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Using web-based instruction to improve large undergraduate biology courses: An evaluation of a hybrid course format

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Abstract

We developed a hybrid course format (part online, part face-to-face) to deliver a high-enrollment, introductory environmental biology course to resident (living on or near campus), non-science majors at a large, public university. The hybrid course was structured to include bi-weekly online assignments and weekly meetings in the lecture hall focused on active-learning exercises. To evaluate the effectiveness of the web-based component of the hybrid course, we taught the hybrid course simultaneously with a traditional course in which we used passive lectures to cover material in the online assignments. Both courses received the same active-learning activities in class. Students in the hybrid course reported that the quality of interaction with the instructor was high, that they read the text more often and studied in groups more frequently. Performance on a post-course assessment test indicated that the hybrid course format was better or equivalent to the traditional course. Specifically, online assignments were equivalent to or better than passive lectures, and that active-learning exercises were more effective when coupled with online activities. Performance gains were greater for upperclassmen than for freshmen, indicating that hybrid course formats might be a superior option for upperclassmen when satisfying general science requirements.

Keywords: Evaluation of CAL systems; Improving classroom teaching; Interactive learning environments; Post-secondary education; Teaching/learning strategies

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1. Introduction

At most colleges and universities, introductory science courses have high enrollments (100 + students per section) and are taught via traditional, passive lectures (Pascarella & Terenzini, 1991; Springer, Stanne, & Donovan, 1999). For non-science majors, 1–2 introductory science courses may be required for graduation. This represents the only opportunity for non-science majors to gain scientific literacy and understand how science works. More importantly, these courses are the only opportunity for students to learn how to understand and interpret scientific data to make life decisions, and to incorporate this knowledge into their own major disciplines. Unfortunately, students in high-enrollment, lecture courses do not retain information, develop higher order thinking skills, or increase their motivation for learning as well as students in smaller classes with more interactive formats (see review by McKeachie, Pintrich, Lin, Smith, & Sharma, 1986). Additionally, large classes in the natural sciences are plagued by poor attendance (Freidman, Rodriguez, & McComb, 2001). If undergraduates are not attending or learning in these courses, then citizens, journalists and policy makers may not have adequate scientific literacy, and the assimilation of scientific discoveries across other disciplines may be hampered.

At Michigan State University, introductory science courses for non-science majors are offered by the Center for Integrative Studies – General Science (CISGS). Because we have observed low attendance and poor performance in some classes, we developed a hybrid course (combination of online and face-to-face instruction) to improve the effectiveness of introductory environmental biology courses. In our hybrid course, we provided bi-weekly online homework assignments in lieu of 2 of the 3 h of lecture time. Once per week, the class met for face-to-face instruction in the lecture hall. These weekly class sessions focused on cooperative, active-learning exercises.

We replaced some of the lecture time with online instructional methods, not only because web-based instruction is becoming increasingly popular and familiar, but also because web-based environments may be superior to more traditional learning environments. Web-based courses may offer students more flexibility and control over where and when to participate (Ostiguy & Haffer, 2001) which can lead to greater motivation to excel (St. Clair, 1999). Learning in web-based courses can also be more active (Hacker & Niederhauser, 2000) and more student-centered (Sanders, 2001) than taking notes in traditional, passive lectures, and can encourage students to learn in different ways (Yazon, Mayer-Smith, & Redfield, 2002).

However, online instruction has potential drawbacks, and this has been reflected by mixed evaluations of online courses (e.g., Russell, 2001). Although some wholly online courses have reported significant improvements in student performance (e.g., Navarro & Shoemaker, 2000), student performance in others is no better (e.g. King & Hildreth, 2001) or worse (e.g., Brown & Leidholm, 2002) than traditional instructional designs. Reasons online courses fail to improve student learning include lack of face-to-face interaction with instructors and classmates (Carstens & Worsfold, 2000; Yazon et al., 2002), high drop-out rates, and lack of accountability (Sullivan, 2001).

We combined face-to-face, classroom instruction with online activities because hybrid courses have the potential to capture benefits of web-based instruction while retaining benefits of traditional classroom instruction. Specifically, we hoped that a hybrid course could retain high-quality student–faculty interaction (Navarro & Shoemaker, 2000; Riffell & Sibley, 2003) and improve learning outcomes (Tuckman, 2002).

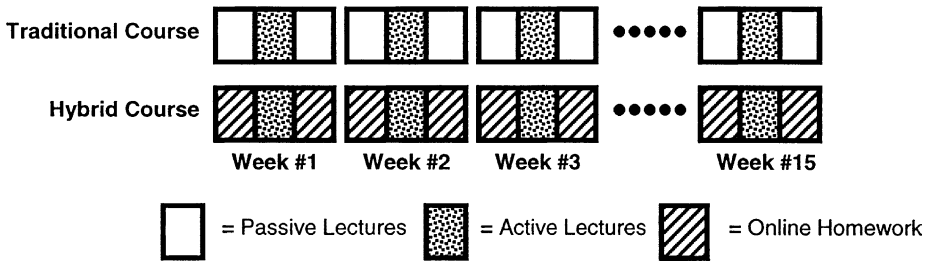

Fig. 1. Experimental design involving the hybrid and traditional formats of the introductory, environmental biology course. Each rectangle represents one 50-min instructional period (passive lecture, active lecture, or online assignment), and each set of three represents a unit (or week) of the course.

