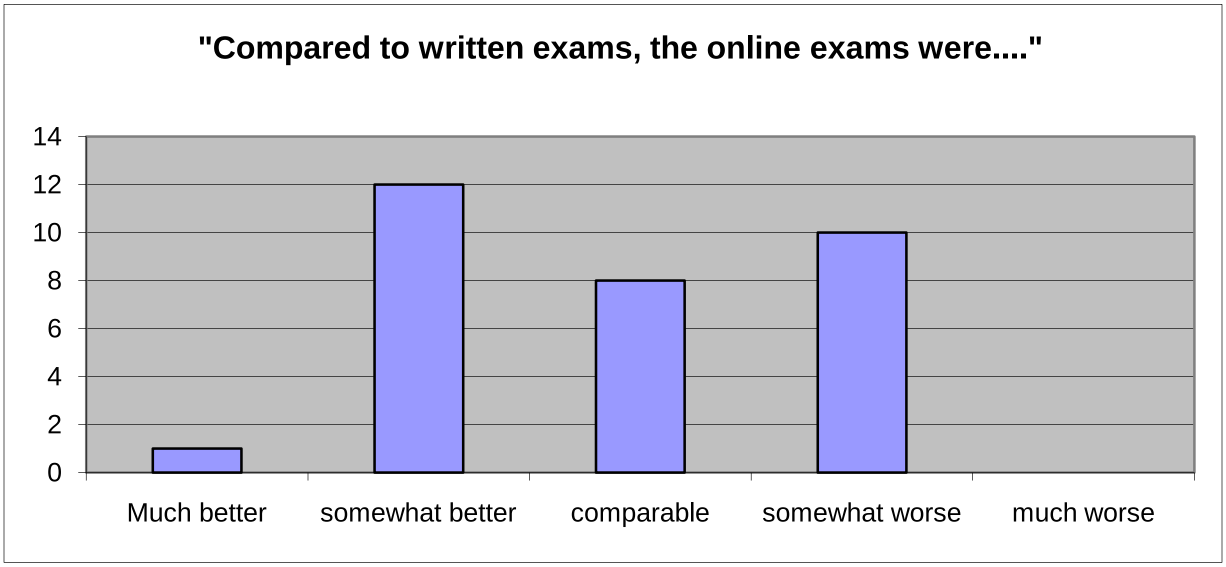
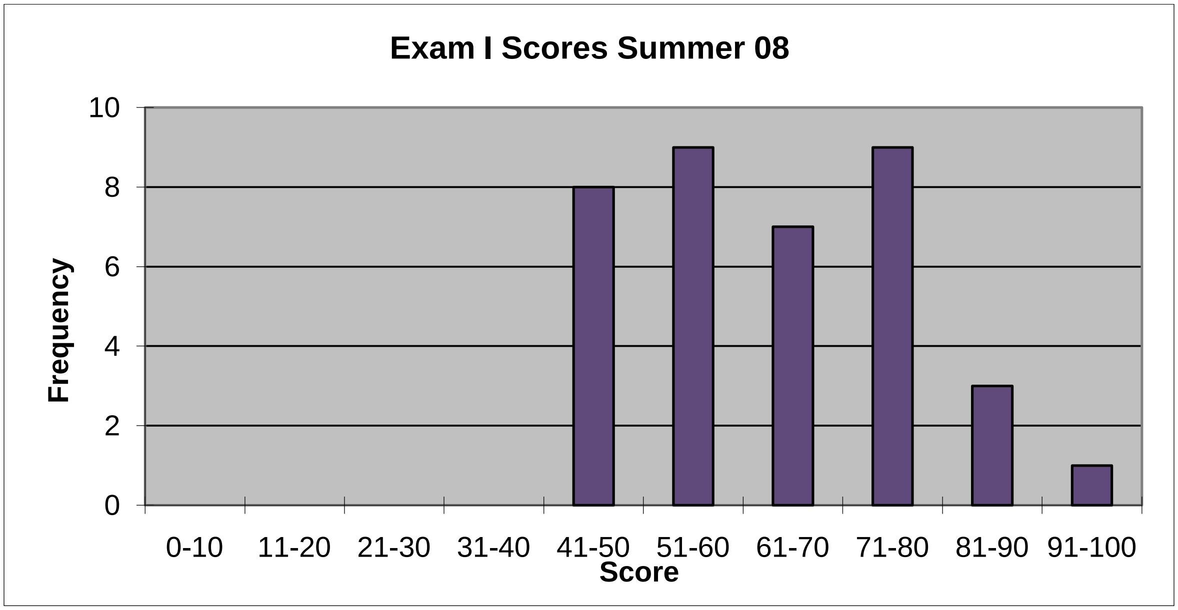


Figure 5.4 Comparison of scores on Exam I. The scoring system involving “residual points” in fall 2008 led to scores that were more reflective of student knowledge than in summer 2008 in that the range and distribution were more spread out.



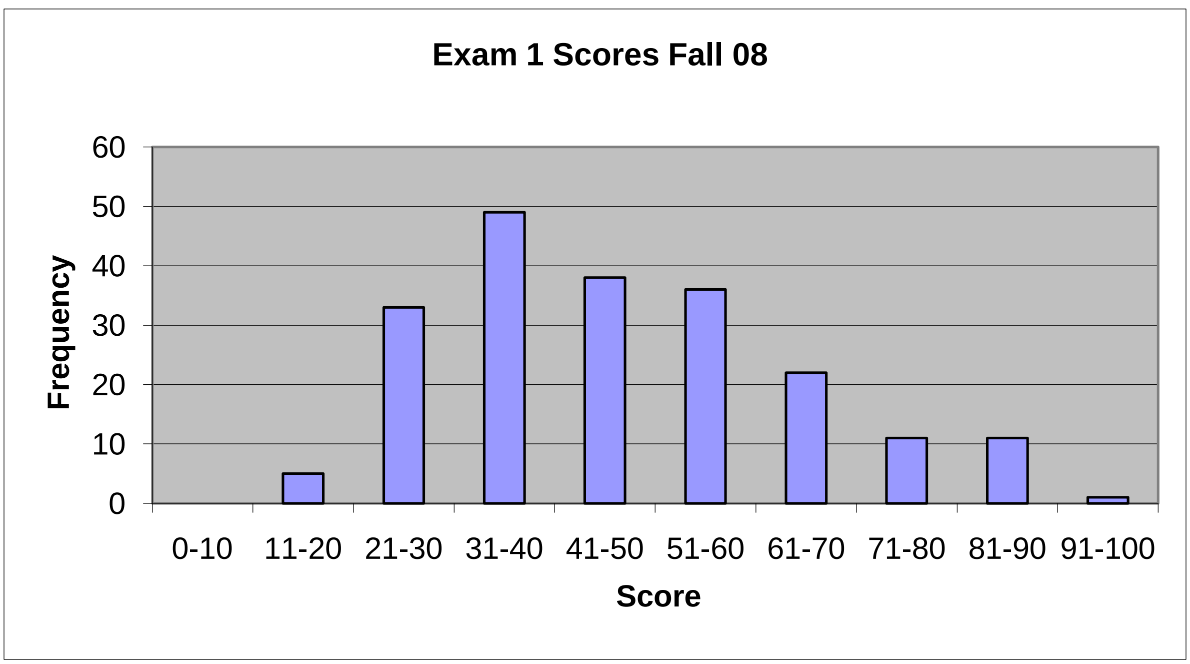
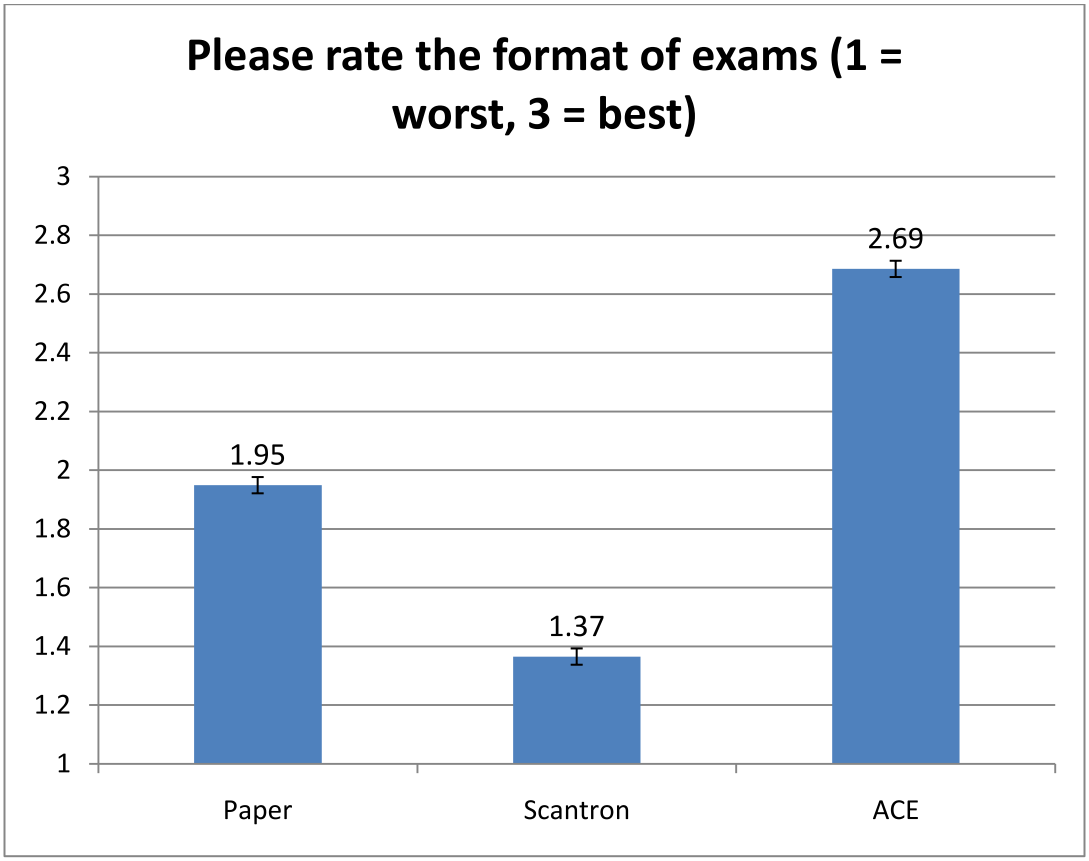


Table 5.1 Comparison of student opinions on exam formats. 471 students out of 602 responded (78.2%). A rank of 3 is the best, and a rank of 1 is the worst. Students overwhelmingly preferred the online ACE exam first, the written exam second, and the scantron exam third.

%	Paper	Scantron	ACE
3	15.7	7.4	76.9
2	63.5	21.7	14.9
1	20.8	70.9	8.3

Figure 5.5 Comparison of student opinions on exam format. The graph shows the average rank of each format along with error bars. This graph shows that students most preferred the online exam format over written exams and scantron.



