Journal of Experimental Psychology: Applied
2002, Vol. 8, No. 2, 85–98

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1076-898X/02/$5.00 DOI: 10.1037//1076-898X.8.2.85

Multimedia Comprehension Skill Predicts Differential Outcomes of Web-Based and Lecture Courses

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College students (134 women and 55 men) participated in introductory psychology courses that were offered largely online (on the World Wide Web) or in a lecture format. Student comprehension skills were inferred from their scores on a multimedia comprehension battery. The learning of content knowledge was affected interactively by comprehension skill level and course format. Differences between format increased with comprehension skill such that the Web-based course advantage became greater as comprehension skill increased. This same pattern was not seen when self-reports of comprehension ability were used as the predictor. Furthermore, comprehension skill did not predict course satisfaction. Generally, students of all skill levels preferred the lecture courses.

As online college courses using the World Wide Web (Web) become more common, questions about their effectiveness become more important. At present, the literature is mixed with respect to the relative effectiveness of Web-based courses. Some studies show differences favoring lecture courses, some show differences favoring Web-based courses, and many show no differences at all. Moreover, other than for methodological problems in some of these studies, the variables that might render Web-based courses more or less effective are not well understood. In this study, we sought to determine the relation between multimedia comprehension skills and learning from Web-based versus lecture courses.

Background

Several studies have compared learning and performance in media-based courses and traditional lecture courses. Table 1 summarizes the results of those studies. Hiltz (1993) compared performance in Web-based versus lecture courses in computer science, statistics, sociology, and management. As can be seen in the table, she found very similar levels of performance on midterm and final examinations. However, students in the Web-based computer science course received higher grades than did those in the traditional course because the Web-based instructor gave them additional assignments when they completed core assignments faster than students in the lecture course. Hiltz reported that grades did not differ for Web-based and lecture courses in the other subjects. Similarly, Sankaran, Sankaran, and Bui (2000) also reported no performance differences in a comparison of examination scores in a Web-based and a lecture version of a business computers course.

Two studies have shown better performance in lecture courses. Although Wang and Newlin (2000) found no differences on midterm examinations for Web-based and lecture versions of statistical methods courses, they reported better performance on the final examination in the lecture course. Students in Wang and Newlin's Web-based course collaborated on examinations prior to the final examination, but the lecture students could not collaborate. This collaboration may have hampered preparation for the individual final examination for Web-based students; lecture students may have been better prepared because all of their examinations were individual. Waschull (2001) compared lecture and Web-based sections of introductory psychology. Mean performance was higher in lecture classes than in Web-based classes, but the difference was significant only on the final examination when students self-selected sections. There were no significant differences on midterm examinations or when students were randomly assigned to sections. Self-selected students were more likely to fail the Web-based course than the lecture course.

In contrast to these reports of no difference or of better performance in lecture courses, we have consistently found better examination performance in Web-based versions of introductory psychology (R. H. Maki, Maki, Patterson, & Whittaker, 2000). In addition, students in the Web-based sections learned more than did students in lecture sections, as indicated by a greater increase in scores on practice questions from the Psychology Graduate Record Examination (GRE; Educational Testing Service, 1994) from the beginning to the end of the semester.

The main goal of college courses is to produce student learning, but student satisfaction with the course is another important consideration. Relatively few studies have compared student satisfaction in Web-based and lecture courses and, as with the learning and performance measures, the results are mixed. Waschull (2001) compared course ratings in his introductory psychology courses and found somewhat higher ratings in the Web-based than in the lecture course, but the difference was not significant. Wang and Newlin (2000) found almost identical student ratings in their Web-based and lecture courses. R. H. Maki et al. (2000) have

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The project was supported by a grant from the National Science Foundation to Ruth H. Maki and William S. Maki, "Using Technology to Transform Instruction and Improve Learning in Introductory Psychology" (NSF DUE-9752349). We thank Kristen Myles for testing some of the participants on the comprehension battery.