To assess the effectiveness of our hybrid course, we taught the course simultaneously with a traditional version of the course which used passive lectures instead of online assignments (Fig. 1). We tested the following hypotheses:

1. We hypothesized that the hybrid format would facilitate high quality interaction with the instructor and more active learning. If this were true, we expected that a greater proportion of students in the hybrid class would: rate the quality of interaction with the instructor as higher or equal to that in other courses they had taken; report reading and/or using their textbook more frequently, and report contacting classmates or studying in groups outside of the lecture hall more frequently.
2. We hypothesized that students in the hybrid course would show more evidence of learning gains than their counterparts in the traditional course. If this were true, we expected students in the hybrid course to score higher on a post-course assessment test.
3. We hypothesized that online homework assignments would be just as effective, or more so, than traditional passive lectures at promoting learning. If this were true, students in the hybrid class would score higher on post-course assessment questions that tested material covered in passive lectures or online assignments.
4. We hypothesized that cooperative, active-learning exercises would be more effective (i.e., more learning) when coupled with online assignments (as opposed to coupled with traditional, passive lectures). If this were true, students in the hybrid course would score higher on post-course assessment questions that tested material covered in active lectures.

2. Description of the hybrid course

Our course, Applications of Environmental Biology, used major environmental issues (e.g., global warming and forest management) as a framework for understanding basic biological (e.g., logistic population growth), ecological (e.g., energy flow), and sociological processes (e.g., economic growth). Our prototype hybrid design incorporated two primary components: (1) active lectures: weekly meetings in the lecture hall focused on cooperative, group activities to learn core skills and concepts; and (2) online assignments: bi-weekly, web-based homework problem sets. Each week of the course began with one online assignment due the night before the active lecture. A second online assignment due at the end of the week reinforced and extended concepts dealt with in class (Fig. 1).

2.1. Active lectures

Active-learning can increase student attention and concept retention (e.g. Ebert-May, Brewer, & Allred, 1997; Springer et al., 1999; Cooper & Robinson, 2000), so our face-to-face sessions featured active-learning exercises. After a short lecture (5–15 min) by the instructor, students were presented a problem to complete. Students worked in informal groups (i.e., not assigned by the instructor) and typically partnered with neighbor(s). Students could ask questions of their peers, the instructor, and/or the undergraduate teaching aide during this time. Each student turned in their own answer to be graded on machine-scored bubble sheets. A short summary lecture (5–15 min) followed each activity. One or two exercises were completed in a single 50-min class session. Each week's activity was worth a maximum of 10 points. A detailed description of these lessons is in Riffell and Sibley (2003).

2.2. Online assignments

Traditionally, students spend 3 h per week in lecture, but we replaced two-thirds of this time with online assignments. Each assignment contained a combination of multiple choice, matching, true/false, and calculation problems with approximately 50 questions per week. We wrote questions to encourage reading the text for content, comprehension of major processes, and applications. Students were also required to manipulate Java-based models to complete certain assignments. Example questions are in Riffell and Sibley (2003).

We delivered the online assignments using an early version of the open-source, web-based platform, LON-CAPA (Speier & Kortemeyer, 2001: www.lon-capa.org). Several features of LON-CAPA are critical to our hybrid course. First, questions were individualized. Each student received a slightly different version of each question (e.g. different choices or different starting numbers for calculations) based on a random number algorithm. This permitted working together in groups, but discouraged students from simply copying another's answers. Second, students received three attempts to get full credit and received partial credit after three attempts which encouraged mastery of the content. Third, LON-CAPA provided feedback to students in two ways: through pre-programmed hints received after incorrect answers, and through a mechanism to contact the instructor with questions about specific problems. Using LON-CAPA also allowed us to capitalize on the general ability of web-based instruction to provide students with flexibility and control (Ostiguy & Haffer, 2001), more active learning (Hacker & Niederhauser, 2000), and a more student-centered learning environment (Sanders, 2001).

2.3. Staff resources

Our hybrid course was taught by a non-tenure stream faculty instructor (SKR) who prepared weekly lectures and active-learning activities, answered e-mails about online assignments (approximately 5 h per week, see Section 5.4), prepared exams and held office hours. An undergraduate TA assisted with active-learning activities, graded active-learning activities, led review sessions before exams, and held office hours (approximately 10 h per week). All online assignments were graded by LONCAPA. LONCAPA support was provided by the LONCAPA support team (see www.lon-capa.org). Although the development and construction of the web-based

materials took about a year, the time and staff to teach the course was not greater than that required for a typical, lecture-based course.

3. Methods

3.1. Experimental design

In spring of 2002, we taught the hybrid course concurrently with a traditional version of the course as an experiment. The traditional course included the same subject matter as the hybrid course and was taught by the same instructor. The traditional course retained the mid-week active lectures, but subject matter covered in online assignments (due on Monday and Friday) in the hybrid course was covered during passive lectures on Monday and Friday in the traditional course (Fig. 1). Both courses completed the same active learning exercises in the mid-week lectures. Monday/Friday lectures in the traditional course were passive in that active-learning exercises or group work were not provided during these times, and the instructor did not directly query students. The instructor did use different forms of media (PowerPoint, VHS) and answered any questions raised by students during class.