CHAPTER 6

ENTIRELY ONLINE ORGANIC CHEMISTRY COURSE

6.1 INTRODUCTION

Entirely online courses reach students wherever there exists an internet connection and a desire to learn. An entirely online organic chemistry course using the exams discussed in Chapter 5 has never been created before the summer of 2008. Students around the world have the potential to learn together using the Internet not just using a method that rivals a traditional classroom but a method that exceeds what any previous course has delivered any time that the student wants to learn. It is organic chemistry on-demand.

Several challenges exist in moving a course entirely online, and these challenges are both theoretical and practical. Instructors must ensure that the proper Information Technology (IT) infrastructure is in place and that the course content itself is amenable to an entirely virtual setting.[1,2] Without proper IT support in the forms of server space, available campus computer labs, and proper training, an online course will not proceed smoothly. Thankfully, the University of Illinois has a talented IT staff who has been willing helpful through the course's creation. The next challenge was in moving the content online, but it has already been shown in the previous chapters that the different aspects of an organic chemistry course were effectively utilized in an online setting. Lecture material, homework, office hours, discussions, and exams have been individually moved into an online environment, so the only difficulty is in combining the different facets in similar yet distinctly different ways to how previous online courses were scaffolded.

Several other courses had been previously administered entirely online with student performance typically either on par[3,4] with or exceeding face-to-face learning.[5] A meta-analysis performed by the US Department of Education in 2009 looked at 51 studies that compared learning outcomes among various aspects of online learning, and the key finding from the meta-analysis was the following: “Students who took all or part of their class online performed better, on average, than those taking the same course through traditional face-to-face instruction.”[6] The meta-analysis does point out that in many cases the time students spent using online facets of courses was greater than the time spent in traditional courses, so the improvement could be due to the increased time on task. Although students may have spent more time working in online courses, one would have a difficult time arguing this as an unfair comparison. Also, another confounding factor is the difference in type of student who decides to take a course online. Perhaps, this type of student is different from the student who chooses only to take courses in person. One struggle educators have is increasing students’ active engagement in course materials. Therefore, if online components of courses facilitate an increase in students’ time-on-task, then that’s an added benefit that can only help to amplify understanding and reinforce core knowledge.

Other findings within the report show results that are more promising than a previous report by Russell.[7] When the US Department of Education meta-analysis looked at the question of how the effectiveness of online learning compares with that of face-to-face instruction, the results show a significant difference between the two at the 95% confidence level with purely online courses having higher learning outcomes in the form of exam scores.[6] Studies comparing blended learning (instruction with significant portions of learning both face-to-face and online) to face-to-face instruction showed that blended learning had significantly higher learning outcomes in the form of exam scores than face-to-face instruction alone at a greater than 99.99% confidence level. Clearly, online components have a positive effect on learning outcomes as evidenced by several other studies.[8-10]

There are several advantages to an online course or to a course with online components, and these advantages have been studied vigorously. One cited advantage to an entirely online course is the asynchronicity it affords the students.[11] Students can learn whenever they are available instead of being forced to learn at certain times. Another advantage to asynchronous learning is that students typically work alone and at their own pace, thereby making the learning deeper and self-reflective, crucial components in constructivist theory.[12-17] Students are able to collaborate with one another continuously, promoting an ongoing sharing of thoughts and ideas about the subject at hand using discussion boards, wikis, and chatrooms. This process allows all students to share their ideas instead of just the dominant students in a face-to-face, question-and-answer session.[18-20] Students' sharing of ideas online facilitates more communication than face-to-face and allows the student to reflect before submitting a question or explanation because the student must read through the question first or edit the video being posted.[21-22]

Another advantage to online learning is what McComb calls "increased social distance" — traits associated with race, appearance, and social status are rendered irrelevant to the collaboration. The first impression of the student is the content given by the student instead of on any other aspects, and this anonymity leads to greater overall participation.[23-26] At the outset, students all enter the online playing field on equal footing, so no student needs to worry about being judged until that student has posted several times on a discussion board or spoken several times in a discussion session.

The third advantage McComb mentions is that information can be accessed more easily and efficiently in an online course than in a traditional face-to-face course. Course information can be divided into two categories: administrative details such as due dates and relevant course content to be learned. The former information easily lends itself to being placed on a course website or emailed to the students. This method is much more accessible than making an announcement in class where students are required to be present to receive the information or from word of mouth. When course notes are also available online, not only is information in the course more readily accessible, but the students also have immediate access to the wealth of information contained within the Internet.

Another valuable aspect of an online course is the logging of everything the students do. It is very easy to know when students perform many actions in the course so effort can more easily be tracked. In traditional courses, there is no way of knowing the study habits of the students, but when course materials are available only from a course website, then the database can track when students are accessing the material. Using this database for tracking will be discussed in more detail in Chapter 7.

Even with the advantages mentioned previously, there are potential disadvantages to online learning. One major advantage of traditional face-to-face learning is that students are given constant structure for how they are to learn the material.[27] Because the only way to obtain course information is by attending class, students are forced to learn at the pace dictated by the schedule and cannot fall behind. In an online course, the asynchronicity, which is one of its three main advantages, allows the less-motivated students to procrastinate. What a good online course must do is keep students motivated, as students are more likely to stay on task and perform better when the course includes instruction in self-motivation and study skills.[28] Students are also more likely to stay on task when the course is monitored by the instructor[29] or by their peers.[30,31]

In a traditional face-to-face course, students are often not given the opportunity to explore their knowledge with the instructor or their classmates in a guided setting. Methods such as Process-Oriented Guided-Inquiry Learning (POGIL)[32] and Peer-Led Team Learning (PLTL)[33] are methods instructors can use to get their students to interact with one another in a traditional face-to-face setting. The online learning method is amenable to these guided learning methods because of the vast virtual community that is created for the students in the course. The students can search for either a guided study session or can form their own study session. When students are given control over the technology that provides learning instead of passively watching the content the technology delivers, performance improves.[6,34] If students are able to take control of their learning and use the technology available to them, then students will see the highest gains in performance and satisfaction. In another study, students were separated into four groups: face-to-face, interactive online video, noninteractive online video, and online without video components. Students in the group with interactive online video performed significantly better than any of the other groups, and students in the group with noninteractive online video performed no differently from the students who were in the online course with no video.[35] The more control students are given, the better the learning outcome.[36-38] Merely using video is not enough for students to learn more effectively online, but when students have control over the video, they perform significantly better.

Even though more interaction leads to higher outcomes, there is no increased effect if the control is too complicated for students to understand.[39-41] For example, when students were asked to review a Flash-based concept map before completing exercises, no significant difference was seen between this group and either the group with a text-based concept map or the group with no concept map.[42] Therefore, any online aspects of the course should not be too conceptually difficult for students to understand.

6.2 FIRST ONLINE ORGANIC CHEMISTRY COURSE

6.2.1 Format of Course

In the summer of 2008, 37 students at the University of Illinois at Urbana-Champaign enrolled in second-semester organic chemistry for non-chemistry majors and experienced an entirely online course. At no time during the entire 8 week semester was there any face-to-face interaction between the instructors and the students. Students viewed 50-minute archived lectures from the spring of 2008 approximately 4 times per week and completed 24 homework assignments on ACE Organic. Office hour sessions through Elluminate Live! were available 5 times a week for students to ask questions and to work problems. Students took 3 midterm exams online using ACE Organic in the manner described in Chapter 5 at the end of the third, fifth, and seventh weeks, and then students completed a cumulative final exam at the end of the eighth week. Students were able to communicate with one another asynchronously using a discussion board on the Blackboard course management system.

Because this type of course is vastly different from any organic chemistry course previously offered at the University of Illinois and because two new variables have changed (i.e., office hours and exams), there is not a valid quantitative comparison to be made with any existing course. Alternatively, surveys were given to the students at the end of the semester, and the results from these surveys are expounded herein.

6.2.2 Results and Discussion

Of the 37 students enrolled in the course, 31 students responded to the survey. The first question asked the students which style of course (live, online, or no preference) they would prefer if they were to retake the course (Figure 6.1). The quantitative results from the survey show no significant differences between the 3 groups, but the individual responses from students give vast insight.

Common complaints about the online format from students who preferred live class included statements such as the following: “I like the real thing. Technology isn’t the best for everyone.” Of the 10 students who would prefer the live course, 6 mentioned that they were not comfortable with technology. One student, though, did mention how technology is growing: “I know we are moving towards a world that relies heavily on technology but there is something to be said about seeing a professor face to face…. As a student I’m better able to expound on where my confusion lies in person verses [sic] typing on the computer.” Although this student makes a point about being better able to express his/her thoughts verbally instead of through the computer, there was an acknowledgment of the rise of technology in the world. If this student is unable to express her thoughts using technology (even though this student writes eloquently), then she will be at a vast disadvantage in the heavily technology-based world she describes. The more practice students get working with new technology, the more comfortable they will be when new technology is unveiled. Although it is a valid point that each new generation of technology is increasingly more complex, it is inevitable that it will come, so ignoring it will only lead to further problems down the road.

Another common complaint is echoed in the following statement: "I just learn better with a person standing in the front teaching to me. I don't know why." Of the 10 students who would prefer the live course, 5 mentioned that seeing a person face-to-face is beneficial, but none give a reason why. Perhaps, part of the reason is mentioned in this student's comments: "After years of schooling in a typical live lecture format, I am used to that environment and thrive within it." Perhaps students are afraid of change because they are good at the system currently in place. A true sign of a knowledgeable student is one who can adapt to different environments when the material is still the same.[43]

Another factor that may have led to frustrations is the motivation that is required to learn from a seemingly unstructured course. Two students mentioned this motivation problem specifically in their comments. One student mentioned the following: "I know a live class would have helped me stay on track, but the other positive aspects of an online course offset that small problem." Another student also acknowledged the motivation problem faced in taking an online course and mentioned that this format should be made available every semester: "I enjoyed kinda taking the class at my own pace and missing a lecture is not the end of the world which is absolutely amazing. However …, I would find myself getting slightly behind on the lectures … because I was lazy and procrastinated. Had I actually watched the video lectures on a daily basis and attended more than 50% of live office hours, there is no doubt in my mind that I would have aced this class…. So besides kids procrastinating, there is no reason why this can't be a thing that the University does every semester." This student is at least self-aware and realizes that the faults were entirely on the student while realizing the potential of the online course. If there were a way to prevent procrastination, then this student would have presumably performed better. An idea for combating procrastination is discussed in Chapter 7.

