Do Hybrid Lecture Formats Influence Laboratory Performance in Large, Pre-Professional Biology Courses?

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ABSTRACT

Introductory biology courses for pre-professional majors at large universities are usually high-enrollment lectures with associated labs that complement the lecture, but are independently taught and administered. Although web-based instructional formats have become popular alternatives to traditional lectures, it is unknown how these formats affect laboratory performance. To test for effects of hybrid formats on laboratory performance, we conducted a teaching experiment. Students taking an introductory biology course enrolled in either a traditional format lecture or a hybrid (part lecture, part online) lecture. We used laboratory scores and performance on common final exam questions to assess laboratory and lecture performance, respectively. Overall, laboratory performance did not differ between students in the hybrid vs. the traditional lecture, but we did observe a significant interaction between minority status and course format. Minority students in the hybrid lecture scored higher in laboratory relative to nonminority classmates. Minorities in hybrid formats may have benefited more from general characteristics of online homework (e.g., learned more actively, improved general problem-solving skills like those used in laboratory). Or, minorities may have benefited because online components may have created a more balanced social atmosphere or helped offset negative effects of lower computer and internet availability in some minority groups. Hybrid course designs and online instructional components may help narrow performance gaps between minorities and nonminorities. We caution, however, that minority students in the hybrid lecture performed worse than classmates on common lecture exam questions (despite laboratory improvement). Hybrid course designs should be implemented cautiously until more research is completed.

During the last decade, web-based instruction has become more common in high-enrollment introductory science courses at undergraduate institutions. A variety of web-based teaching materials also have been developed and are available to instructors developing online courses. Although online courses are now a ubiquitous part of higher education (e.g., Young, 2002), the effects of online instruction on student performance and learning are not clear (see Russell, 2001 for review). Online instruction, when done well, can be more student-centered, interactive and flexible then traditional course environments (Ostiguy and Haffer, 2001; Sanders, 2001). But, just as often, poorer student performance is reported for online instruction (Russell, 2001), possibly because adequate face-to-face interaction between instructors and classmates is lacking (e.g., Yazon et al., 2002).

An increasingly popular design is to combine both classroom and online activities into a hybrid course. This way, potential benefits of both web-based and traditional classroom instruction may be captured. Early evidence suggests that hybrid courses may indeed lead to better student performance on exams (Navarro and Shoemaker, 2000; Riffell and Sibley, 2004a), better student perceptions of and attitudes toward the course (Navarro and Shoemaker, 2000; Riffell and Sibley 2003), and higher attendance rates (Riffell and Sibley, 2004b).

Large, introductory science courses typically contain a laboratory component in addition to lecture. In general, laboratory should be a more active and more social learning experience. Although the lecture class may be large (100–400+ students), the laboratory portion of the course is often subdivided into sections of 30 or fewer students. Thus, laboratory class size is much smaller, and lab exercises are more interactive, group-oriented, and targeted toward problem solving than the associated lecture. It is in the laboratory portion of the course that students acquire hands-on experience with the subject matter and laboratory skills needed for success in upper-level biology courses or biology-related careers. It is not clear how hybrid course formats (substituting online work for part of the lecture time) impact student performance in laboratory. Do students receiving hybrid instruction suffer in laboratory because of less classroom interaction with the lecture professor? Or, does the more interactive and problem-solving nature of web-based materials better prepare students for lab and enhance their performance?

To answer these questions, we took advantage of a situation where two instructors were providing lectures to a total of 28 lab sections (approximately 700 students) of a pre-professional, introductory biology course. One instructor delivered lectures using a traditional instructional format, while the other used a hybrid format substituting a weekly online problem set in lieu of 1 of the 3 hours of lecture. All laboratory sections followed an identical schedule and curriculum with a graduate student assigned to instruct each section. Our hypothesis was that students in the hybrid lecture format would perform as well or better in laboratory than their classmates in sections receiving a traditional lecture format.

DESCRIPTION OF THE COURSE

Our course—BS110 Organisms and Populations—was the first semester of a two-semester, introductory biology sequence taken by pre-professional, science majors (predominantly pre-medical, preveterinary) and is also required by various other science and engineering majors. Typically, 500 to 900 students may take BS110 in a given semester. The traditional format of the course is three 1-hour lectures per week (or two 1.5-hour lectures) and a single 3-hour laboratory each week. The laboratory is instructed independently of the lecture part of the course, although they are designed to complement each other and encounter major topics in the same general order. Students were required to enroll in both lecture and laboratory simultaneously. Fifteen graduate teaching assistants taught the laboratories; each teaching assistant was typically assigned two sections. The lab exercises were standardized so that each lab section received similar instruction and completed identical exercises.

