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A Comparative Study of an Online and a Face-to-Face Chemistry Course

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Abstract

While online and face-to-face (F2F) courses have been compared in numerous studies, there has been a lack of focus on online chemistry courses. This study was conducted to compare the success of students instructed in an online or F2F general chemistry course for non-majors. One hundred forty six exam questions were categorized according to Bloom's revised taxonomy and student success on each problem was analyzed. Comparison of online and F2F courses showed significant differences at the lowest order of thinking, "remember," with online students performing better than F2F students. A similar result was seen with the next order of thinking, "understand," but there were no significant differences observed between online and F2F students for exam questions at the "analyze" level. The observed advantage for online students may be because online instruction promotes better memorization of facts or because students good at memorization gravitate towards online courses. No significant differences were seen between online and F2F courses when comparing the various chemistry topics covered in the exams. Online instruction appears to be as effective as F2F instruction when teaching introductory chemistry topics.

Since the inception of online instruction, enrollment in online courses has continued to increase for students in higher education. A recent survey conducted by Allen and Seaman (2011) showed that, in the last few years, the rate of increase in online enrollment has slowed about 10%, but has still outpaced the overall growth in higher education enrollment of approximately 1%. Despite this trend, the study showed that fully one third of professors surveyed still believe that face-to-face education (F2F) is superior to online education in providing students quality instruction. This proportion has remained nearly constant since 2003 (Allen & Seaman, 2011).

Strictly speaking, face-to-face education is broken down into two categories (Allen & Seaman, 2011): traditional, for which no portion of the course is available online, and web-enhanced, in which a classroom management system (CMS) is used to provide extra resources, such as posting lecture notes or syllabi, to supplement the F2F course. Hybrid (or blended) courses are newer courses which blend F2F instruction with online instruction; online instruction in these courses ranges from 30-80% of the material. The final category of instruction, then, is online courses, in which greater than 80% the instruction is provided online. Similar to online courses, classroom-in-a-box (CIB) courses are offered via CD or DVD-ROM's and contain an

entire course's worth of material (Skylar, Higgins, Boone, & Jones, 2005). CIB's are, of course, unmediated as the students can take the course at their own pace.

Overall, classroom management systems (CMS), web-based software for hosting file sharing, discussions, and other online activities, have been demonstrated to encourage interaction between students and teachers (Vidakovic, Bevis, & Alexander, 2003), and have been correlated with student success in general chemistry courses (Bowman, 2012). In exploring the various learning styles of online students, Mupinga, Nora, and Yaw (2006) observed a wide range of learning styles, preparedness, and engagement in online courses, all of which had influence on student success in the online environment. It was determined that online learning environments are less instructor centered in nature than F2F courses, which allow students to pursue a more independent level of learning; no specific learning style dominates the students taking online courses. Furthermore, online systems can foster a constructivist approach by allowing students to move at their own pace and develop their own ideas (Evans & Leinhardt, 2008). West, Rosser, Monani, and Gurak (2006) found that students in a scientific writing course were more successful if they focused on the process of learning (i.e., metacognition), rather than the content. Additionally, students who were unsuccessful spent more time on easy assignments, giving up on the hard ones. This was comparable to the findings of Bowman (2012), who found that students who focused on chemistry homework problems, rather than giving up quickly, were more successful than those that did not give up quickly.

In an early study on the effectiveness of online education, Piccoli, Ahmad, and Ives (2001) found no significant differences in student performance between F2F and online instruction. This study, a course in computers for business majors, used a virtual learning environment (VLE) for daily instruction, but held all course exams in person. While no differences between students' performances were detected, students in the online sections of the course evaluated themselves as more able to use computers (i.e., higher self-efficacy) than did their F2F peers. This, however, came at the expense of satisfaction, as online students reported lower satisfaction in the course.

Research into the effectiveness of online education has continued and shows varying results when comparing online and F2F courses. In a teacher education course, traditional, online, and classroom-in-a-box were compared and no significant difference in student performance was found between the three different delivery methods (Skylar et al., 2005). Student satisfaction was likewise shown to be roughly equal. However, in a Thai business statistics course, students in the online course were observed to perform significantly better than students in an equivalent F2F course (Suanpang & Petocz, 2006). The authors concede that there may have been significant contribution from teaching style difference between the traditional and online courses that accounted for the observed difference. Martín-Blas and Serrano-Fernández (2009), though not studying an online course, did note that increased use of an online CMS in a F2F physics course taught in Madrid, Spain was equated with higher exam performance for individual students. Unfortunately, no statistical tests were reported to quantify the significance of the difference, though it was noted that lecture notes were the most popular resource.