The most common praise of the online format from students who said they would prefer to retake the course online is echoed in the following: "Overall, I thought that I learned just as much in the online session as I would have the live one, and it was much more convenient to watch all the lectures and do all the homework behind my computer at home." Of the 14 students who replied that the online format would be more beneficial, 12 mentioned the convenience of working at their own pace and being able to work anywhere as mentioned by the following response: "I really think that the online exams are more ideal for me, because I tend to second-guess myself too much on regular paper exams. Also, I liked the online office hours where we could just ask questions from our computer. Also, I loved the flexibility of living at home, which was the main reason why I took Chem 332 over the summer." As this student points out, the course could be taken from home at whatever pace the students wanted, and the student also enjoyed being able to ask questions while at home from the computer, a sentiment shared by 8 of the students in this group. The flexibility of the course format allowed students to learn whatever their schedule happened to be and from wherever their travels took them as this student pointed out: "I have a crazy schedule and you can't beat the convenience of taking it online!"

Despite the mixed reviews from students about their preferred course format, the responses from the next question asked were fascinating (Figure 6.2). Students were asked whether their opinions of an online course had changed after having taken this course. Of the 31 students who responded, 21 answered "yes," a statistically significant percentage over random chance, showing that the perception of online courses of an average student did indeed change.

Students were asked to expound on their response to the question, and their responses are discussed below.

There were two common responses from students who answered “no” to the previous question. The most common response was that the students had no opinion to begin with: “This is the 1st class I’ve taken online. So if they all run like this one, I would take more for sure.” Of the 10 students who replied “no” to this question, 8 responded that they had formed no opinion previously, and if no opinion had been formed before having taken the course, then there was indeed no basis for comparison. The other common response is echoed in the following: “I had taken an online course before, and it was a bad experience, and after taking a course like chemistry online, my opinion hasn’t changed and I totally regret doing so.” This sentiment was shared by 2 students who were self-described as “not being tech-savvy,” so their experiences in a course with much technology were perceived to be worse than a course less dependent on technology.

When the responses of students who answered “yes,” were studied, some interesting insight was gleaned from the responses. One student mentioned how the course was highly interactive: “I used to think that online courses weren’t interactive, but with the discussion board and office hours, that was refuted.” In order to make the online experience at least as good as a live course, the interaction must still be present, as this student mentioned. Another student mentioned taking the course again online if required: “I feel like this online course sets the standard for what online courses should be. Seriously, I really enjoyed the format of this class, and I would take it like this again if I had to.” These students were highly engaged in the course because of the interactivity that could not be available in a traditional large-enrollment lecture course.

One of the more interesting responses about the interactivity in the course is the following: “This online format was great, but I do not expect other courses or professors to be as good with the online format. Professor Moore is a very approachable guy and is very enthusiastic about the content and quality of his course, I feel that other classes just would not stand up to this quality.” The portion of greatest significance is that Prof. Moore was described as “a very approachable guy” when students never met him face-to-face all summer! This comment shows that face-to-face time is not necessary to garner an emotional connection with an instructor and gives merit to the style of this course for distance learning. An initial complaint from students taking this online course was that they were afraid they wouldn’t be able to interact with the instructors or get the individual help they needed. This comment shows that this individual attention is feasible in the online format provided that the instructors are vigilant in making the course interactive. This style of course requires instructors to take the extra step to make students comfortable. Some steps taken during the summer course to make the students more comfortable were to upload a short biography and profile photo of the instructors that gave insight into the personal side of life, and the students were encouraged to do the same. During office hour sessions and on the discussion board, students were referred to by name, and one student mentioned this fact in the survey as a positive aspect of the course.

One student mentioned difficulty of working in person with other students but mentioned how the online course was still challenging: “In general, I would think that taking an online course is a blowoff, but that is certainly not the case with organic 121hem.. It was still challenging, especially for me because I love to study with friends, and taking the course online makes that very difficult. However, attending the live office hours when possible was REALLY helpful!” This student enjoyed the office hour sessions and mentioned that his/her previous views of online courses were that they would be a “blowoff.” This sentiment was shared by 7 students in the survey about how challenging the course was, and it was certainly a goal of ours. Just because a course is made available online, it does not mean that the course should be any easier or harder than its live counterpart. The fact that the course is online should not change the difficulty level of the material, and many students noted this fact.

The following comment is striking: “You can actually learn from online courses.” This student had the initial impression that not much learning occurred during the previous 2 online courses this student had taken, and this previous perception was changed in this course. This course clearly forced students to think and challenge themselves just as a live course would, and this student, like others, came away with a better appreciation for online courses in general. We are definitely doing something right to receive responses like these.

The comments received by students were taken at the end of the semester, so the students who were very disgruntled with the format more likely dropped and did not fill out the survey. Because no students were surveyed who had dropped the course, the only indication of how dissatisfied students were who had dropped the course was to look at the retention rates for the course over previous summer semesters (Figure 6.3). Looking at the retention rate for Su08 vs. the previous 3 summers, there is no significant difference between the different semesters (82% vs. 91%, 80%, 93%). The retention rate is defined as the percentage of students remaining when final grades are submitted when compared to the ten-day enrollment. This data show that students did not drop the course substantially.

6.3 IMPROVEMENTS IN ONLINE COURSE

6.3.1 Scale-up to 200 students

After administering the entire course online in the summer of 2008, the next issue was whether the class could be scaled by a factor of 5. The class was taught in the fall of 2008 entirely online with an enrollment of 199 students. The retention rate of 85% is not significantly different statistically from retention rates from previous fall semesters (Figure 6.4), so the change in format is not correlated with a higher rate of students dropping the course. The retention rate is defined as the percentage of students remaining when final grades are submitted when compared to the ten-day enrollment. Complaints have been made regarding the online format, but they are no different from the complaints made during the summer term about wanting to see a person face-to-face. Based on the post-survey, students preferred the online format over the traditional format in roughly the same proportion as students in summer 2008 (Figure 6.5). Students also significantly changed their minds about online courses because of taking the course in the fall of 2008 with the results significant at the 99% confidence level (Figure 6.6).

Most of the challenges with scaling-up to 200 students were related to procedural matters. During the summer exam sessions students had been effectively accommodated in one Elluminate room with several exam moderators monitoring for security purposes. However, it was discovered that having more than 50 students in one Elluminate session hindered our ability to monitor the exams sessions en masse. The solution was to create multiple sessions in Elluminate that occurred at the same time and delegating one moderator to each session, which consisted of no more than 30 students. The 30 student threshold was chosen because of the stress from placing students into individual rooms and securing control of their desktops for security purposes. The average amount of time it takes to put one student into a room and secure control of his desktop is roughly 35 seconds. Students are asked to come to the exam room 30 minutes in advance of the exam start, and roughly 80% comes at least 20 minutes in advance. If there is an onslaught of students arriving within 5 minutes of the exam starting, there is not enough time for the moderator to set these students up in the online environment and get the exam started on time.

6.3.2 Scale-up to 300 students

Because the course could be scaled up to accommodate 200 students in the fall semester, the next step was to push the boundaries to see whether upwards of 300 students could be accommodated in the spring 2009 semester. Just as had been observed for the previous semester, complaints were the same ones received during previous trials of the course, and the retention rate of 82% was not significantly different from previous years (Figure 6.7). Based on the post-survey, students had similar feelings to the previous semesters about the course preference (Figure 6.8) and whether their opinion of an online course changed (Figure 6.9).

There were some noticeable limitations when the course scaled up to 280 students in the semester. The first limitation was the number of discussion sessions. As was mentioned in Chapter 4, the Elluminate “office hour” sessions were given a rebranding as “discussion” sessions, so sessions were added at various times to accommodate more students. Having all of the students at one session would have been very difficult to execute, so two more discussion sessions were added. Adding these sessions generated a higher workload for the TAs which pushed the allotted TAs above the weekly limit in hours. Attendance at sessions was still around 10%, but those who attended rated the sessions highly.

The other limitation was in exam administration. In this semester, only 90 working computers could be reserved at one time, so students needed to be split into 4 different groups to take exams. Because of time and room limitations, these different groups had to be on different days. This extra day was certainly a security risk with the "anything but a friend" policy described in Chapter 5. There is anecdotal evidence that students taking the exam on Thursday were getting information from students who took the exam on Wednesday, and students taking the exam at a later time in the day were getting information from students who took the exam at an earlier time in the day. The obvious solution around the security issue would have been to create 4 different exams; however, this was not feasible for two reasons: time and parity. In order to write an exam, a considerable amount of time is needed to find quality, exam-level questions and program them into ACE Organic along with the proper feedback and tools. If four exams had been written, the instructor would have had no time available to do anything except for writing exams. Even if four exams had been written, there would be no way to externally validate the efficacy of the four exams. Students would be judged on four separate scales, and there would be no way to know whether one exam was harder than another. If students performed better on one exam over another, then the metric for comparing scores to calculate score adjustments would be based on a faulty assumption that the exams should have equal averages. In this conflicting situation, one of the two aspects needed to be sacrificed, and security was chosen. Much effort was put into monitoring students during exams and reminding them that they were continually being watched through Elluminate and in the exam rooms.

6.3.3 Scale up to 700 students and first-semester organic chemistry

Because of the success of the previous scale-ups, the upper boundaries of “class size” need to be discovered. To test this boundary one more time, first-semester organic chemistry (CHEM 232) was moved to the entirely online format with an enrollment of 622 students. The main issue that needed to be addressed was that of computer lab space because with a limit of 90 computers at one time, a minimum of 7 exams would be needed, and the resources were not available for this endeavor. Luckily, more campus computer services were obtained, and upwards of 400 students could take the exam at one time. With this number, the exam could be split into two times on the same night to reduce the incidence of information leaking. The security problem is still not solved entirely, but the problem is lessened. What was not expected, however, was the upper limit on the server that housed ACE Organic which has a capacity of 150 concurrent users with 120 concurrent users operating comfortably. This threshold was not discovered, however, until the first exam, and the problem has yet to be fixed. Various exam alternatives were used during the semester. For the first exam, students were given a traditional paper exam. For the second exam, students were split into 26 different time periods and given 26 different exams using ACE Organic. For the third exam, students were given a scantron exam. For the final exam, students were split into 6 different time periods and given the same final exam. Needless to say, students were not pleased that the exam format kept changing as evidenced by both the comments on the post-survey and also the retention rate for CHEM 232 Fa09 (Figure 6.10).

Another variable that was explored was that the course was the first-semester course instead of the second-semester course. The typical student who takes the second-semester organic chemistry course for non-chemistry majors is taking the course, because the student wants to fulfill a chemistry minor, because the student is in a pre-health track, which requires two semesters of organic chemistry, because first-semester organic chemistry was interesting enough to take another course, or a combination of the previous reasons. The typical student is already more interested in organic chemistry than the typical student in first-semester organic chemistry. Therefore, the entirely online approach may work differently with this group of students, possibly in a negative way. The online course has had success with students who are interested in the subject matter, so when a larger percentage of students are presumably less interested in the subject matter, the students may react to the format worse than students in second-semester organic chemistry.