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METHODS

Experimental Course Design

In Spring 2004, students could enroll in one of 28 sections of BS110. Fourteen sections were taught by Dr. Frank Ewers of the Department of Plant Biology (Michigan State Univ.), and another 14 sections were taught by Dr. Samuel Riffell of the Department of Zoology (Michigan State Univ.). Each instructor's 14 sections met together in a common lecture hall, and then each section (approx. 25–30 students) met separately for laboratory. Dr. Ewers used a traditional lecture format: students met for traditional lectures on Tuesday and Thursdays (1.5-hour lectures) for a total of 3 hours of face-to-face instruction. Dr. Riffell used a hybrid lecture format: students met for a 1-hour lecture on Mondays and Wednesday, but were required to complete an online problem set due each Friday in lieu of the third hour of lecture (2 hours of face-to-face plus online assignment). Both instructors scheduled lecture topics to coincide with the laboratory topics, and covered similar material: Mendelian and population genetics; natural selection and evolution; diversity, form, and function in the plant and animal kingdoms; and ecology. Students were self-selected in that they could enroll freely in either section; however, they were not aware of the difference in course format until the courses began. Our research methods met institutional review board approval, and we used data only from students who consented to participate.

Online Assignments

For the hybrid lecture, Dr. Riffell replaced approximately one-third of the time traditionally spent in lecture with online assignments. He used online materials developed specifically for first year biology (McGroarty et al., 2004). Homework pages contained additional content and examples, animations (e.g., meiosis), and embedded questions. The pages were designed to focus students on the major concepts, provide them with multiple representations of these concepts, and require them to interact with the content as it was presented (McGroarty et al., 2004). These embedded questions consisted of a mixture of multiple choice, matching, true–false, and calculation problems. We believed that online assignments would be equal to or better than lecture time because: (i) students have more flexibility and control with online assignments (Ostiguy and Haffer, 2001) compared with being required to attend lecture at a required and specific time; (ii) online exercises can be more active than taking notes in lecture (Hacker and Niederhauser, 2000); and (iii) online exercises can provide a greater encouragement for students to learn in different ways (Yazon et al., 2002). Online exercises accounted for 10% of students' final course grade.

We delivered the hybrid version of the course on the open-source platform, LON-CAPA (Speier and Kortemeyer, 2001; www.lon-capa.org; verified 28 Aug. 2005). Several features of LON-CAPA are unique relative to other web-based learning platforms. First, LON-CAPA provides individualized questions that are slightly different for each student (e.g., different choices or different starting numbers for calculations). Thus, we encouraged students to work together (a good way to learn), but did not have to worry about students simply copying another student's answers (a poor way to learn). Second, LON-CAPA allowed us to emphasize mastery of content by providing full credit on the first three attempts for each question and partial credit after three attempts. Third, students received feedback via pre-programmed hints that appeared after the first incorrect answer or by contacting the instructor via an email link associated with each question.

Outcome Variables

We used the total laboratory scores for each student (highest possible score = 180) as our primary outcome variable. We refer to this outcome variable as adjusted laboratory scores. The score was comprised of two lab practical exams (60 points each) and homework assignments designed by the teaching assistant (another 60 points). The number of assignments varied among teaching assistants but the total points for homework was 60 points for all lab sections. To account for potential variation in laboratory scores due to different teaching assistants, we adjusted students' scores so that the mean score for each teaching assistant equaled the mean score of the highest teaching assistant.

We measured performance in lecture by including 16 identical questions (representative questions from each topic area listed in Experimental Course Design, above) on the final exam for both the hybrid and traditional lecture sections. We refer to this outcome variable as common exam questions.

Independent Variables

We used current grade point average (GPA) (on a 4.0 scale) to measure general academic aptitude of students. We also included three categorical variables: course format (traditional vs. hybrid); gender (male or female); and minority (Caucasian vs. non-Caucasian). Students provided information about their gender and race when completing the consent form.