A recent study of master's level teacher education courses found that students taking the class in the traditional method performed better than those who took the class online (Kirtman, 2009). Kirtman believes that the face-to-face students got together and formed study groups, which was something the online students may have had a more difficult time doing. Nonetheless, a large review of online course effectiveness studies found no significant differences in most comparisons of online and F2F instruction (Tallent-Runnels et al., 2006).

Overall, this suggested that neither method of instruction offers a clear advantage in learning. However, a meta-analysis of 176 studies comparing online and face-to-face instruction conducted by the U.S. Department of Education including the Tallent-Runnels study revealed that students who took all or part of their classes online performed better than those who took the class in the traditional method (Angiello, 2010; Policy and Program Studies Service et al., 2009). However, the combination of online and face-to-face instruction (i.e., hybrid courses) proved more advantageous than either F2F or online-only instruction. Most online studies have been conducted with college or graduate level courses, though similar results have been found for mathematics students at the middle-school level (Edwards & Rule, 2013; Edwards, Rule, & Boody, 2013).

Despite the available literature on the effectiveness of online education, studies of physical science courses are few and far between; even in a large review article, Tallent-Runnels et al. (2006) make no mention of online physical science courses, nor did Policy and Program Studies Service et al. (2009). As such, the literature suggests a need for studies on the effectiveness of online chemistry instruction and the appropriateness of various chemistry topics for online instruction. Seery (2012) described the creation of an online module in a computers-for-chemistry course, but provided no information about student performance. Weaver, Green, Epp, and Rahman (2009) performed a study on general chemistry courses in two different universities, comparing F2F with online general chemistry courses. Unfortunately, no performance data were analyzed because the two courses were too dissimilar. The authors did note significant differences in the level of discourse between students: more content questions were asked in the online course when compared with the F2F course. Moreover, the online course seemed to encourage more higher-order thinking than did the F2F course, though both still saw lower-order thinking dominate in their respective courses. One potential reason for this difference was that students in the online course had to be very specific in describing their solutions and had to be able to describe their thoughts textually (not verbally or pictorially).

In order to classify how students are learning, a coherent system must be used. Amongst the most popular methods of classifying learning are Multiple Intelligences (Brualdi, 1996; Gardner & Hatch, 1989a, 1989b) and Bloom's taxonomy (Anderson, 1999; Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956; Eber & Parker, 2007). Bloom's taxonomy can be used to classify the level of thought processing involved with learning activities or test questions. Higher level questions are generally considered to be better indicators of how well students have learned the course material (Eber & Parker, 2007).

Bloom's taxonomy has six levels of learning, which are (from highest level to lowest) evaluation, synthesis, analysis, application, comprehension, and knowledge (Bloom et al., 1956). This was revised by Anderson (1999), one of Bloom's former students, who slightly reordered the classification (the top two levels were switched) and renamed the categories from nouns to verbs. The result of this revised taxonomy is (from highest to lowest) creating, evaluating, analyzing, applying, understanding, and remembering. Individual evaluations based on Bloom's taxonomy will differ between teachers based on the techniques they use in class (i.e., where one teacher may ask a question that requires evaluation from their students, another can ask the same question but may only require remembering, depending on how the information was presented in class) (Vidakovic et al., 2003). Used in this way, Bloom's taxonomy is helpful in developing or evaluating questions used in classroom examinations (Halawi, McCarthy, & Pires, 2009). This is important as chemistry courses have wide importance in many aspects of life, and many

students have difficulty connecting the microscale interactions discussed in chemistry to the macroscale observations made in day-to-day life (Evans & Leinhardt, 2008).

Method

Participants

This study was performed in an introductory chemistry course for non-science majors, *Chemistry and Public Concern*, in a medium size public university in northern New York State. The study consisted of one face-to-face (F2F) class and six smaller online classes. The F2F section of the study was a single class in Fall 2010 that contained 148 students. The online sections contained 157 students. Of those students, 78 took the class during a fall semester, either Fall 2008, 2009, or 2010; 79 took the class during the summer, with one class during Summer 2009 and two during Summer 2010. The summer online students were two-thirds traditional students (i.e., taking classes full-time during the year) and one-third non-traditional (i.e., not taking classes full-time; generally working full-time). The fall online students were more heavily non-traditional students, about two-thirds, with only one-third traditional. Most of the online students accessed the course from their home (about 75%), with the remaining students accessing the course from their place of work. During the fall online courses, the students tended to be older than traditional undergraduate college students, with nearly half at or above the age of 30; during the summer, only 12%, on average, were above the age of 30.