Given the concerns stated above and the multiple exam formats, the post-survey was expected to give worse results than had been seen previously. In fact, the results were surprising. Based on the post-survey, the majority of students preferred to take the course online instead of live or having no preference, and this result was significant at the 95% confidence level (Figure 6.11). Presumably, those upset with the format dropped the course as noted in the retention rate in Figure 6.10. Students' opinion of an online course was also significantly changed at the 99.99% confidence level (Figure 6.12). These results give confidence that the online approach can resonate with a larger variety of students and still motivate them to learn organic chemistry.

Based on the work with office hours discussed in Chapter 4, it is feasible to assume that students at other colleges in other countries could also be accommodated in this course. In the fall of 2009, 22 students at Lahore University of Management Sciences in Lahore, Pakistan, under the auspices of Professor Irshad Hussain received the same content, assignments, and exams as students at the University of Illinois in Urbana-Champaign. The students also participated in discussion sessions alongside students in Illinois as described in Chapter 4. Circumstances beyond our control prevented proper quantitative comparison; however, qualitative comparisons can be made. According to a post-survey, the students in Pakistan greatly enjoyed the course, and one student changed his major to chemistry because of the course. These students had only online interaction with the instructors in Illinois, yet the students reported feeling a connection with the instructors and students at Illinois. More research certainly needs to be done with this project.

6.3.4 Continuation of CHEM 232 in spring 2010

CHEM 232 is currently being offered in the spring of 2010, and the results are currently promising. The enrollment is 463 students with a retention rate of 92%, a number not significantly different from previous spring semesters (Figure 6.13). To accommodate the ACE Organic server, exams have once again been split into four time periods on two different days. The added security problem has returned, and it is hoped that the problem will be fixed in the near future.

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6.5 FIGURES AND TABLES

Figure 6.1 Responses from students in Summer 2008 to their preference of course delivery should they retake the course. Although a plurality of students preferred the online format to in-person, the results are not significant at the 95% confidence level.

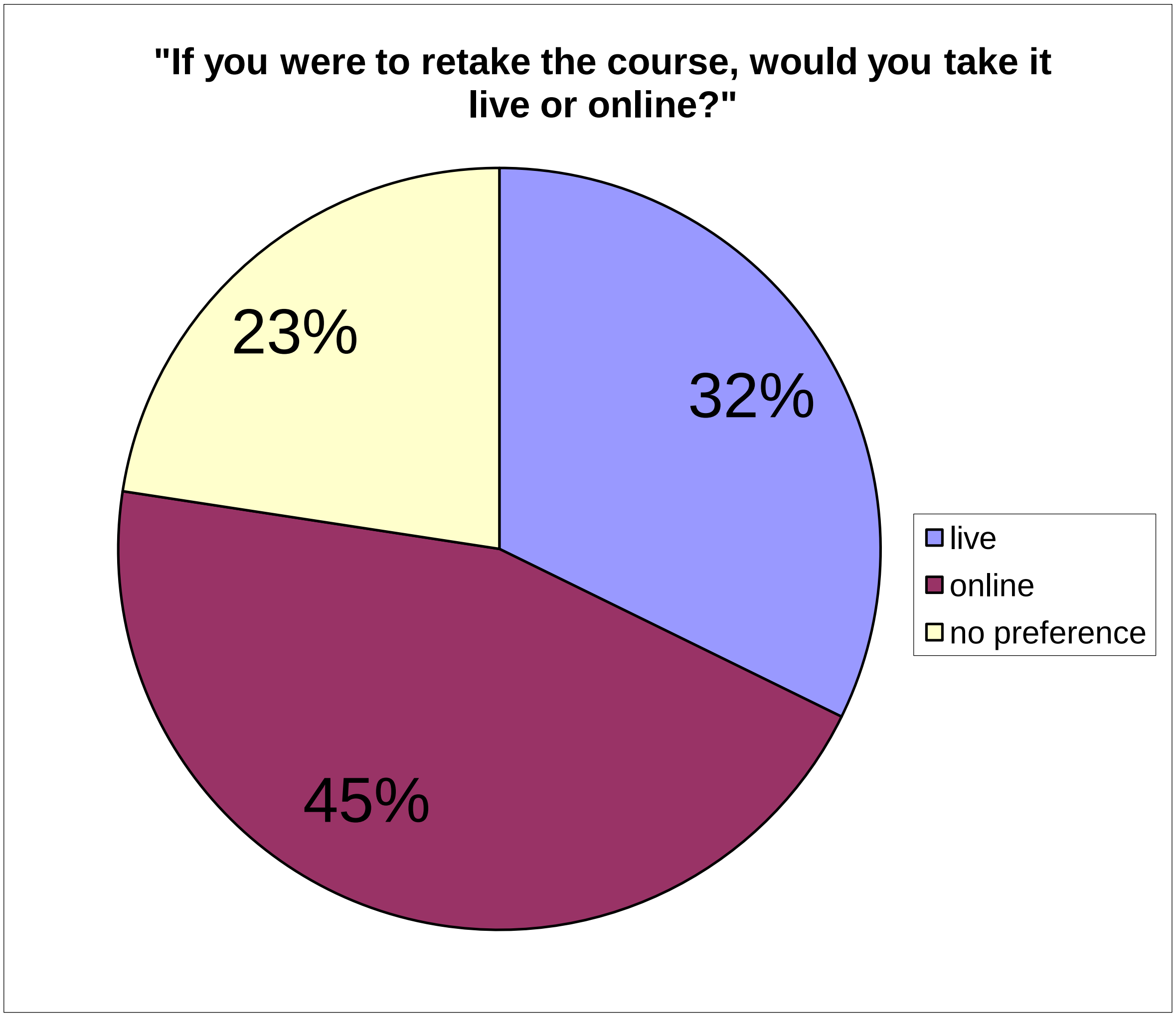


Figure 6.2 Percentage of students who answered whether their opinions of an online course changed in Summer 2008. The results were found to be significant at 95% confidence level. (error = +/- 17%)

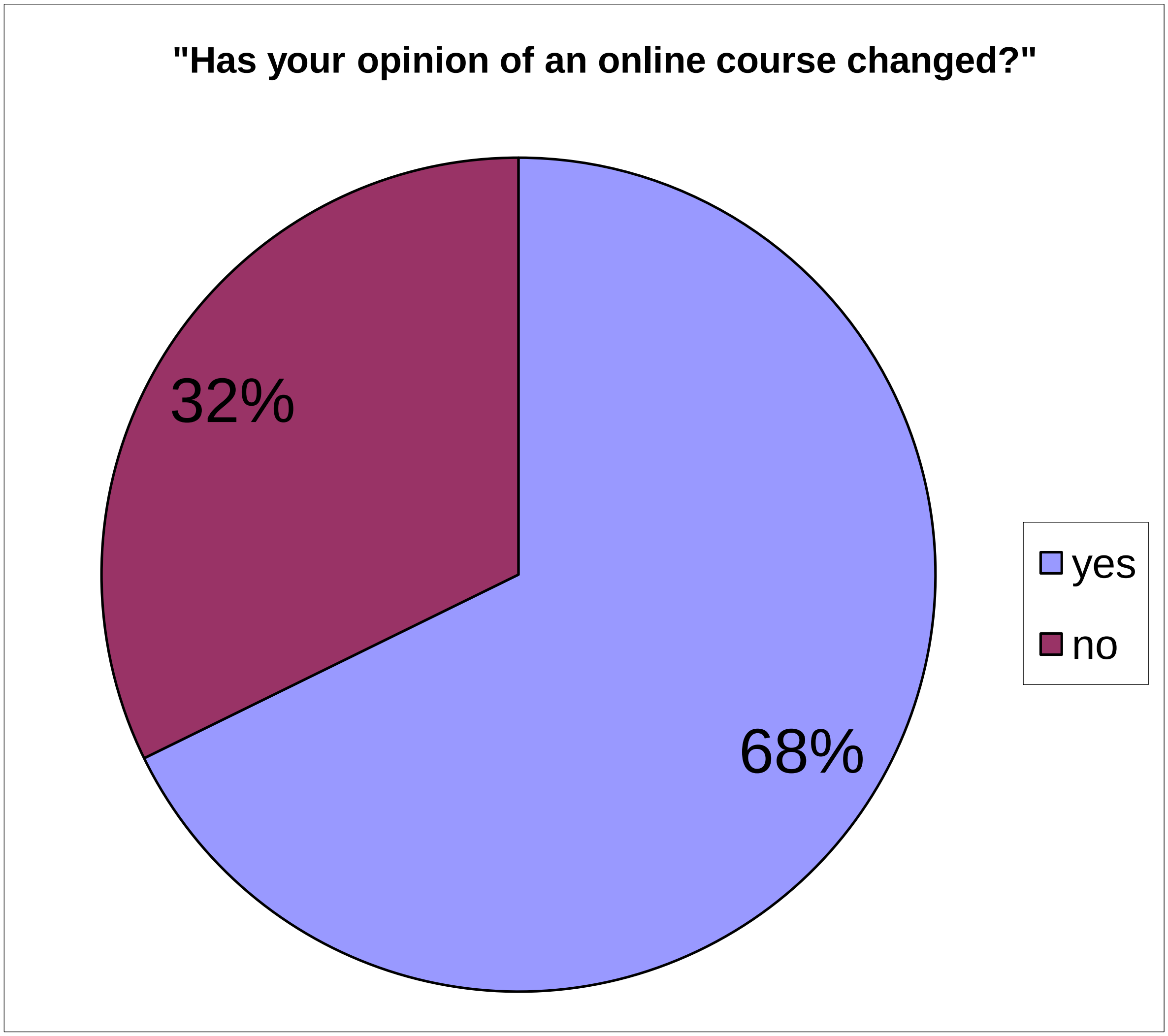


Figure 6.3 Comparison of retention rates for CHEM 332 in the summer terms. The online course did not have a significant change in student retention when compared to previous summer semesters.