Statistical Analysis

We tested our hypotheses about hybrid course formats by constructing a mixed model (Laird and Ware, 1982) for each outcome variable using SAS Proc Mixed (Littell et al., 1996). We included a covariate (GPA), three main effects (course format, gender, and minority), and three interaction effects (course format × gender, course format × minority, and gender × minority) in our model. Because we suspected that our observations (students) might not be independent across teaching assistants (i.e., one teaching assistant might be more challenging than another), we included teaching assistant as a random effect.

We used Type III tests at an a priori $\alpha = 0.05$ for all main effects and $\alpha = 0.10$ for interactions. When significant interactions were present, we used main effect slices (SAS Institute, 1999) to determine how the effect varied over different levels of the factors. We did not interpret main effects in these cases because main effect tests are not interpretable in the presence of interaction effects (Underwood, 1997).

Some, but not all, of the teaching assistants were assigned one laboratory section from the hybrid course and one section from the traditional course, providing the opportunity for a paired-design analysis with a subset of the students. We conducted this analysis, but the results (*P* values and conclusions) approximated the results based on the full dataset. Using adjusted laboratory scores and including teaching assistant as a random effect most likely accounted for variation related to teaching assistant in the full dataset. Thus, we report only results from analyses involving the full dataset.

RESULTS

Student Populations

Total enrollment in the course was 738 (398 in the traditional lecture and 340 in the hybrid lecture). Sixty-four percent of these students consented to be included as subjects in this experiment (246 in the traditional lecture and 230 in the hybrid lecture). Student populations of the two lectures did not differ significantly in mean GPA (3.04 traditional vs. 2.98 hybrid) or percentage minority students (19.9 vs. 17.8%). The traditional lecture contained a significantly greater proportion of female students (65%) than the hybrid section (53%).

Laboratory Performance

Not surprisingly, overall GPA was significant, indicating that students with higher overall GPA earned higher adjusted laboratory

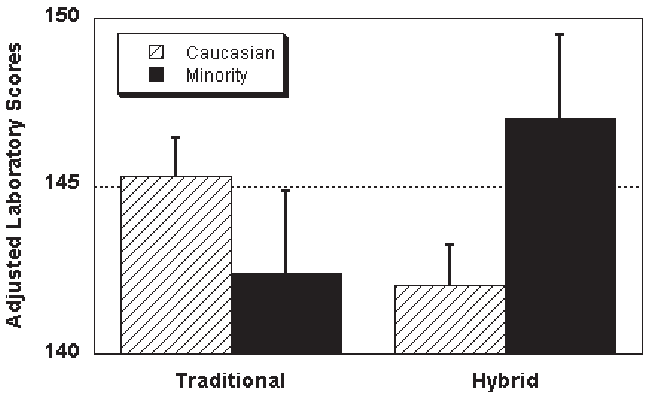

Fig. 1. Least-squared means for adjusted laboratory scores for minority and Caucasian students in traditional and hybrid lecture formats. The difference in the hybrid format is significant ($P = 0.0736$).

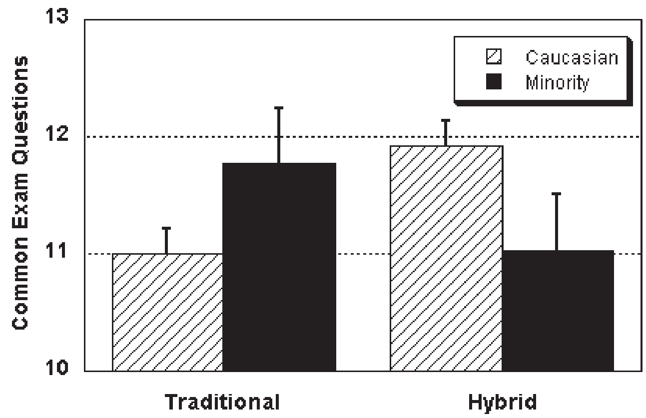

Fig. 2. Least-squared means for common exam questions for minority and Caucasian students in traditional and hybrid lecture formats. The difference in the hybrid format is significant ($P = 0.0921$).

Table 1. Main effects for mixed models of student outcomes.