3.2. Characteristics of student populations

Enrollment was open for both courses, so student populations were self-selected, but students were not aware of the nature of the research when enrolling. 102 students enrolled in the traditional course, and 85 enrolled in the hybrid course. After we omitted students who declined to grant permission for inclusion in the study, missed one or more of the surveys or assessments, or incompletely filled out a survey, we were left with $N = 74$ (traditional course) and $N = 55$ (hybrid course). The two student populations did not differ in the ratio of males to females, the proportion with previous experience in an online course or the proportion who had previously taken an Integrative Studies biology course at Michigan State (Table 1). Also, both student populations were almost entirely comprised of full-time students ($\geqslant 98\%$). The traditional course, however,

Table 1
Characteristics of student populations in the hybrid and traditional courses

	Traditional	Hybrid	χ^2	P value
% Male	34%	33%	0.723	0.448
Classification			9.775	0.020
% Freshman	46%	30%		
% Upperclassmen	54%	70%		
% Full-time	100%	98%	1.270	0.442
% Commuter	6%	17%	4.381	0.060
Previous online experience	9%	12%	0.563	0.585
Previous experience in an Integrative Studies biology course at MSU	6%	6%	0.001	1.000

contained more freshmen ($P = 0.020$) and fewer commuter students ($P = 0.060$) than the hybrid course (Table 1).

3.3. Collection of survey data

We administered a survey at the beginning and end of the course to collect data about the demographic composition of the students in the courses, self-reported measures of effort, and student perceptions of the course. This survey contained questions relating to a variety of assessment aims that are beyond the scope of this paper (e.g., changes in perceptions about online learning environments), and we list only those questions that provide data used in these analyses. The relevant questions included:

1. What is your classification?
   A. Freshman B. Sophomore. C. Junior D. Senior
2. Are you a part-time or full-time student?
3. Are you a resident or commuter student? Consider yourself a commuter if you live more than 5 miles from campus.
4. Have you ever taken an online course before (at any institution)?
5. Have you ever taken an ISB (Integrative Studies Biology) course at MSU?
6. Rate the overall quality of interaction with the instructor compared to other, more traditional classes you have taken.
   A. Much higher; B. Higher; C. About the same; D. Lower; E. Much Lower
7. How often did you read or reference the textbook outside of the classroom?
   A. Many times per week; B. 1–2 times per week; C. Several times throughout the semester; D. Only before tests; D. Never.
8. How often did you opt to contact a classmate (phone, e-mail, in person, etc.) when you had questions?
   A. Many times per week; B. 1–2 times per week; C. Several times throughout the semester; D. Only before tests; D. Never.
9. How often did you work on problems or study with a classmate or group of classmates outside the classroom?
   A. Many times per week; B. 1–2 times per week; C. Several times throughout the semester; D. Only before tests; D. Never.

3.4. Collection of attendance data

3.4.1. Active lecture attendance rates (both courses)

We used the number of graded exercises turned in by each student to measure attendance at these lectures (an exercise was turned in during each active-lecture). Active lecture attendance rates (AL_ATTEND) were calculated as the percent of exercises turned in by each student.

3.4.2. Passive lecture attendance rates and online assignment attendance rates

To measure attendance at passive lectures and online assignments (ATTEND), we needed two measures which were directly comparable. We calculated passive lecture attendance rates (traditional course only) as the percent of lectures for which students were present. To record at-

tendance, students passed their identification card through a wall-mounted card reader when entering and exiting the lecture hall.

In the hybrid course, students completed two online assignments per week in lieu of lecture time. We considered a student to have "attended" a computer assignment if at least one-half of the homework problems for an assignment had been attempted. This measure should be equivalent to passive lecture attendance rates because attention in passive lectures can vary (e.g., wandering thoughts, sleeping, studying other subjects). Only part of the lecture material may be assimilated even though the student is physically present the entire time (Cooper & Robinson, 2000).

3.4.3. Motivation for attendance

Students in both courses had similar grade incentives to attend lectures or complete assignments (students could earn full credit at approximately 80% compliance). Passive lecture attendance contributed 17% of the final grade in the traditional course, and was awarded on the following scale: attend $\geqslant 80\%$ of the lectures – 17%; attend $\geqslant 70\%$ – 15%; attend $\geqslant 60\%$ – 12%; etc. In the hybrid course, completion percentages of online assignments (points earned/total points assigned $\times$ 100) counted as 15% of each student's final grade. Several bonus assignments allowed students to miss approximately 20% of the regular assignments and still recoup those points.

3.5. Collection of performance data

To estimate in-class effort, we calculated the mean percent score received on each *completed* active-learning activity (SCORES_AL). This variable represents the amount of effort (or performance) by a student when actually present in class, and is different from attendance to active lectures (ATTEND_AL).

To assess learning gains over the course of the semester, students in both courses took a 30-question assessment test on the first day of the course (PRETEST). The students received the same 30 questions on the last class day (post-test scores). These questions covered the central ideas and included a range of skills (i.e., interpreting data and graphs, making predictions). We wanted to assess not only basic knowledge gains, but also students' ability to comprehend and apply key processes. To determine the extent to which our test questions actually measured these outcomes, we asked 3 introductory science instructors at MSU (not involved with teaching the course) to classify each question according to Bloom's taxonomy (as listed in Grolund (1970)). Their ratings indicated that our pre-/post-course assessment test was comprised of 20% Level 1 Knowledge questions (basic recall), 40% Level II Comprehension questions (translating and interpreting material), and 40% Level III Application questions (applying concepts to new, concrete situations).

3.6. Statistical analysis

To test the hypothesis that the hybrid format would facilitate a more interactive learning experience, we used responses to the survey questions about the quality of interaction with the instructor, frequency of book use, frequency of contacting classmates, and frequency of working

in groups (see Section 3.3). We tested the null hypothesis that the proportions of students listing each response were equal in both courses using contingency table analyses with exact χ^2 statistics (SAS Institute, 1999). Our a priori $\alpha = 0.05$ for these tests.