Study

Chemistry and Public Concern was an introductory chemistry course focusing on chemistry and its interactions with society; a course relating chemistry with current and future social and environmental problems. The textbook used was *Chemistry in Context* (American Chemical Society et al., 2008). The course included topics such as: over-the-counter, prescription and illegal drugs; energy; food; pesticides; detergents; chemical contraceptives; and environmental concerns. No laboratory instruction was included. Student success in the course, as measured by correct responses to individual exam problems, was only analyzed for this study after all of the courses in the study had completed. All students were assigned their final course grades before analysis was begun to ensure that students' grades were unaffected by the study.

The face-to-face course was 14 weeks long, as were the three fall online courses; the summer online courses were 6 weeks long. Face-to-face classes usually accommodate 100-160 students per term. All students were given the same three mid-term tests (with question order changed for each test). Tests were administered on computer for online students and on paper for F2F students. Test questions were taken from the provided test question bank associated with the course textbook and from discussion questions posed to students. Both the online and F2F exams were timed. Online students had a period of three days in which to begin a test; once started, they had 80 minutes to finish the exam.

Face-to-face students were lectured using lecture notes and the course textbook. Online students did not meet online and were not lectured but given the same course notes and textbook for self-learning. Online courses included discussion questions (in addition to exams) in which students were asked to provide answers for, or discuss a given question related to the chapter being studied. Online students were required to post at least one response to each of those discussion questions. Face-to-face students also participated in discussions, though in person. The same topic as the online question was discussed, though without requiring a response from each student; follow-up questions were frequently posted by the instructor to facilitate a

continuing discussion. Additionally, several supplemental reading materials were provided to both the online and F2F classes.

Analysis

Both the online and face-to-face courses had three mid-term exams and a final exam to assess student learning. Identical exam questions from both the online and F2F courses were classified according to the revised Bloom's taxonomy (Anderson, 1999). In total, the three mid-term exams from each course were used for the study; all of the exams were multiple choice. Each individual exam question was coded from one (for the lowest level, remember) to six (for the highest level, create). All three researchers coded the exams using Bloom's taxonomy, and the two sets of coding with the highest inter-rater agreement, according to Cohen's Kappa (Carletta, 1996), were chosen for further use in the research; kappa scores ranged from .70 to .84. In the final analysis, no Bloom classification was chosen to be higher than "apply," the third of the six levels, as multiple-choice problems were not thought to be able to assess students' abilities beyond this level of thinking. Each exam question was also labeled according to chemistry topic, by agreement of all authors. It was generally agreed that the classifications determined by the course instructor were the best to use, as they were the chemistry topics that had been taught in the course.

To analyze student success on individual problems, the number of students from a particular class who answered a given exam question correct was expressed as a fraction between zero and one. This resulted in an essentially continuous variable for each of the exam problems, which allowed for the use of most common statistical tests. For example, the mean success of the face-to-face students on all exam problems was calculated and compared with the mean success of the online students in the fall (14 week course) and the summer (6 week course) in an ANOVA to determine if there was any significant difference in performance.

IBM's SPSS 20 was used to run the statistical tests (Field, 2009). The tests run were correlation analysis using Pearson's correlation coefficient, student's *t*-Tests, ANOVA (analysis of variance), and ANCOVA (analysis of covariance). Post-hoc tests and contrasts were used to determine differences between groups after ANOVA and ANCOVA were run.

Discussion

To begin the analysis, the data were analyzed to determine if they exhibited a normal distribution in student success levels. Initially, a normal distribution was not found, but rather a bi-modal distribution. However, when questions where zero percent of students answered correctly were excluded, a normal distribution was achieved. Excluding problems with zero correct answers was determined to be acceptable because zero percent on a question implied either an error in the data collected or an error with the problem. Data errors would, of course, adversely affect the acquisition of meaningful results, and, as statistically 20% of the students should have gotten the answer correct by guessing, problems in which no students answered correctly may have some pedagogical error that led to improper answers.