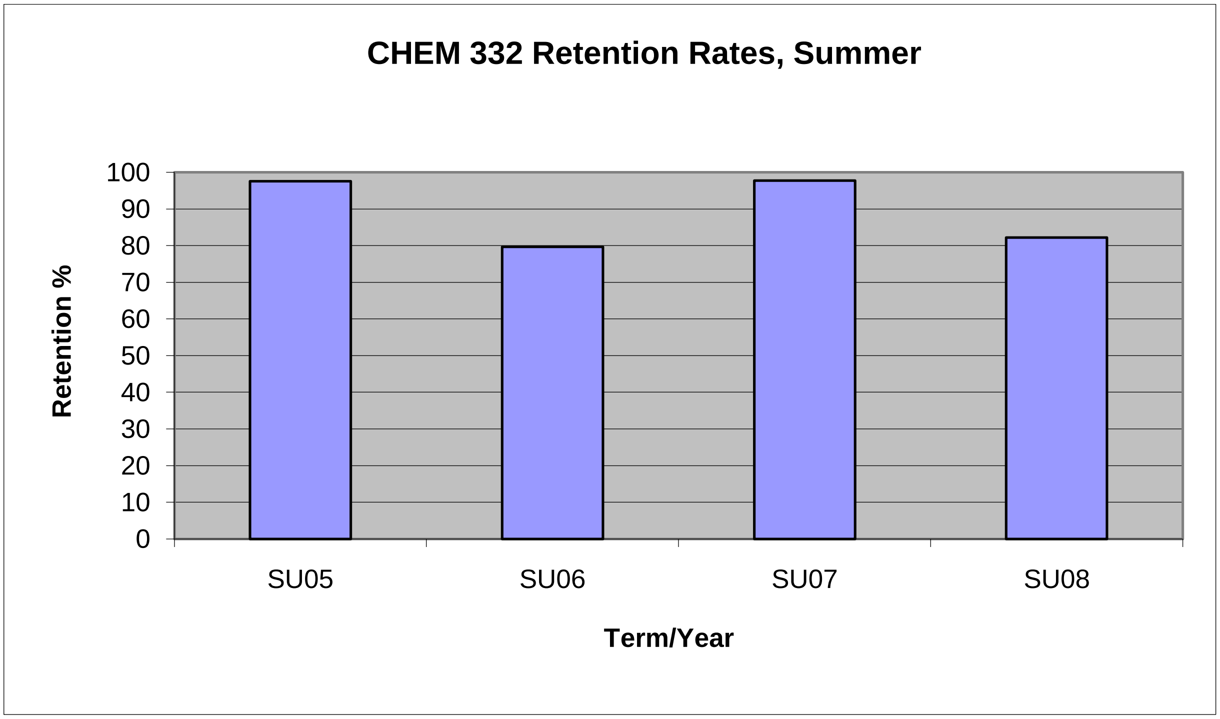


Figure 6.4 Comparison of retention rates for CHEM 332 taught in fall semesters. The online courses taught in fall 2008 and 2009 did not have significantly different retention rates when compared to previous fall semesters.

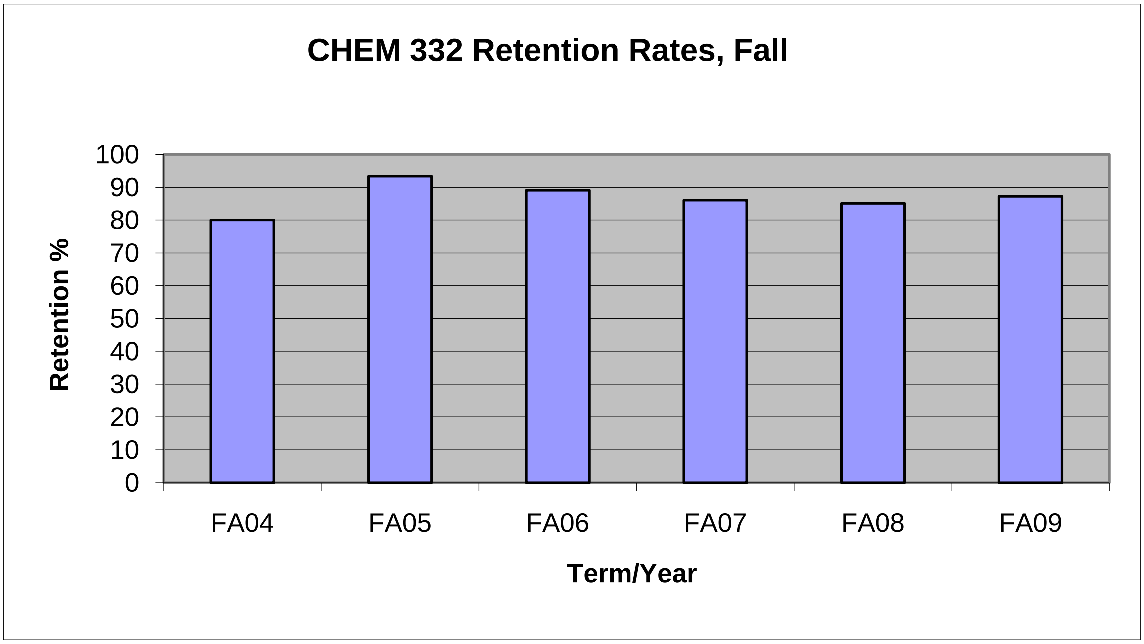


Figure 6.5 Responses from students in Fall 2008 to their preference of course delivery should they retake the course. Although a plurality of students preferred the online course to an in-person course, the results were not significant at the 95% confidence level.

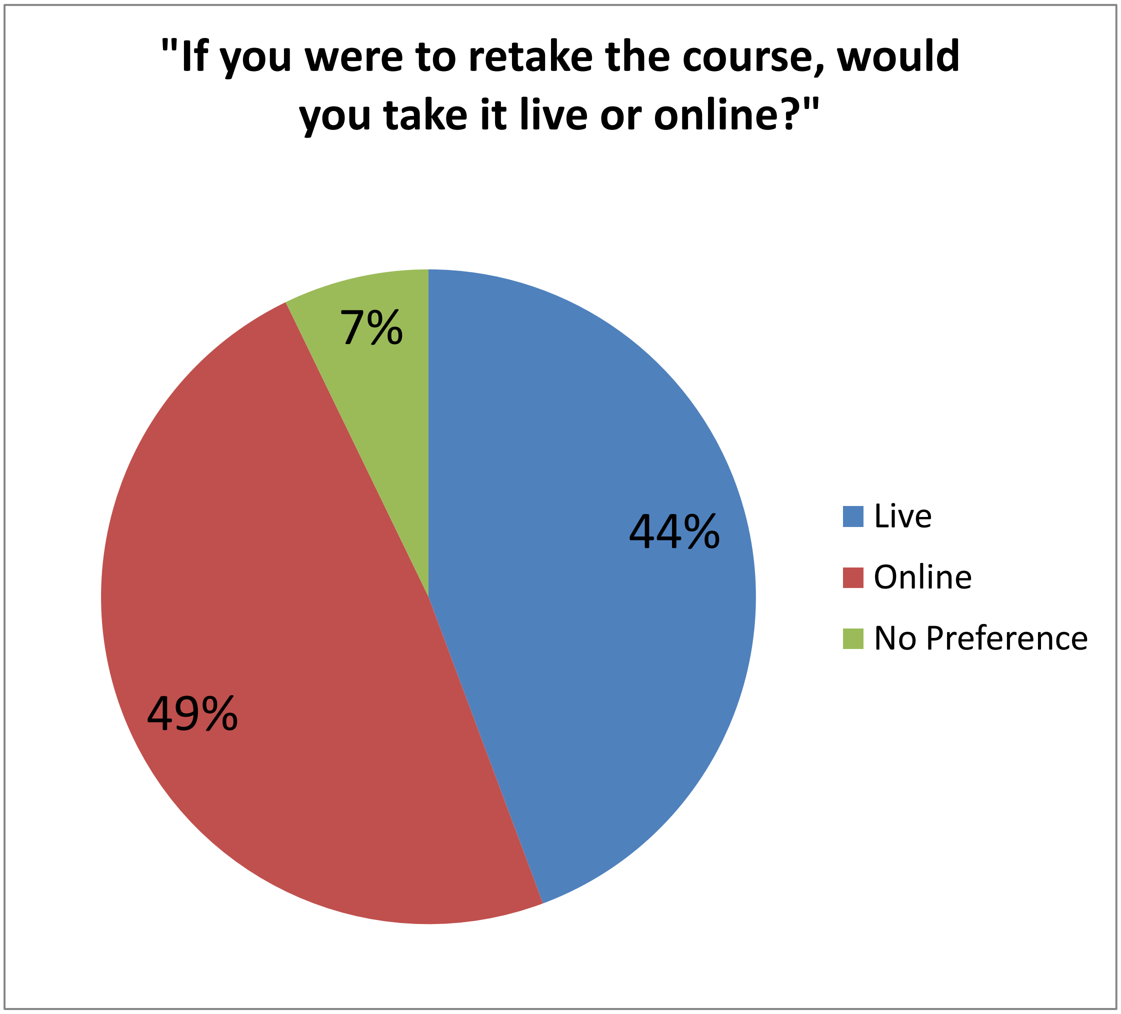


Figure 6.6 Percentage of students who answered whether their opinions of an online course changed in Fall 2008. The results were found to be significant at the 99% confidence level. (error = +/- 7.3%)

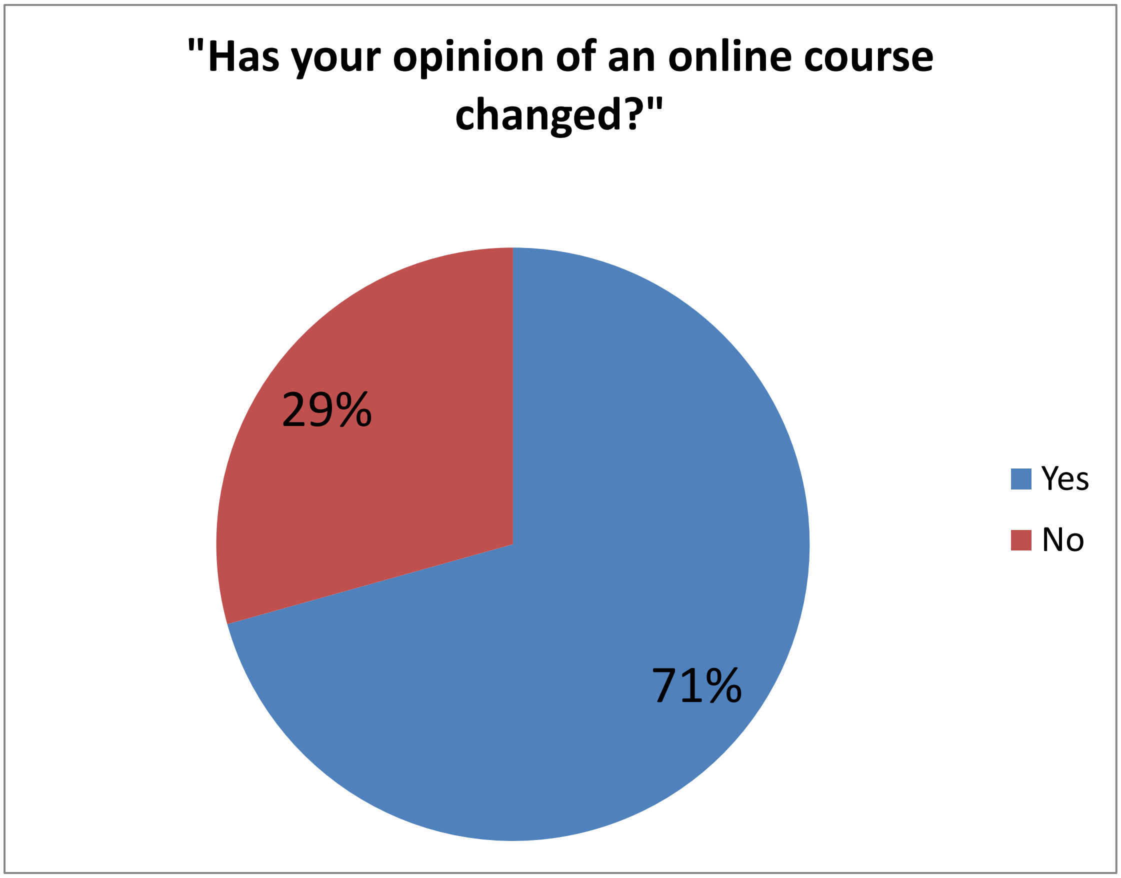


Figure 6.7 Comparison of retention rates for CHEM 332 taught in spring semesters. Retention rate for CHEM 332 SP10 is based on drop-date enrollment. The online courses taught in spring 2009 and 2010 do not have significantly different retention rates when compared to previous semesters.