To test hypotheses that students would learn more in the hybrid course, we used scores on the post-course assessment text (# correct out of 30 possible) as the outcome, or dependent, variable in a general linear model (Proc GLM in SAS). Because factors other than course format had the potential to influence learning gains and post-test scores, we first included covariates to remove the effects of these factors before testing our hypotheses about post-test scores. We included pre-test scores (PRETEST) to account for differences in pre-existing knowledge among students. We included GENDER (0 = male; 1 = female) to account for gender-related performance differences among students (Kirkpatrick & Cuban, 1998; Sullivan, 2001). We included active-learning lecture attendance rates (ATTEND_AL) and passive lecture/online assignment attendance rates (ATTEND) to account for potential effects of attendance (Moore, 2003). To account for potential effects of effort in the active lectures, we included performance on active-learning activities (SCORES_AL). We did not include covariates for performance on online activities because we did not have an equivalent metric for effort during passive lectures. Because students with previous experience in an online class might be better equipped to succeed than novices, we included online experience (ONL_EXP: 0 = no previous experience, 1 = previous experience as determined from survey) as a covariate. Because the hybrid course had significantly more upper-classmen ($P = 0.020$) than the traditional course (Table 1), we included class-standing (CLASS: 0 = freshman; 1 = sophomore, junior, or senior) as a covariate. The hybrid course may have also contained a greater proportion ($P = 0.060$) of commuter students (Table 1), so we included commuter status (COMMUTE: 0 = resident; 1 = commuter) as a covariate.

To test our hypothesis about the effect of the hybrid format on post-test scores, we included class format (FORMAT: 0 = traditional, 1 = hybrid) as a main effect. Because we suspected that the effect of format might vary with gender, classification, or online experience, we included FORMAT × GENDER, FORMAT × CLASS, and FORMAT × ONL_EXP interactions. We used Type III sums of squares for all tests. This way we corrected for differences in post-test performance that might be related to factors such as pre-existing knowledge (PRETEST), gender, and attendance (ATTEND and ATTEND_AL). This ensures that we are testing for the effect of course format per se rather than an indirect effects of course format on other factors related to learning (for example, if the hybrid format increases attendance, this would be an effect of course format on attendance which in turn impacts learning). For all tests, we used an a priori $\alpha = 0.05$. We did not interpret significant main effects when significant interactions were present (Zar, 1999). Rather, we interpreted differences in group means using effect slices for each level of the covariate (SAS Institute, 1999).

One-half of the questions on the pre-/post-assessment test were based on material covered in either passive lecture (traditional course) or online assignments (hybrid course) only. This allowed us to test our hypothesis that online assignments can effectively substitute for traditional lectures by repeating the analysis we described above, but substituting post-test scores on only those 15 questions as the dependent variable. The other half of the assessment questions tested material covered in active-learning exercises only. By using post-test scores on these remaining 15 questions, we could test our hypothesis that active-learning activities would be more effective in the hybrid format (coupled with online assignments).

4. Results

4.1. Measures of interaction and active learning

Just over 85% of the students in the traditional course stated that the quality of interaction with the instructor was the same or better than in other traditional courses they had taken (Fig. 2). In the hybrid course, just over 80% of the students responded in this way. This difference was not significant statistically ($\chi^2 = 8.14$, exact $P = 0.084$).

In the traditional course, over half of the students reported that they used their textbooks only before tests (39%) or not at all (14%). In contrast, over 80% of the students in the hybrid course reported using their textbooks a minimum of 1–2 times per week (Fig. 3). Clearly, students in the hybrid course used their textbook more often ($\chi^2 = 47.59$, $P \ll 0.001$).

In the traditional class, 29% of the students reported contacting other students for help on at least several occasions during the semester (Fig. 4), compared to 43% in the hybrid course ($\chi^2 = 16.73$, $P = 0.002$). The hybrid course, however, also had a greater proportion of students who reported never contacting other students (53%) than did the traditional course (43%).

In the traditional course, 18% of the students reported studying or working in groups outside regular class hours at least several times throughout the semester (Fig. 5), but in the hybrid course, 40% reported studying or working in groups outside regular class hours at least several times during the semester ($\chi^2 = 25.17$, $P < 0.001$). However, the hybrid course also had a greater proportion of students (56%) who reported never studying in groups than did the traditional course (44%).

4.2. Performance on the post-course assessment test

4.2.1. Overall performance

Three covariates were related to post-test scores: PRETEST, GENDER, and performance on active-learning activities, SCORES_AL (Table 2: P's $\leqslant 0.020$). Post-test scores were related to course format ($P = 0.004$), but because the FORMAT $\times$ CLASS interaction was also significant

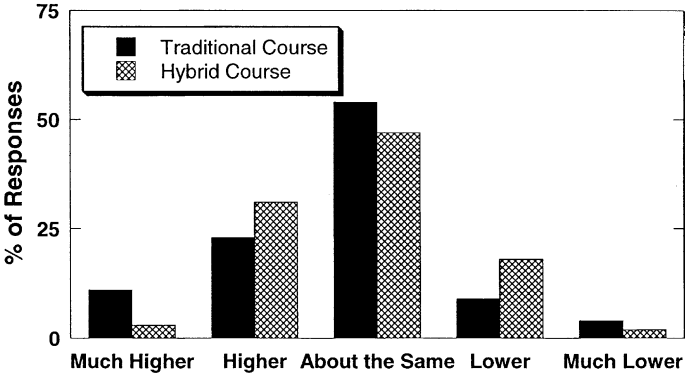

Fig. 2. Student ratings of the overall quality of interaction with the instructor when asked "Rate the overall quality of interaction with the instructor compared to other, more traditional classes you have taken". Difference between traditional and hybrid environments is significant ($\chi^2 = 8.14$, exact $P = 0.084$).