To verify that the classification of the exam problems by Bloom's taxonomy was reasonable, a correlation was run between students' success on each problem and the problem's classification. It was predicted that there would be a negative correlation between the percentage

of students correct and the Bloom classification (expressed as 1 through 6). In other words, higher order problems, according to Bloom, are more difficult problems (Bloom et al., 1956).

Pearson's correlation coefficient, r, was calculated for all courses combined (overall), for the face-to-face (F2F) course, and for each online course (fall, summer, and all online courses combined). All but the F2F course showed a significant, negative correlation between the percentage correct on a question and that question's Bloom classification, and all were significant at the 99.9% confidence level (one-tailed; see Table 1).

Table 1

Correlations between student success on exam questions and classification by Bloom's taxonomy.

Classification	*R*	Sig. (1-tailed)	N
Overall	-.328	<.001	583
Face-to-face	-.132	.056	146
Online – Summer	-.373	<.001	145
Online – Fall	-.444	<.001	146
Online – All	-.428	<.001	146

In general, this supports the prediction that there was a negative correlation between student success and the Bloom classification of a given problem. Higher order questions gave students more difficulty or students were less inclined to put forth the proper effort on higher order questions. It is not known why this correlation was not observed with the F2F students, though this may contradict Weaver et al. (2009), who proposed that online courses may promote higher order thinking. The F2F course saw no decline in student success as the problem difficulty increased, while the online classes did. Perhaps since the online courses were self-guided, students may have spent more time focusing on the memorization than on the application of the knowledge. F2F classrooms usually spend more time focusing on application of the knowledge (e.g., doing the calculations) and leave the memorization for students to do on their own.

Given that the fall and summer online courses were of different lengths (14 weeks and 6 weeks respectively), a *t*-test was run to determine if there was any significant difference between student performance in the fall and summer online courses. Results of the test showed a significant difference between the two courses, $t(289) = 2.55$, $p < .05$. The significance was two-tailed as there was no prediction made about which course may have more successful students. On average, students in the summer online course answered questions correctly on 73% of the questions, 68% for the fall online students. While the significance of this difference was not as strong as the correlations shown above, it was enough to suggest that the two courses remain separate for the analysis.

Comparison of Online courses with Face-to-Face

Finally, a series of ANOVA (analysis of variance) tests were run to determine if there were any significant differences in student performance between the face-to-face class and the

online classes. ANCOVAs (analysis of covariance) were considered for the incorporation of a control (e.g. Bloom's taxonomy classifications), but did not pass a test for the equality of error variances, which rendered the ANCOVAs unreliable. All tests below compared the F2F course, the fall online courses, and the summer online courses.

The first test was to compare the overall success rate of students in each of the courses. There was a difference, significant at the 99.9% confidence level, between the three courses, $F(2,434) = 10.427$, $p < .001$. Post-hoc tests showed that students in the online summer course were significantly more successful than either the F2F students or the fall online students. This suggests that there may be some advantage to the shorter course (6 weeks vs. 14 weeks), and also suggests that there is no disadvantage to online courses over F2F. During the summer term, students took fewer classes than in the fall, which may have allowed them to get a better grade by being able to focus on one or two courses, rather than four or five. However, no data from a F2F summer course are available, so no conclusions can be drawn. A comparison of the means can be seen in Figure 1.

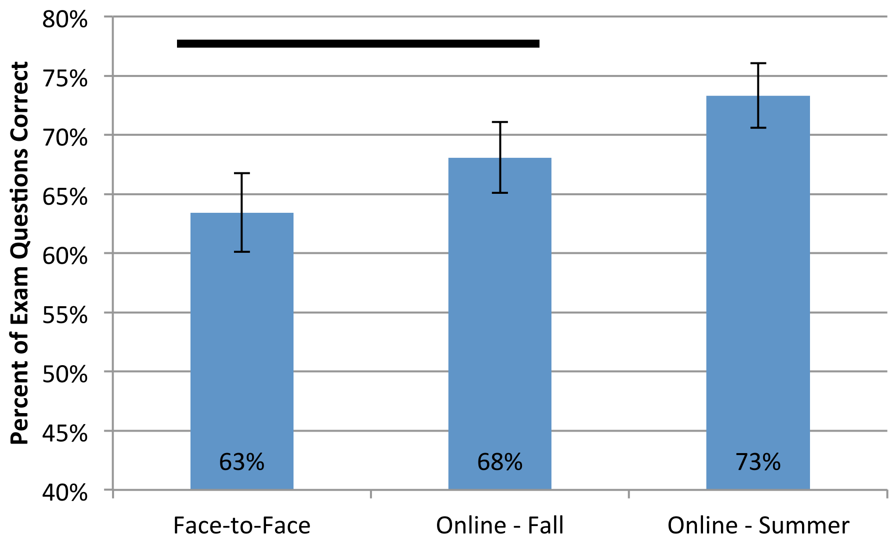

Figure 1. Comparison of mean values for number of students correct on a given exam question. Error bars represent the 95% confidence interval. The thick lines at the top of the figure show which groups are significantly different from each other according to post-hoc tests. Groups under the same line are not significantly different from others under the same line.