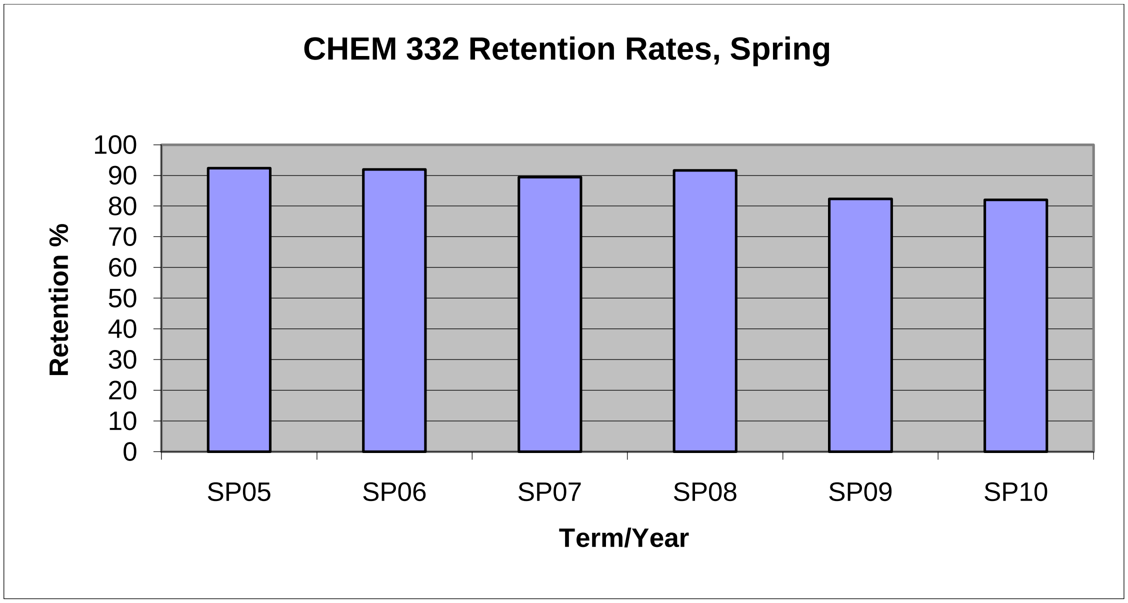


Figure 6.8 Responses from students in CHEM 332 Spring 2009 to their preference of course delivery should they retake the course. Although a plurality of students prefer the online format to the in-person format, the results were not significant at the 95% confidence level.

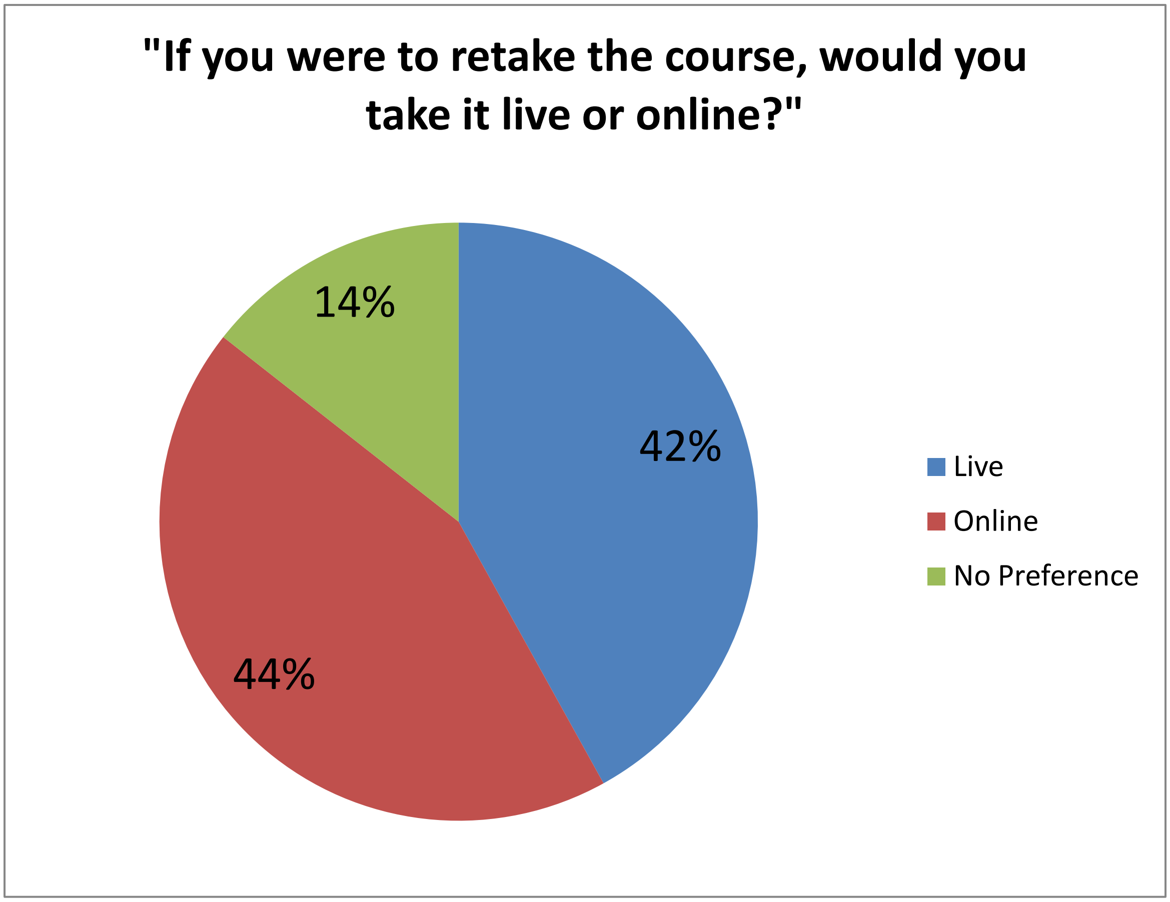


Figure 6.9 Percentage of students who answered whether their opinions of an online course changed in CHEM 332 Spring 2009. The results were found to be significant at the 99% confidence level. (error = +/- 6.3%)

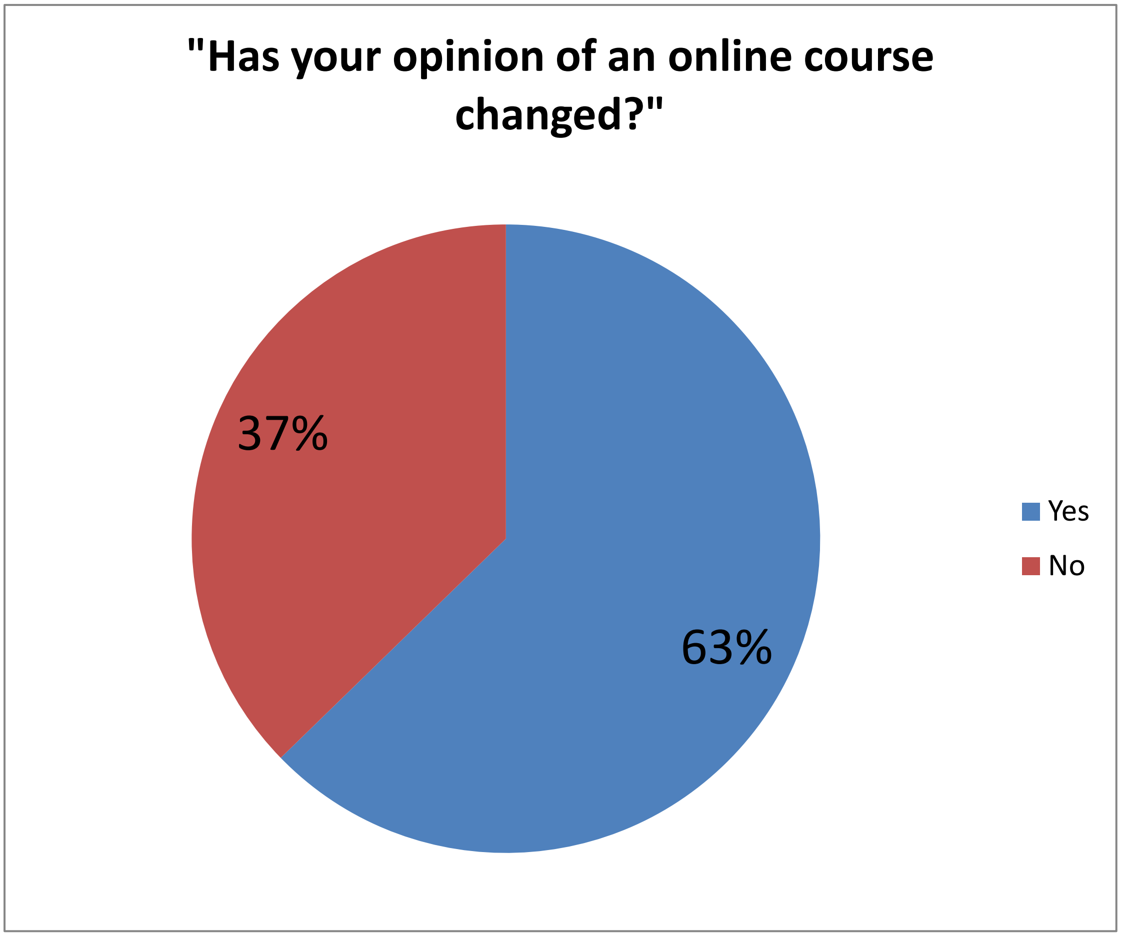


Figure 6.10 Comparison of retention rates for CHEM 232 taught in fall semesters. The online course taught in fall 2009 does not have a significantly different retention rate when compared to previous semesters.