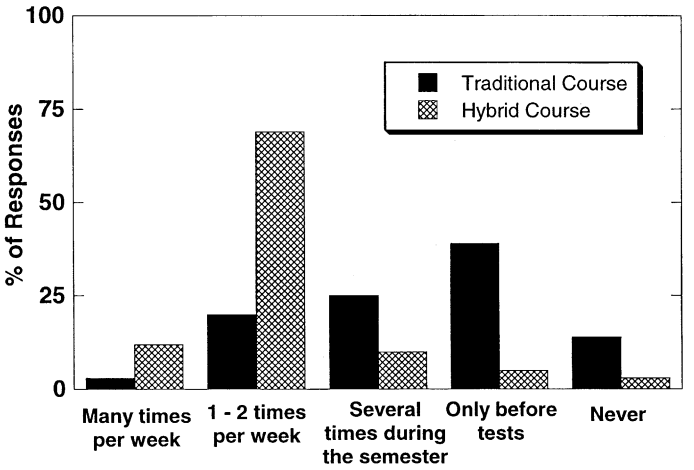

Fig. 3. Frequency of students' use of the textbook during the semester in the traditional and hybrid courses ($\chi^2 = 47.59$, $P \ll 0.001$).

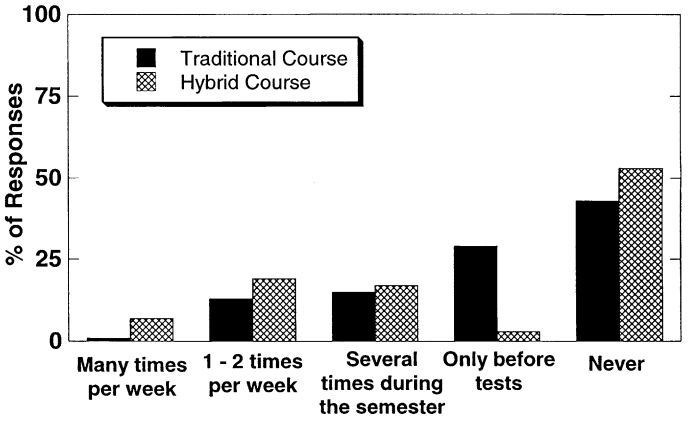

Fig. 4. Frequency at which students contacted classmates for help or with questions during the semester ($\chi^2 = 16.73$, $P = 0.002$).

($P = 0.041$), we interpret only the main effect slices (see Fig. 6). Post-test scores were higher in the hybrid course than in the traditional course for both freshmen ($P = 0.102$) and upperclassmen ($P < 0.001$), but this difference was significant only for upperclassmen (Fig. 6).

4.2.2. Passive lectures vs. online assignments

Post-test scores for material covered only in online assignments or passive lectures were related to pre-test scores (PRETEST), GENDER, and performance on active-learning activities, SCORES_AL(Table 3: P's $\leqslant 0.014$). Post-test scores were higher in the hybrid course, but the FORMAT $\times$ CLASS interaction was significant (Table 3: $P = 0.006$), so we interpret the main effect slices only (Fig. 7). Post-test scores of freshman did not differ ($P = 0.467$) between the two course formats, but those of upperclassmen were higher in the hybrid course ($P < 0.001$).

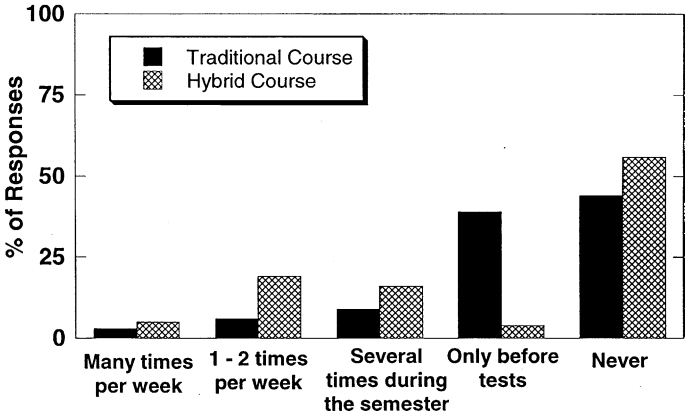

Fig. 5. Frequency at which students studied or worked in groups outside the lecture hall during the semester. ($\chi^2 = 25.17$, $P < 0.001$).

4.2.3. Active-learning exercises in two different environments

The same three covariates were significantly related to post-scores on questions pertaining to material covered in active lectures – pre-test scores (PRETEST), GENDER, and performance on active-learning activities, SCORES_AL (Table 4: P's $\leqslant 0.032$). Post-test scores on active lecture material were higher in the hybrid course ($P = 0.003$). None of the interactions were significant, so we interpreted the main effect for course format directly. However, we displayed least-squared means for freshman and upperclassmen separately to be consistent with displays for the previous two tests (Fig. 8).

5. Discussion

5.1. Did the hybrid course facilitate interaction and active learning?

One of our primary concerns was retaining high quality faculty–student interaction in the hybrid course where face-to-face opportunities were limited. Student ratings of the quality of interaction with the instructor were slightly lower in the hybrid course (Fig. 2). This difference was not significant, indicating that there was not a substantial decrease in the quality of interaction between the students and the instructor in the hybrid course. A pattern worth noting is that fewer students in the hybrid course rated the interaction "about the same" as other courses, indicating that students in the hybrid course were less ambivalent (more likely to rate quality of interaction either better or worse) than students in the traditional course.