To determine what, if any advantage was conferred by the summer online course, the courses were compared by grouping the questions by Bloom's taxonomy categories. Three ANOVA's were run, one each for "remember," "understand," and "apply." Significant differences were measured between courses for the lowest two levels of Bloom, "remember" and "understand," but not for "apply."

The mean difference with the largest F value and strongest significance was for the exam problems that examined the lowest level of thinking, remember, $F(2,249) = 10.107$, $p < .001$. Post-hoc tests found that the face-to-face students were significantly different from either of the online courses; the comparison of means can be seen in Figure 2. Online students answered these low-level questions better than did the F2F students. This may be because the method of instruction for online, which was primarily student driven (no lectures; only reading from the

book or lecture notes), which helped students memorize more facts. It could also be that the type of student more likely to enroll in an online course is a type better at memorization. Recalling the advantage seen for the summer online courses, it is suspected that the shorter time needed to remember facts in a six week course may have given those students an apparent advantage over students, either online or F2F, who had to remember the same facts for a longer period.

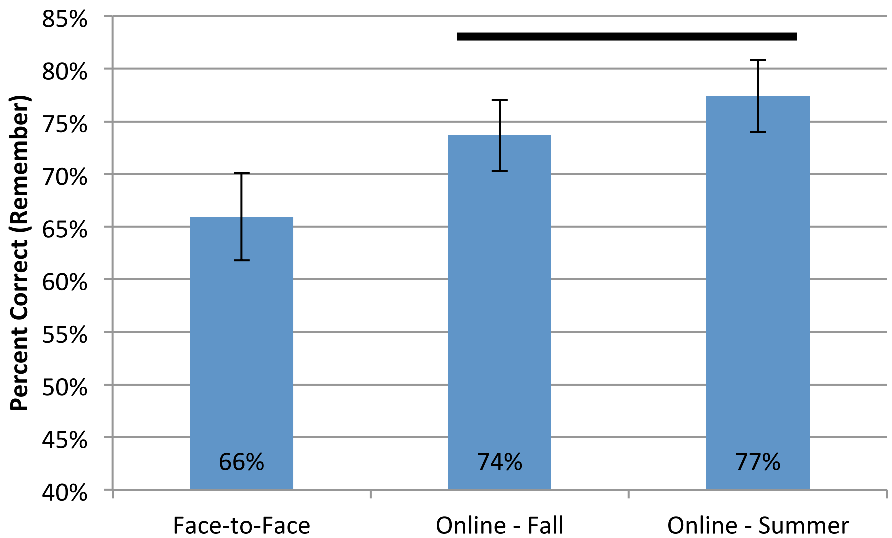

Figure 2. Comparison of mean values for number of students correct on exam questions categorized as "remember" by Bloom's taxonomy. Error bars represent the 95% confidence interval. The thick lines at the top of the figure show which groups are significantly different from each other according to post-hoc tests. Groups under the same line are not significantly different from others under the same line.

A comparison of the means for the questions at the second level of Bloom's taxonomy, "understand," the F value and significance was weaker than that of "remember" , $F(2,116) = 4.206$, $p < .05$. Post-hoc tests found that F2F students and online summer students were significantly different from each other, with online summer students performing better than the F2F students. However, the online fall students were not significantly different from either the F2F students or the online summer students; the comparison can be seen in Figure 3. The margin of difference is essentially unchanged between the remember and understand levels (i.e., F2F students got 11% fewer remember questions correct and 13% fewer understand questions correct), but the 95% confidence intervals in the understand level are much wider. As can be seen with the much reduced F statistic (4.2 vs. 10.1), the difference between online summer and F2F is much less significant for the understand level. There is probably some of the memorization effect carrying over from the remember level that accounts for this difference. The reduction in the power of this difference is probably due to the fact that the students are moving away from strict memorization.