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Table 1
Summary of Comparisons of Learning in Media-Based and Traditional Lecture Courses

Study	Type of Course	Exam Type	Web based			Lecture			Cohen's d [a]	Results
			M	*SD*	*n*	*M*	*SD*	*n*		
Hiltz (1993)	Computer science, sociology, statistics, management	Midterm	75.2	22.96[b]	80	78.5	22.96[b]	96	−.135	*ns*
Hiltz (1993)	Various (see above)	Final	70.1	23.93[b]	80	71.4	23.93[b]	96	−.054	*ns*
Sankaran et al. (2000)	Business computers	Final	57.9	11.84[b]	46	59.5	11.84[b]	70	.144	*ns*
Wang & Newlin (2000)	Statistical methods	Midterm	89.30	—[c]	49	89.40	—	66	—	*ns*
Wang & Newlin (2000)	Statistical methods	Final	72.30	26.70[b,d]	49	86.80	26.70[b]	66	−.543	Lecture higher
Waschull (2001)	Psychology—Self-selected	Midterms	81.09	12.62	13	85.25	10.54	16	−.361	*ns*
Waschull (2001)	Psychology—Self-selected	Final	76.54	12.51	13	86.00	10.17	16	−.839	Lecture higher
Waschull (2001)	Psychology—Randomly assigned	Midterms	79.4	9.50	16	83.48	13.58	21	−.414	*ns*
Waschull (2001)	Psychology—Randomly assigned	Final	76.93	14.14	16	81.9	8.91	21	.249	*ns*
R. H. Maki et al. (2000)	Psychology	Midterms	72.28	12.63	116	69.42	11.44	138	.238	Web-based higher
R. H. Maki et al. (2000)	Psychology	GRE increase	10.12	11.66	97	5.4	9.96	121	.437	Web-based higher

Note. GRE = Graduate Record Examination.
[a] Calculated such that a positive value indicates better performance in the Web-based course and a negative value indicates better performance in the lecture course. [b] Standard deviations were not reported. These were estimated by using the means and the F or t values to calculate the mean square error (*MSE*), which was used to calculate the pooled standard deviation. [c] Standard deviations given in the article ranged from .90 to 1.7. Although A. Y. Wang (personal communication, November 26, 2001) asserted that the values are correct, they appear to be too low. No F was given for the midterm exam, so the *MSE* could not be calculated. [d] Standard deviations were estimated from the means and F because the reported standard deviations appear to be too low.

consistently found higher student satisfaction in lecture sections than in Web-based sections of introductory psychology.

There are a number of possible reasons for the different outcomes in the studies just cited. One is that the nature of the Web-based courses differed across studies. Students appear to do worse in Web-based courses than in lecture courses if the courses are relatively unstructured. For example, in Wang and Newlin's (2000) course, students were encouraged to collaborate with each other, and all examinations except the final examination were open book. There were apparently few deadlines and few requirements that had to be met by each student individually. Waschull (2001) posted lecture notes on the Web, but there were apparently no contingencies to ensure that students read these by certain dates. Students learned more in our very structured Web-based course than in our more traditional lecture course (R. H. Maki et al., 2000). In the Web-based course, students were required to meet weekly deadlines to gain course points. In the lecture course, they simply were assigned reading material. Because tests occurred every 3 weeks, the students in the lecture course could put off reading until the night before the test. The specific activities in which the students engage, then, appear more important than the media by which the activities are delivered, a view consistent with that of Clark (1994), who argued that media per se do not influence learning.

A second possible reason for the discrepancies among conclusions involves the characteristics of students who take the courses. Web-based courses may be better suited to some types of students than to others, and lecture courses may be better suited to those other students. Hiltz (1993) found that both ability and attitude explained variance in a series of regression analyses to predict grades and satisfaction in Web-based courses. Her measure of ability, verbal Scholastic Assessment Test (SAT) scores, related positively to course performance. The other significant predictor of student performance was an attitude measure. Students who found the Web-based course to be convenient performed better on examinations than those who found the course to be less convenient. However, with 12 predictor variables, only 14% of the variance in grades was explained. In contrast, Hiltz was able to explain 67% of the variance in satisfaction ratings with 18 predictor variables, including ratings of course convenience, ratings of ease of access to the professor, and ratings of course involvement. Hiltz did not examine how well the same variables predicted performance and satisfaction in traditional lecture classes. Sankaran et al. (2000) also found that attitude was important. They reported that students with a positive attitude toward the Web format learned more in the Web-based course than in a lecture course, but students with a positive attitude toward the lecture format learned more in the lecture course than in the Web-based course. (Sankaran et al., however, did not report statistical tests of the implied interaction.)