Consistent with our a priori expectations, students in the hybrid class read and/or referenced their textbook more frequently than their counterparts in the traditional course (Fig. 3). In the traditional course, over 50% of the students reported they read their textbook only before tests or not at all. For these students, passive presence at lectures (totaling approximately 3 h per week) is the only exposure to the material that they received throughout the semester. In contrast, approximately 80% of the students in the hybrid course reported reading or referencing their

Table 2
General linear model of post-test scores for students in hybrid and traditional formats

Variable	Type III SS	*F* statistic	*P* value
Covariates			
PRETEST	**369.52**	**30.66**	**<0.001**
GENDER	**66.93**	**5.55**	**0.020**
ATTEND	0.84	0.07	0.792
ATTEND_AL	21.67	1.80	0.183
SCORES_AL	**135.09**	**11.21**	**0.001**
CLASS	7.58	0.63	0.429
ONL_EXP	0.39	0.03	0.858
COMMUTE	4.56	0.38	0.540
Course format effects			
FORMAT	**104.43**	**8.66**	**0.004**
FORMAT × GENDER	3.82	0.32	0.574
FORMAT × CLASS	**51.54**	**4.28**	**0.041**
FORMAT × ONL_EXP	23.55	1.95	0.165

Key to variables: PRETEST = scores on pre-course assessment test; GENDER = 0 (male) or 1 (female); ATTEND = attendance rates to passive lectures (traditional course) or online assignments (hybrid course); ATTEND_AL = attendance rates to active lectures; SCORES_AL = mean score on active-learning exercises; CLASS = 0 (freshman) or 1 (sophomore, junior or senior); ONL_EXP = 0 (no previous experience with online courses) or 1 (previous experience); COMMUTE = 0 (resident student) or 1 (commuter student); FORMAT = 0 (traditional course) or 1 (hybrid course).

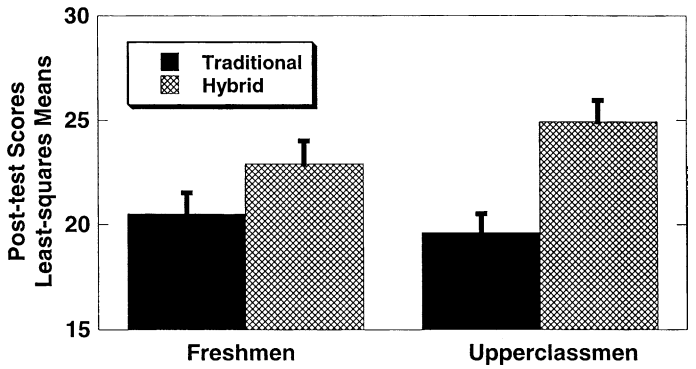

Fig. 6. Least-squared means for post-test scores for freshmen and upperclassmen in traditional and hybrid courses (+ 1 SE). Mean effect slices were significant for upperclassmen ($F = 13.67$, $P < 0.001$), but not for freshman ($F = 2.71$, $P = 0.1024$).

textbooks twice each week or more. We suspect this was strongly influenced by our course structure. Two online assignments were due each week, and students used the textbook to help complete assignments (many assignments could not be completed without the textbook). Nonetheless, this does represent a striking improvement over rates reported in the traditional course. Online assignments may be very effective in encouraging students to use their textbooks at regular intervals during the semester, whereas students may not be motivated to read the textbook before

Table 3
General linear model of post-test scores on material covered only in either passive lectures or online homework for students in hybrid and traditional formats

Variable	Type III SS	*F* statistic	*P* value
Covariates			
PRETEST	**81.23**	**20.33**	**<0.001**
GENDER	**24.82**	**6.21**	**0.014**
ATTEND	3.05	0.76	0.384
ATTEND_AL	8.98	2.25	0.136
SCORES_AL	**41.89**	**10.49**	**0.002**
CLASS	1.74	0.44	0.511
ONL_EXP	0.83	0.21	0.648
COMMUTE	0.04	0.01	0.925
Course format effects			
FORMAT	**20.08**	**5.03**	**0.027**
FORMAT × GENDER	0.15	0.04	0.848
FORMAT × CLASS	**31.33**	**7.84**	**0.006**
FORMAT × ONL_EXP	8.74	2.19	0.142

Key to variables : PRETEST = scores on pre-course assessment test; GENDER = 0 (male) or 1 (female); ATTEND = attendance rates to passive lectures (traditional course) or online assignments (hybrid course); ATTEND_AL = attendance rates to active lectures; SCORES_AL = mean score on active-learning exercises; CLASS = 0 (freshman) or 1 (sophomore, junior or senior); ONL_EXP = 0 (no previous experience with online courses) or 1 (previous experience); COMMUTE = 0 (resident student) or 1 (commuter student); FORMAT = 0 (traditional course) or 1 (hybrid course).

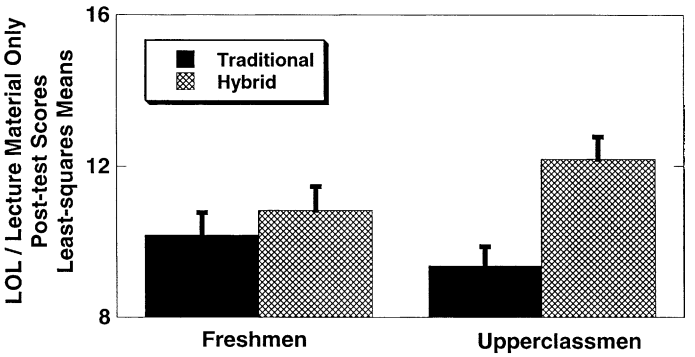

Fig. 7. Least-squared means for post-test scores on material covered in passive lectures (traditional course) or online assignments (hybrid course) for freshmen and upperclassmen (+1 SE). Mean effect slices were significant for upperclassmen ($F = 11.51$, $P = 0.001$), but not for freshman ($F = 0.53$, $P = 0.467$).

attending a passive lecture. Oftentimes, unannounced or weekly quizzes (e.g., Wilder, Flood, & Stromsnes, 2001) or writing assignments (e.g., Day, 1994) are used to generate this type of accountability, but online assignments in LON-CAPA have two critical advantages over this approach. First, they may encourage students to learn more actively. Second, they are automatically graded (with feedback) so there is no grading burden on the instructional staff, nor do they use up valuable face-to-face instructional time.