Effects	*F*	*P* value
Adjusted lab scores		
GPA	481.47	<0.0001
Hybrid	0.13	0.7215
Sex	0.67	0.4138
Minority	0.28	0.5961
Hybrid × sex	1.88	0.1709
Hybrid × minority	4.12	0.0428
Sex × minority	0.08	0.7835
Final exam questions		
GPA	133.95	<0.0001
Hybrid	0.05	0.8236
Sex	0.49	0.4846
Minority	0.03	0.8709
Hybrid × sex	0.27	0.6035
Hybrid × minority	5.06	0.0250
Sex × minority	0.70	0.4036

scores ($P < 0.0001$; Table 1). Although there were no overall differences in laboratory performance between the hybrid and traditional course, the course format × minority interaction was also significant ($P = 0.0428$; Table 1), so we interpreted effect slices (Fig. 1). Minority students in the hybrid lecture had higher adjusted laboratory scores than classmates ($P = 0.0736$). Based on least squared means (Fig. 1), this difference was the equivalent of 3.5 percentage points in the laboratory part of the course. The difference between minority and nonminority students in the traditional lecture was not significant.

Performance on Common Lecture Exam Questions

Overall GPA was also a significant predictor of performance on common lecture exam questions ($P < 0.0001$; Table 1). Again, the course format × minority interaction was significant ($P = 0.0250$; Table 1), but the effect slices indicated a different interaction (Fig. 2) from what we observed for laboratory performance. Minority students in the hybrid lecture scored lower on common exam questions ($P = 0.0921$) than nonminority classmates. Based on least squared means (Fig. 1), this difference was equivalent to 8% points. There was no significant difference between minority and nonminority students on common exam questions in the traditional lecture.

DISCUSSION

Effects on Laboratory Performance

We could not assess overall differences in the effect of lecture course format on laboratory performance because the course format × minority interaction was significant (Underwood 1997). Thus, we considered the interaction effects directly (Wolfinger, 1997, p. 497). Minority students (students who identified themselves as something other than Caucasian descent) enrolled in the hybrid lecture outperformed Caucasian classmates in laboratory ($P = 0.0736$), but not in the traditional lecture. These differences existed after controlling for student-to-student variation in overall academic performance (measured by GPA) and variation related to gender by using Type III tests, and after controlling for variation related to teaching assistant ability by using adjusted scores (and including teaching assistant as a random effect in the model). Thus, they likely represent effects of the hybrid lecture format per se on laboratory performance.

We would have liked to have used a more detailed breakdown of ethnicity to test for minority effects (rather than simply Caucasian vs. non-Caucasian) because different minorities can respond to educational approaches in very different ways (Seymour and Hewitt, 1997). However, had this been done, we would have had very small sample sizes (i.e., <10 students) for some minority groups, which would have resulted in low statistical power and questionable conclusions. However, we do present the raw means for four minority groups (Hispanic, Asian-American, African-American, and other) and Caucasian students in the two lecture formats (. 3 and 4) to explore which particular minority groups might be responsible for the differences we observed. From Fig. 3, it appeared that all four minority groups performed better in laboratory when enrolled in a hybrid rather than a traditional lecture. The improvement appeared more marked for Hispanic and African-American students.

Because this was an applied experiment designed to detect broad

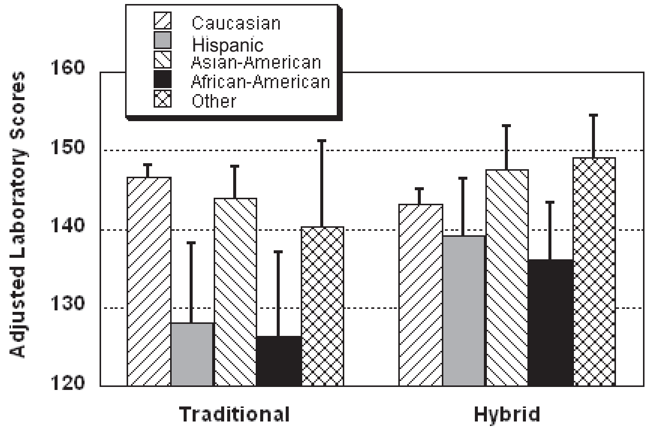

Fig. 3. Mean adjusted laboratory scores for five student groups in traditional and hybrid lecture. Unadjusted means are present without statistical analysis because sample sizes for some categories are very small (<10).