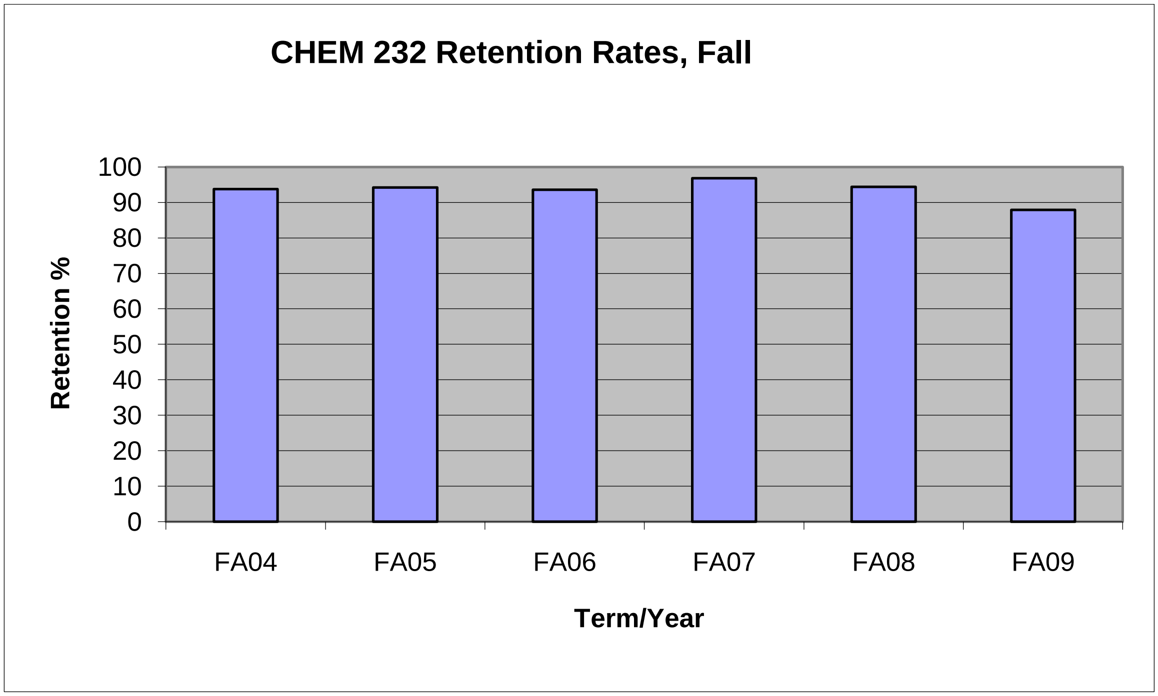


Figure 6.11 Responses from students in CHEM 232 Fall 2009 to their preference of course delivery should they retake the course. A majority of students prefer the online format to the in-person format, and the results are significant at the 95% confidence level.

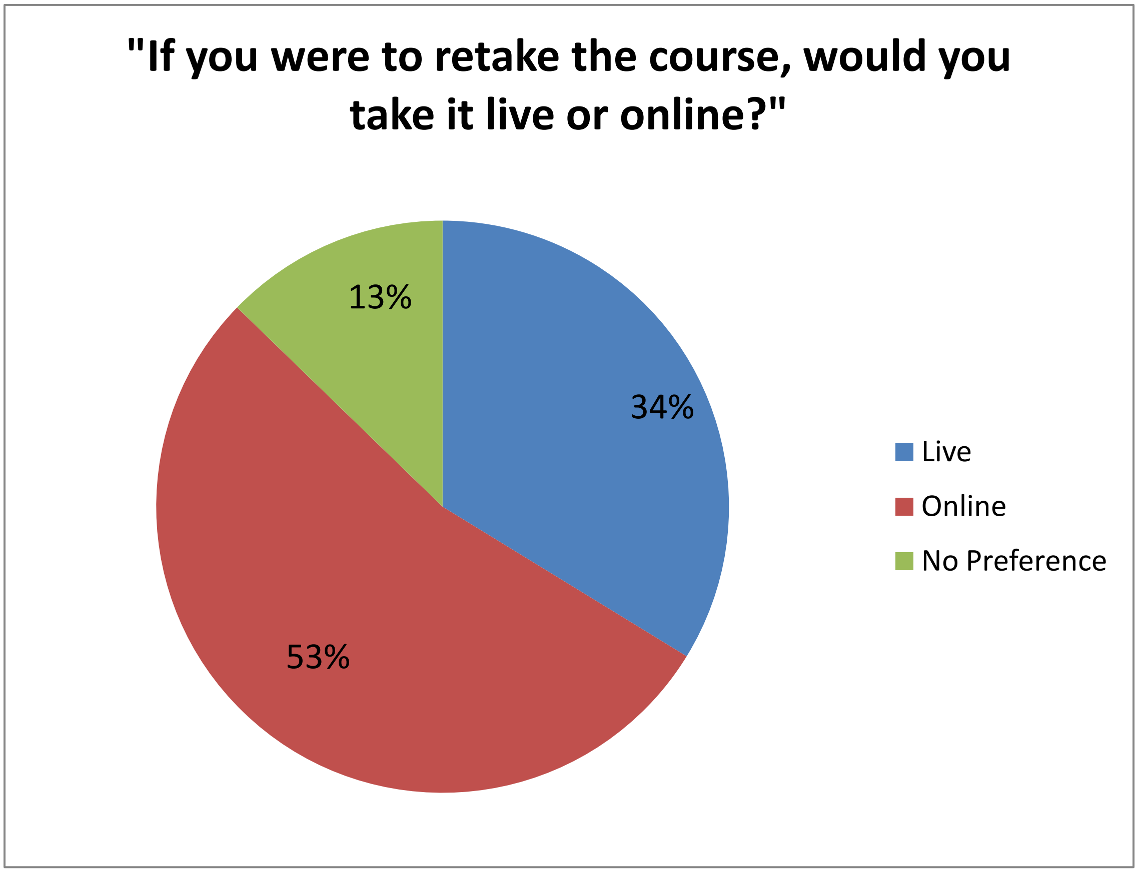


Figure 6.12 Percentage of students who answered whether their opinions of an online course changed in CHEM 232 Fall 2009. The results were found to be significant at the 99.99% confidence level. (error = +/- 4.1%)

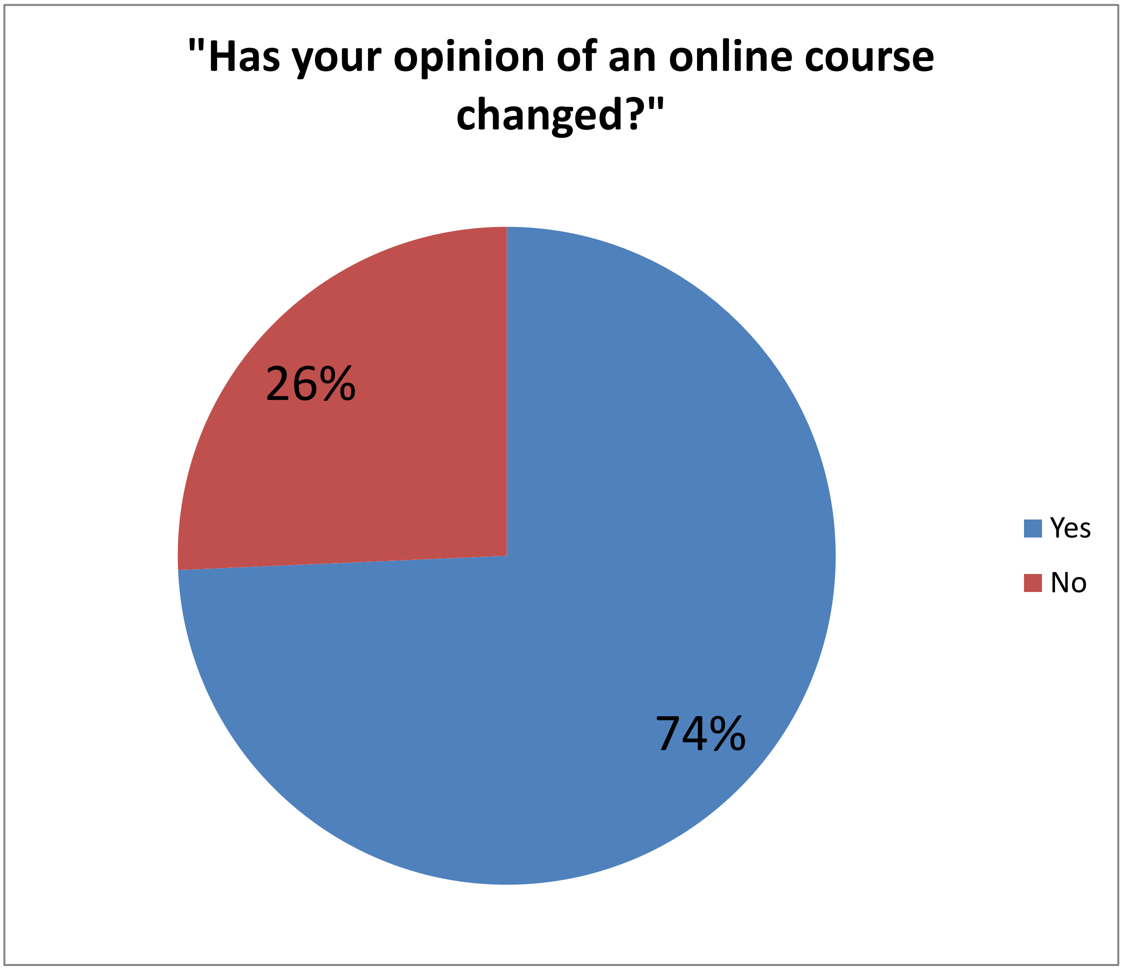
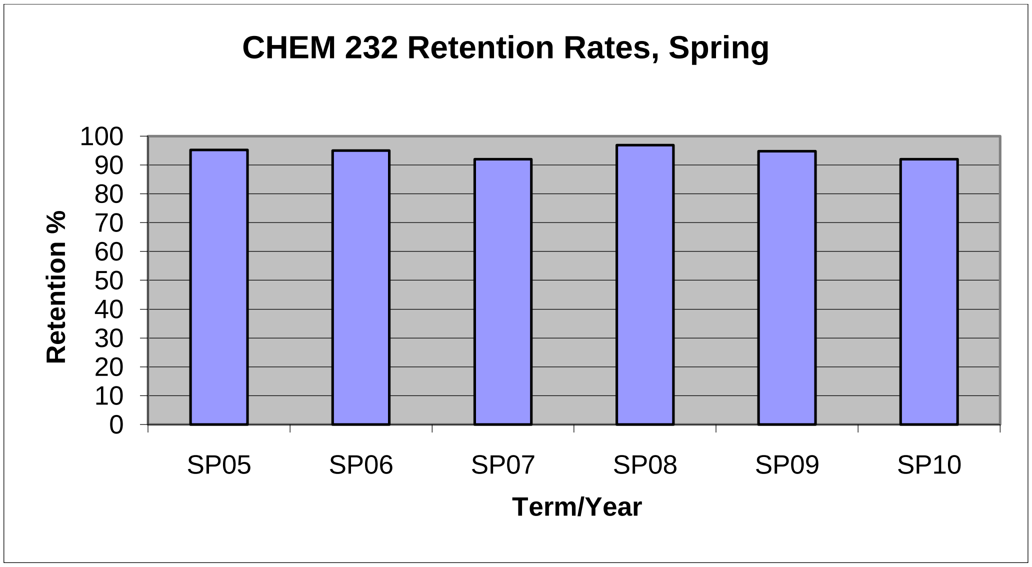


Figure 6.13 Comparison of retention rates for CHEM 232 taught in spring semesters. Retention rate data for CHEM 232 SP10 is calculated from drop-date enrollment. The online course in spring 2010 does not have a significantly different retention rate when compared to previous semesters.