Table 4
General linear model of post-test scores on material covered in active-learning exercises for students in hybrid and traditional formats

Variable	Type III SS	*F* statistic	*P* value
Covariates			
PRETEST	**52.54**	**11.45**	**0.001**
GENDER	**21.69**	**4.73**	**0.032**
ATTEND	0.31	0.07	0.794
ATTEND_AL	2.77	0.60	0.439
SCORES_AL	**44.39**	**9.67**	**0.002**
CLASS	4.81	1.05	0.308
ONL_EXP	0.89	0.19	0.661
COMMUTE	0.92	0.20	0.655
Course format effects			
FORMAT	**41.31**	**9.00**	**0.003**
FORMAT × GENDER	2.73	0.60	0.442
FORMAT × CLASS	3.73	0.81	0.369
FORMAT × ONL_EXP	9.99	2.18	0.143

Key to variables: PRETEST = scores on pre-course assessment test; GENDER = 0 (male) or 1 (female); ATTEND = attendance rates to passive lectures (traditional course) or online assignments (hybrid course); ATTEND_AL = attendance rates to active lectures; SCORES_AL = mean score on active-learning exercises; CLASS = 0 (freshman) or 1 (sophomore, junior or senior); ONL_EXP = 0 (no previous experience with online courses) or 1 (previous experience); COMMUTE = 0 (resident student) or 1 (commuter student); FORMAT = 0 (traditional course) or 1 (hybrid course).

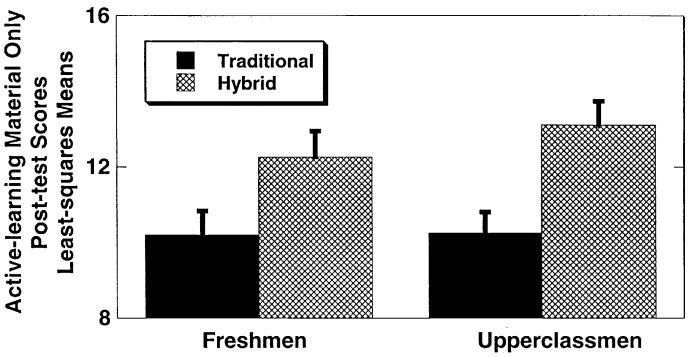

Fig. 8. Least-squared means for post-test scores on material covered in active-learning exercises for freshmen and upperclassmen in traditional and hybrid courses (+1 SE). Mean effect slices were significant for both freshman ($F = 4.79$, $P = 0.031$) and upperclassmen ($F = 10.25$, $P = 0.002$).

We observed a significant increase in the frequency that students contacted other students with questions and the frequency of studying in groups in the hybrid course (Figs. 4 and 5). Because we did not do anything to explicitly stimulate the formation of study groups (i.e., assign homework groups, pass out contact information for students in the same dormitories), this increase most likely represents an effect of the hybrid course format per se. We propose two reasons why this may have happened. First, decreased face-to-face interaction with the instructor may have en-

couraged students to seek out peers with questions relating to course content or structure. Second, the hybrid environment gave students more control over their learning (St. Clair, 1999; Freidman et al., 2001), and this may have resulted in a greater motivation to seek out peers.

5.2. Were online assignments equivalent to passive lectures?

Freshmen in the hybrid course did just as well as their traditional course counterparts, and upperclassmen in the hybrid course performed markedly better (Fig. 7), indicating that online assignments are equivalent for freshman and a superior option for upperclassmen. Further evidence of the effectiveness of online assignments is provided by the significant correlation of grades on online assignments (total points earned) to post-test scores ($\rho = 0.45$, $P < 0.001$ after correcting for pre-test scores). One possible explanation is the upperclassmen may be more likely to skip traditional lectures but will complete online assignments (Riffell & Sibley, unpublished manuscript). Also, upperclassmen may be more motivated by the flexibility and control (St. Clair, 1999) offered by asynchronous, online learning. Thus, hybrid formats may foster a better attitude toward learning in upperclassmen. Or, freshman may lack the self-motivational and discipline skills needed in a hybrid environment (e.g., Sullivan, 2001). But, if this is the case, hybrid environments must have other benefits for freshmen (such as more active learning or reading the text more frequently during the semester) as the net effect was neutral, not negative.

5.3. Were active-learning exercises more effective in a hybrid format?

Both freshmen and upperclassmen in the hybrid course scored higher on questions dealing with material covered in active lectures than students in the traditional course (Fig. 8). This suggests that active-learning exercises may be more effective when coupled with online assignment rather than traditional, passive lectures, or that online assignments may do a better job of preparing students for participating in active-learning exercises. Several mechanisms may account for this. First, if students are more likely to skip passive lectures than they are to miss an online assignment (Riffell & Sibley, 2003), online assignments would do a better job of preparing students for the active-learning exercises. Second, many students in the traditional course had not read the textbook beforehand (see above), so they may not been as prepared to benefit from the active-learning exercises as were students working online assignments. Third, working online assignments may have improved students' problem solving skills which improved the effectiveness of the active-learning exercises. Fourth, students in the hybrid course may have been more focused on, and motivated to work on, active-learning exercises when they came to class. Students may have been more motivated because they had more control over their learning than students in the traditional course (St. Clair, 1999), or students in the hybrid course may have been simply been aware that the mid-week meeting was their only chance to interact with the instructor in a face-to-face, classroom setting.