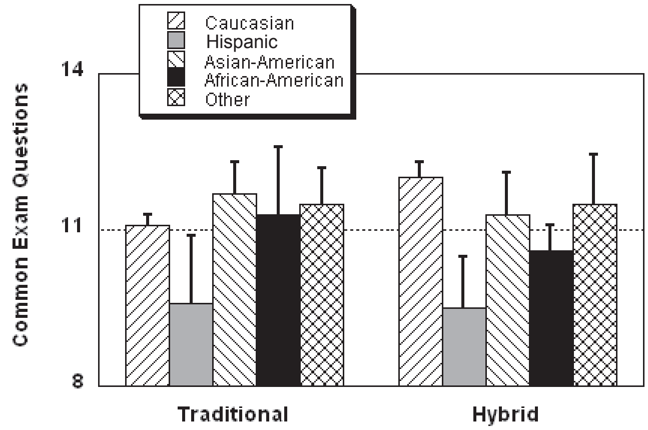

Fig. 4. Mean number of common exam questions answered correctly for five student groups in traditional and hybrid lecture. Unadjusted means are present without statistical analysis because sample sizes for some categories are very small (<10).

effects of an emerging teaching strategy on laboratory performance, we cannot statistically identify the causal mechanisms for these differences. However, ample theories exist that could explain these differences: minorities may learn better in hybrid formats because it is easier for them to read material and work problems online than it is to follow a native English speaker in lecture; working online homework in lieu of some of the time spent in lecture may improve minority students' problem solving skills that are needed in laboratory; and hybrid formats may generally be a superior educational practice (Riffell and Sibley, 2004a, 2004b). These explanations, however, would not necessarily apply only to minority students, but to all students.

Two other explanations are more intriguing. First, students from some minority groups have lower rates of computer-ownership and internet access. The *Journal of Blacks in Higher Education* (Anonymous, 2000–2001) reports that African-American college students are much less likely to have a computer at home or to have internet access, although it is not clear whether this is true for other minority groups. Biology laboratories are becoming increasingly computer-dependent (e.g., virtual lab experiments, online dissections, data analysis, etc.), and some minorities may not be as comfortable using computers as their classmates. Online computer work included in the lecture part of a course would encourage these students to use computers, and thus increase their computer skills. These improved skills might result in more confidence in the laboratory setting. Second, online and hybrid formats may influence the social fabric of the learning environment. Recent research suggests that the anonymous nature of online components softens the confrontational social atmosphere often present in lecture courses that discourages females, minorities, or outsiders from participating in class activities and discussions and asking questions (Sullivan, 2001). For example, Brown and Leidholm (2002) discovered that while males performed better than females in a traditional economics course, this performance gap disappeared in hybrid and online versions of the same course. Science laboratories, where students often work in groups of two to six to solve problems, are more socially complex than large lectures. It is possible that the benefits of having weekly online homework (i.e., improved problem-solving skills, higher confidence, increased accountability each week, and so forth) may permit minority students to better navigate the social aspects of learning in laboratory settings. Incorporating online problems into science courses may be a valuable tool for narrowing the performance gap of minority students.

Effects on Lecture Performance Warrant Caution

Although our main objective was to evaluate the effect of hybrid lectures on laboratory performance, we also wanted to assess learning in the lecture part of the course. Both instructors identified a set of 16 common questions that were included in the final exam. Although the format × minority interaction was once again significant, the direction of the effects was reversed. In the hybrid course, minority students did not perform as well as their classmates. Thus, while the hybrid format benefited minority students in laboratory, their performance relative to classmates may have suffered in the lecture part of the course (Fig. 2). As with laboratory scores, we display raw means for each of the minority groups in Fig. 4 (sample sizes were too small to conduct formal statistical tests on the expanded categories). Figures 2 and 4 suggest that in lecture (in contrast to our results for laboratory performance), minority students did not score as well on the lecture exam questions as their classmates. One possible explanation is that minority students benefit from increased personal contact with the instructor more than Caucasian students, even when it is in the context of a large-enrollment lecture setting.

Conclusions about How Hybrid Courses Impact Laboratory Performance

Overall, the hybrid lecture format (2 hours lecture plus one online homework assignment weekly) was at least as effective in preparing students to do well in the laboratory course as a more traditional course format (3 hours of lecture per week). Even without improved learning (which may be occurring for some groups), this is an important finding because institutions could reap other benefits of online education (e.g., increased flexibility for students and instructors, reduced demand on classroom facilities, easing logistical constraints of offering courses at satellite institutions) without diminishing the quality of the learning environment.