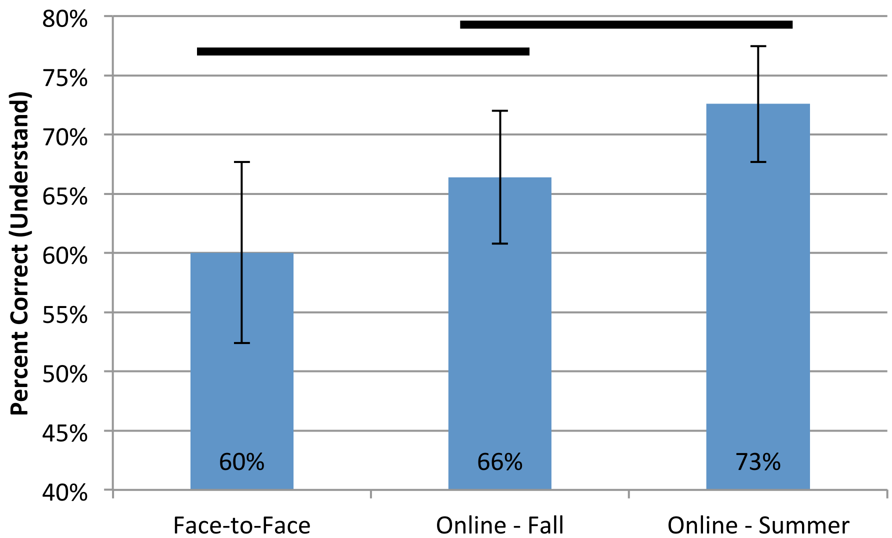

Figure 3. Comparison of mean values for number of students correct on exam questions categorized as "understand" by Bloom's taxonomy. Error bars represent the 95% confidence interval. The thick lines at the top of the figure show which groups are significantly different from each other according to post-hoc tests. Groups under the same line are not significantly different from others under the same line.

Once students moved beyond memorization and interpreting knowledge into application of that knowledge, the difference between the three classes disappeared, $F(2,63) = 2.535$, $p = .087$. The memorization effect that may have assisted in the first and second levels of Bloom's taxonomy appears to have faded as students had to apply their knowledge to new problems (usually in the form of calculations). A significant difference favoring the F2F class is not, however, observed. Rather, all classes appear to be equivalent in student success, which bodes well for teachers developing further online courses. Overall, there appear to be no advantages to either F2F or online instruction except in short-term memorization.

Comparison of Chemistry Topics

As mentioned before, most studies of online and face-to-face classes are not in the physical sciences (Policy and Program Studies Service et al., 2009; Tallent-Runnels et al., 2006). Given that this study was run in a chemistry course, it was of interest to see if there were any chemistry topics that were better taught online or F2F. A series of ANOVA tests were run to compare the online fall, online summer, and F2F courses for each of the twelve chemistry topics, as determined by the authors. See Table 2 for the list of all chemistry topics used and the ANOVA tests on each topic.

Table 2

Comparison of means between face-to-face, online fall, and online summer courses for each chemistry topic.

Mean Success	F	df1	df2	Sig.
Health	6.238*	2	75	.003
Nomenclature	4.877*	2	48	.012
Periodic Trends	2.381	2	21	.117
Molecular Geometry	4.403	2	3	.128
Electromagnetic Spectrum	1.679	2	15	.220
Environmental	1.411	2	105	.248
Bonding	1.263	2	18	.307
Properties of Matter	.919	2	24	.412
Stoichiometry	.552	2	15	.587
Atomic Structure	.240	2	26	.788
Thermodynamics	.051	2	12	.951
Concentrations	.037	2	15	.964

* Denotes signifcance at .05 level

Note. Comparison of means (ANOVA) between face-to-face, online fall, and online summer courses for each of twelve chemistry topics as shown in the left-most column. Degrees of freedom (df) one and two are shown, as is the significance level (sig.).

As can be seen in Table 2, there were only two chemistry topics in which a difference significant at the 95% level or better was observed: health chemistry, $F(2,75) = 6.238$, $p < .01$ and nomenclature $F(2,48) = 4.877$, $p < .05$. Post-hoc tests determined that, just like “remember,” students in the F2F course did significantly less well on the health problems than did students in either online course. Ninety three percent of the health chemistry questions were at Bloom’s “remember” level of cognition, so the effect observed here is most likely the same as was observed for the “remember” level, a memorization effect. Given the resemblance to the “remember” category, it is unlikely that there was any effect from the method of teaching on health chemistry specifically.