One might argue that post-test scores were higher because students in the hybrid course may have scored higher on the active-learning exercises (due to being better prepared by the online assignments). However, we included performance on active-learning exercises as a covariate in our analysis. This covariate was significant indicating that students who scored highly on the active-learning exercises did better on the test questions. But, because we used Type III sums of

squares, any difference between the traditional and hybrid courses in active-learning performance was factored out before we tested for the effects of learning formats. Thus, the effect is one of hybrid environment per se, and given the same level of performance on the active-learning exercises (i.e., effort or motivation in class), a student in a hybrid environment would retain more of the concepts than students in a traditional environment.

5.4. Overall performance

Overall, students in the hybrid course, regardless of class standing, did better on the pre-/post-course assessment test. Had the assessment test been the final exam, students in the hybrid course would have scored an average of one letter grade (i.e., approximately 10% points) higher than their counterparts in the traditional course. Students received the pre-test at the beginning of the course, and the same set of questions (post-test) during the last week of the semester as opposed to before and after a particular unit. Because the post-test was given >1 week before the final exam, post-test scores were not affected by study efforts directed toward the final. Thus, these improvements represent an increase in long-term retention (up to 14 weeks).

The hybrid course also provided students more self-control over the when and where and how of learning, which can improve motivation (St. Clair, 1999), especially in upperclassmen. Students in the hybrid course formed study groups more often and used their textbooks more frequently during the semester. At the same time, our use of computer graded assignments due twice per week incorporated accountability throughout the semester. This accountability is sometimes lacking in many other forms of online and more traditional, classroom-based learning environments. Because of this, the active-learning exercises were more effective when used in a hybrid course format.

Also, we managed to retain high quality interaction between students and the instructor. One factor which may account for this is that the instructor was available by e-mail during the semester during most hours of the week. Over the course of the semester, the instructor answered 428 e-mails regarding online assignments and other course content. Assuming an average of 10 min to answer each e-mail, the instructor spent approximately 5 h per week answering student e-mails. This is not an unmanageable amount of time for the instructor because online assignments replaced 2 h of lecture (and associated preparation time) each week. For students who took advantage of the instructors availability in this informal setting (i.e., e-mail), this may have increased their perceptions of the quality of interaction (Pascarella & Terenzini, 1991). For students who did not use this mode of interaction, the mere availability may have increased their perception of the quality of interaction, even though it was not used (Pascarella & Terenzini, 1991).

5.5. The relationships between class attendance and class performance

Attendance has often been related to better performance in class (e.g., Gatherer & Manning, 1998; Moore, 2003), but in our analysis, neither attendance at active lectures (ATTEND_AL) nor attendance to passive lectures/online assignments (ATTEND) were related to post-test scores. Two factors may account for why we did not find any relationship. First, although active lecture performance (SCORES_AL) was calculated independently of active lecture attendance (ATTEND_AL), these two variables were still positively correlated ($\rho = 0.37$, $P < 0.001$). Thus, part

of the significant effects of active lecture performance may be, in part, because students performing well on active-learning exercises also tended to be the same students with high rates of attendance to active lectures. Second, students omitted from this dataset because they either declined to provide permission or were not present for one of the assessment tests were strongly biased toward students with low attendance rates. Thus, we caution against using our results to conclude that attendance was not an important factor in predicting post-test scores. Any inference about the influence of attendance should be restricted to the set of students used in our analyses and the range of attendance rates (ATTEND [mean = 88.5, SD = 10.27, range = 55.26–100.00]; ATTEND_AL [mean = 89.4, SD = 13.70, range = 27–100]).

5.6. Drawbacks of the hybrid course

One pattern we did observe was a tendency for student responses to be more polarized in the hybrid course than in the traditional course. This was evidenced by several distributions being more bimodal in the hybrid course. Students in the hybrid course were more likely to rate the quality of interaction with the instructor as higher than in other courses, but were also more likely to rate it as lower (Fig. 2). Likewise, a greater proportion of the students in the hybrid course more frequently contacted classmates and/or formed study groups, but the hybrid course also had a higher proportion of students who reported never engaging in these activities (Figs. 4 and 5).

These results indicate that students tend to have stronger opinions (positive or negative) about hybrid or online learning environments than about traditional, classroom-based learning environments. Others have reported similar patterns in student opinions after engaging in computer-based learning (Dewhurst, Macleod, & Norris, 2000: Table 3). While most students performed better in the hybrid course, we caution hybrid courses should not be viewed as a panacea for problems in undergraduate curriculum. Just like with any single learning environment, a hybrid format will not facilitate learning for all individuals, all groups of individuals, or all types of learners.

5.7. Conclusions

Our results indicate that hybrid course formats can substantially improve the amount of active learning in and effectiveness of high-enrollment, lecture courses for resident, non-science majors, especially for upperclassmen. Specifically, online assignments were just as effective, if not more so, than traditional lectures; and classroom-based active-learning exercises were more effective when coupled with online assignments. Instructors of large lecture courses could improve the learning environment by adopting hybrid course formats.

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