CHAPTER 7

QUO VADIMUS?

7.1 INDIVIDUALIZED INSTRUCTION

7.1.1 Introduction

With the advent of putting organic chemistry instruction entirely online and having it taught effectively, the obvious direction to go is efficiency in material delivery. The previous chapters mention that students learn best when they are intrinsically motivated and receive the instruction that best fits their learning style. The future of education, not just in organic chemistry, is individualized instruction. ACE Organic already uses a form of individualized instruction in that the feedback is tailored to each student's individual response. As seen in Chapters 2 and 5, students respond favorably to this individualized feedback. Similar results were found by Nguyen when enhanced context-sensitive features were integrated into tax preparation software.[1] Just because individualized instruction works for fixed question homework assignments, there is no reason to stop there. What every students needs to see is a completely individualized course that is designed exclusively for that particular student and is available whenever and wherever that student happens to be. Motivation can be fleeting, so allowing students to take the most advantage of that motivation when it strikes affords larger returns.

7.1.2 Scaffold of system

In the context of organic chemistry, the design of the system is similar to the ALEKS system for math.[2] The entire subject of organic chemistry is broken down into a concept map which shows each of the major concepts and how they all relate with one another. For example, a major concept is resonance, and one concept that is a prerequisite of resonance is Lewis structures. If a student is unable to draw correct Lewis structures, then giving the student a series of resonance questions is moot. Students begin with a pre-test of material in each of the major concept areas. Once scores are tallied, the system sets a threshold mastery level of each concept that is required before advancing to the next concept. Because every student learns differently and at a different pace, a student who needs a longer time period to master Lewis structures should receive that longer time period whereas a student who has mastered them on the pre-test should not have his time wasted with such exercises.

This type of instruction includes not only problems to work but also short Webcasts that were discussed in Chapter 3. The system decides whether the student is lacking in a certain area and provides certain Webcasts to view. After each Webcast is a short problem that tests whether the basic information was gleaned by the student, and if it was not, then the student will be forced to view the Webcast again.

Because the main goal is for the student to learn the concepts, the best metric to judge this is using the system's best estimate for the student's competency level for each concept. Whereas students with the same competency level may score drastically different on examinations because of test-taking ability, this system would eliminate that anxiety from the metric. Examinations would still be a part of the system as a whole, but they would be worth much less.

In order to ensure the student working on the system is indeed the student enrolled in the system, security checks will be put in place. Periodically, questions will be asked that are at a concept that has previously been marked as "mastered." If a series of these questions are missed, and the competency level drops below the mark, then questions revert back to that concept. This reversion prevents a student from having a friend do the work for a certain period of time or if the concept is later forgotten.

7.1.3 Examinations

Exams will work in a similar way to the ACE Organic exams discussed in Chapter 5 except that the security issues would no longer be a problem. The exams would be computerized adaptive exams in which the exam adapts its difficulty to the projected ability level of the student. If a student answers a question correctly in one attempt, the next question will be of a higher difficulty level than if the question were answered correctly in two attempts. The exam system would then use a similar competency algorithm that is used in the learning system described in the previous section to measure the student's competency score in various conceptual and practical areas. This data would give the student an exam score and would also feed back into the overall system to guide the next set of lessons.

The details of exactly how the system will work are adjustable, and variables can easily change, but the basic outline of the system provides an individualized exam. Instead of using a fixed question exam similar to the ACE exams described in Chapter 5, these exams give different questions to different students, thereby greatly reducing the security risk. If two students are taking the exam at the same time next to each other, the students will very likely be working on different questions. Also, students with different ability levels will see questions with difficulty nearer their ability level. According to Item Response Theory (IRT), a student with innate ability level θ will answer a question with difficulty level b 50% of the time with a normal distribution centered around θ. In order to delineate between students of similar θs, a question with $b = \theta$ would give the maximum information. For example, to delineate between two students with θ between 0.7 and 0.8, the question chosen should have a b between 0.7 and 0.8. A question with b between 0.2 and 0.3 would not provide valuable information as both of these two students will very likely answer this question correctly.

Because students would receive different questions, there is no reason to force students to take the exam at the same time. Students have been working at their own pace with the learning system, so students may be ready to take the exam at different times. For a large class size of up to 1680 students, every student could take a two-hour exam in one week in one computer lab with 40 computers that is open from 8am-10pm Monday-Saturday. The need for large computer lab reservations diminishes to just a handful of designated computer labs for exams. Another scale-up issue, noted in Chapter 5, was the exam server capacity, but the capacity need only hold 40 concurrent users given the scenario above. Computerized adaptive organic exams are not only an effective means of scale-up but also a more psychometrically valid method than the current method of measuring student ability.

7.1.4 Seeking extra help

No matter how good a computerized feedback system is, students will have a question that the computer cannot answer. What the system will have available is a button next to a problem that instantly connects the student to “Organic Chemistry Customer Service.” The student is then immediately in a video chat session with an expert in the subject, and the expert already has the information on what the student has done incorrectly and what the system thinks the student’s problem may be. The student can then ask a question, and the expert can help answer the question. When the student’s question is properly answered, the session is logged so that the computer feedback system can be updated to include this new type of help.

The beauty of the system is that, like insurance, resources are pooled together. Instead of having sparsely attended office hour sessions, instructors, TAs, and tutors from around the world can spend a couple hours a week answering questions for anyone who has a question. Students can log in for individualized help whenever it is needed, and instructors can deliver that help as well. Just like insurance, as more students and instructors join the system, the time instructors spend as experts decreases just like insurance premiums. As this system spreads across the world, students in Illinois who may be working at 4am can get real time help from a professor in Beijing working during daylight hours. The goal is to deliver help exactly where it needs to go in both a cost-efficient and time-efficient manner.

7.1.5 Implications

This system could completely destroy the current model of higher education. If students are no longer required to perform actions at specified times, then there is no longer a need for a semester or quarter. Students can take a module and complete it whenever the student is able to do so. The student can complete the course as quickly or as slowly as the student wants. This student can take a break in the middle of the course for illness, vacation, or a job, for example. The system truly caters to the student's schedule.

The cost of the system would be large at the start, but later costs would be necessary for server upkeep, new question creation, and paying experts to be in the customer service center a few hours a week. This cost passed on to the student could be less than the cost of taking the course on a traditional campus because fees associated with living on campus are no longer necessary. This potential lower cost and better product would drive educational consumers away from traditional universities and to the online system. The loss in revenue from tuition and fees would force universities to cancel many programs and scale back services or else the future of higher education at a traditional university is in dire straits.

7.2 OUTLOOK OF EDUCATION

As an individualized approach becomes more popular in terms of both educational and monetary outcomes, the traditional educational system will begin to crumble. When universities expanded, they scaled-up linearly in manpower and resources. Now that an alternative is available that is both educationally sound and monetarily potentially more attractive, universities would be foolish not to use them.

Even though these changes have mountains of evidence supporting them, it is unlikely that real change will be made because those in power are resistant to change without an impetus. The one good part about the fiscal crisis in higher education is that universities are starting to rethink their learning models and are more willing to accept solutions to their problems that are not just a rehash of the same policies that drove higher education into the bind it is currently in.

Change will be slow at traditional R1 universities and small liberal arts colleges, and without an impetus like the current financial one, the rate of change is only as fast as retirement. If R1 universities decide to keep going down the same path they have been going down for the past 50 years, then they will be in even larger financial problems. Small liberal arts colleges will still exist, albeit fewer of them, because people with money will spend $100,000 per year to send their children to schools with small intimate class sizes and the same education they themselves received as college students. The rest of the country, however, will not be able to afford the price, and cheaper online options will overtake R1 universities.

One method R1 universities can do to thrive is to completely separate the teaching and research components. If any R1 wants to improve the quality of undergraduate education, educational experts should be hired as tenure-track faculty to focus entirely on undergraduate education. However, it is not enough just to hire this faculty, but this faculty needs to be treated with the same respect as the research faculty. The purpose of the university is to educate both the undergraduate students and the graduate students, so each branch should be treated with equal respect regardless of grant money. If the individualized instruction catches on for large enrollment classes, then the teaching faculty need only direct curricula, hands-on laboratories, and specialized upper-level courses. Removing this teaching load would free up time for research faculty to spend on their research.

If teaching and research were split and individualized instruction caught on, then higher education would be vastly different. The university would become a bastion for research, and coursework would be left to individual companies that manage several accredited courses. The coursework would be outsourced to private entities which would in turn become accredited online colleges. The logical step would be for textbook publishers to assume this role seeing as course management systems along with digital books and practice problems are currently being managed by these companies. If the textbook publishers are unable to adapt to the current digital change, then they might not be around in ten years. The free market could potentially create two-three giant conglomerates of education which would compete with each other for students, and this competition would spur greater educational advancements. The university consequently would exist largely for its specialized curricula, graduate programs, and athletics.

That is the foreseeable outlook for higher education. Instead of schools avoiding technology because of tradition, they should find new ways to use it to their advantage. The world is changing and it is time the education system caught up.

7.3 REFERENCES

1. Nguyen, F. The effect of an electronic performance support system and training as performance interventions. **2007,** PhD diss., Arizona State University, Tempe.
2. *ALEKS -- Assessment and Learning, K-12, Higher Education, Automated Tutor, Math*. http://www.aleks.com accessed March 24, 2010.