More importantly, hybrid course formats may be a valuable tool for narrowing the performance gap between minority (or other under-represented groups) and nonminority students and for improving retention of minorities in science, math, engineering, and technology majors. A hybrid course format appeared to help all minority groups in our student population perform better in laboratory, but the hybrid format did not benefit their performance in the lecture part of the course. Instructors interested in improving minority performance could provide weekly, online homework, but should carefully weigh whether these assignments should be in lieu of or in addition to regular classroom time. Much more research is needed to identify the mechanisms by which online teaching approaches aid learning and how different factors such as nationality, ethnicity, gender, and socio-economic background interact with these mechanisms.

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REFERENCES

Anonymous. 2000–2001. Why are blacks less likely than whites to use the internet? Journal of Blacks in Higher Educ. 30:40–41.

Brown, B.W., and C.E. Leidholm. 2002. Can web courses replace the classroom in principles of macroeconomics? Am. Econ. Rev. 92:444–448.

Hacker, D.J., and D.S. Niederhauser. 2000. Promoting deep and durable learning in the online classroom. New Directions for Teaching and Learning 84:53–64.

Laird, N.M., and J.H. Ware. 1982. Random effects models of longitudinal data. Biometrics 38:963–974.

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. The SAS system for mixed models. SAS Inst., Cary, NC.

McGroarty, E., J. Parker, M. Heidemann, H. Lim, M. Olson, T. Long, J. Merrill, S. Riffell, J. Smith, J. Batzli, and D. Kirschtel. 2004. Complementing introductory biology with online curriculum. Biochem. Molec. Biol. Educ. 32:20–26.

Navarro, P., and J. Shoemaker. 2000. Performance and perceptions of distance learners in cyberspace. Am. J. Distance. Educ. 14:15–35.

Ostiguy, N., and A. Haffer. 2001. Assessing differences in instructional methods: Uncovering how students learn best. J. Coll. Sci. Teach. 30:370–374.

Riffell, S.K., and D.F. Sibley. 2003. Student perceptions of a hybrid learning format: Can online exercises replace traditional lectures? J. Coll. Sci. Teach. 32:394–399.

Riffell, S., and D. Sibley. 2004a. Using web-based instruction to improve large undergraduate biology courses: An evaluation of a hybrid course format. Comput. Educ. 44:217–235.

Riffell, S.K., and D.F. Sibley. 2004b. Can hybrid course formats increase attendance in undergraduate environmental science courses? J. Nat. Resour. Life Sci. Educ. 33:16–20.

Russell, T.L. 2001. The no significant difference phenomenon. International Distance Education Certification Center, Montgomery, AL.

Sanders, W.B. 2001. Creating learning-centered courses for the world wide web. Allyn and Bacon, Boston, MA.

SAS Institute. 1999. SAS/STAT user's guide. Version 8. SAS Inst., Cary, NC.

Seymour, E., and N.M. Hewitt. 1997. Talking about leaving: Why undergraduates leave the sciences. Westview Press, Boulder, CO.

Speier, C., and G. Kortemeyer. 2001. Open source objects for teaching and learning. Syllabus Magazine. Available at www.campus-technology.com/article.asp?id=5671 (accessed 29 Aug. 2005; verified 13 Sept. 2005). 101Communications, Chatsworth, CA.

Sullivan, P. 2001. Gender differences and the online classroom: Male and female college students evaluate their experiences. Community College J. of Research and Practice 25:805–818.

Underwood, A.J. 1997. Experiments in ecology. Cambridge Univ. Press, Cambridge, UK.

Wolfinger, R.D. 1997. An example of using mixed models and Proc Mixed for longitudinal data. J. Biopharm. Stat. 7:481–500.

Yazon, J.M.O., J.A. Mayer-Smith, and R.J. Redfield. 2002. Does the medium change the message? The impact of a web-based genetics course on university students' perspectives on learning and teaching. Comput. Educ. 38:267–285.

Young, J.R. 2002. 'Hybrid' teaching seeks to end the divide between traditional and online instruction. Chron. Higher Educ. 22 March.