Similarly, the nomenclature problems mimicked the “understand” problems when comparing classes by post-hoc test. As the nomenclature problems were 22% “remember” and 56% “understand,” it again suggests that the effect seen here is the same effect attributed to the “understand” category and not an effect due to topic of nomenclature. Overall, there appear to be no differences between online and F2F courses in the instruction of various chemistry topics.

Conclusions

Though online courses are in abundance now (Allen & Seaman, 2011), the few online chemistry courses that are offered have little to no literature measuring their efficacy (MIT, 2013; Oregon State University, 2013). Evans and Leinhardt (2008) created a framework to analyze the pedagogy of online chemistry courses, but thus far, the framework has only been used by the original authors (Evans, Yaron, & Leinhardt, 2008). Their research did show a slight improvement in performance for the online students, though the course type (online or face-to-face) was less significant a factor than external factors such as SAT scores. One large reason for the lack of online chemistry courses is a lack of desire to eschew the in-person laboratory experiment. Even recent publications that support the use of virtual laboratories, such as could be used in online chemistry courses, prove the efficacy of these components when used in a face-to-face course (Su, Lin, Tseng, & Lu, 2011; Yaron, Karabinos, Lange, Greeno, & Leinhardt, 2010).

In an effort to better understand the differences, if any, between online and face-to-face chemistry (F2F) courses, Bloom's taxonomy was applied to analyze the exam questions from a general chemistry course for non-majors (there was no lab component). A significant, negative correlation was seen between student success on individual exam problems and higher order thinking problems. That is, problems requiring higher order thinking were more difficult, an expected result (Bloom et al., 1956). This negative correlation was not observed for the F2F students. The reason for this lack of a significant correlation is unknown, though it is perhaps because F2F courses promote higher order thinking and, thus, students perform as well on higher order problems as they do on lower order problems. It may also be that F2F courses do not emphasize the lowest orders of thinking. Specifically, most F2F chemistry courses spend more time working calculations and other applications of the knowledge discussed in lectures, which means students spend class time practicing higher order thinking. As the online courses studied here were self-guided, students may have spent more time focusing on the memorization than on the application of the knowledge.

Overall, there were few significant differences between online courses and face-to-face courses. F2F students answered fewer of the memorization ("remember" from Bloom) questions correctly than did online students. Most likely this is either because online instruction promotes better memorization or because students good at memorization gravitate towards online courses. Or, as suggested above, online students may spend more time focusing on memorization because it is easier than working at the higher levels of thinking. There was a significant difference at the second level of Bloom's taxonomy, "understand," though it was less significant than the difference for "remember." As understanding is generally being able to recognize the knowledge you have learned in new contexts or larger frameworks, memorization still plays a role in differentiating students, though not as large a role. However, for "apply," the third level of Bloom's taxonomy, there were no statistically significant differences between the performance of any of the classes. This means that all of the students studied, in both the online and F2F courses, scored equally well on these problems. The advantage conferred on online students in the lower order thinking problems no longer applies, but neither did the online course confer a disadvantage to these students. What is unknown is what difference, if any, would be observed at the highest levels of thinking (i.e., analyze, evaluate, and create). This study was unable to analyze any higher order thinking as multiple choice problems do not lend themselves to evaluating thinking beyond the application level.

When the various chemistry topics covered in the course were compared (see Table 2), no significant differences between various chemistry content questions were observed. It can be concluded, then, that for most introductory chemistry material, there is no difference between online or face-to-face instruction. This comparison does not, however, include analysis of a laboratory component, as none was offered with the course being studied.

Limitations

The course analyzed in this study had no laboratory component and, as such, discussion about the effectiveness of online lab instruction is beyond the scope of this paper. As there were some observed differences between the 14-week online course (fall) and the 6-week online course (summer), it would have been ideal to include a 6-week F2F course to compare the effect of instruction length on student success. Since the institution where the study took place does not offer this course as F2F during summers, no conclusions about the effect of instruction length were made in this study. Finally, no comparisons between F2F and online courses were made for the higher orders of thinking in Bloom's taxonomy (i.e., analyze, evaluate, and create) as the course exams only included multiple choice problems. Comparisons at higher orders of thinking would require the use of student-generated responses, such as short answers, essays, or student-drawn chemical structures.

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