We also have examined personality variables in an effort to predict the differential performance and satisfaction in the Web-based and lecture versions of our general psychology course (R. H. Maki & Maki, in press). Among these variables are the Big Five personality factors (McCrae & Costa, 1987), including Extraversion–Introversion, Agreeableness, Conscientiousness, Emotional Stability, and Intellect or Openness to Experience. We found that students who were more introverted and who were more intellectual or open to new experiences performed better in both the Web-based and lecture courses than did students who scored

lower on these characteristics. The relation between Openness to Experience and course performance may be due to the variance common to the openness and cognitive measures (Ackerman & Heggestad, 1997). However, none of the personality characteristics predicted performance or satisfaction differentially for the two course formats.

In this study, we switched our focus to the cognitive characteristics of our students. We were interested in determining whether preexisting comprehension skills mediate learning, performance, or satisfaction, or some combination of these, differently in Web-based and lecture courses. That is, student cognitive characteristics may interact with course format, producing an Aptitude × Treatment interaction (ATI; Cronbach & Snow, 1977). Three hypothetical ATIs are diagrammed in Figure 1 (which are a subset of those described by Snow & Yalow, 1982, Figure 9.5). In each panel of Figure 1, outcome is plotted as a function of skill level for both Web-based and lecture courses. For all three patterns, the average for the Web-based format is higher than the average for the lecture format. Thus, any of these ATIs could account for the superior learning and performance in the Web-based course reported previously (R. H. Maki et al., 2000). The left panel illustrates the case in which the effects of instructional format are reversed for students with different skill levels. Although reputed to be rare (Landauer, 1995), this ATI with a crossover pattern does occur (Shute, 1992, 1993).

A second possible ATI is shown in the middle panel of Figure 1. It might be argued that students with weaker comprehension skills would benefit more from the structured Web-based course because of the cognitive aids available in that course format. Students with a higher level of skill might be able to structure their own study in ways that would benefit them, leaving little need for external cognitive aids. This is the case where the advantage shown by the Web-based format (e.g., R. H. Maki et al., 2000) is explained by the compensatory effects of the Web-based format on the low-skill students. ATIs such as this have been shown, for example, in studies of user interfaces for database queries (Greene, Devlin, Cannata, & Gomez, 1990).

There is some evidence that the opposite may occur from comparisons of hypertext (such as material found on the Web) versus more linear learning materials, producing the kind of ATI that is diagrammed in the right panel of Figure 1. In this case, the advantage shown by the Web-based format is explained by the beneficial effects on high-skill students. Recker and Pirolli (1995) reported this kind of ATI in a study in which students studied two versions of the same text on computer programming. The hypertext environment was mostly beneficial to students who had learned more in an earlier programming session. Students who had learned less actually decreased in performance after using hypertext. Recker and Pirolli hypothesized that the lower performing students may have been overwhelmed by the amount of learner control provided by the hypertext environment, and thus they could not take advantage of the complex learning environment. Shute and Gawlick-Grendell (1994) reported a similar finding based on cognitive abilities. They compared learning from a computer-based statistics tutor with learning of the same material presented in a paper-and-pencil workbook. They divided participants (consisting of a community sample) into high or low cognitive ability on the basis of an extensive battery of computerized tests. Shute and Gawlick-Grendell found that low-aptitude participants performed similarly in the computerized and workbook conditions; however, high-aptitude participants performed better in the computerized condition. They hypothesized that the low-ability students did not benefit from the computerized tutorial because the novel learning environment required too many cognitive resources.

Conklin (1987) argued that more cognitive resources are used in hypertext than in standard text environments because learners need to monitor their current location and make navigational decisions. This added cognitive overhead might make it difficult for students with lower ability to use Web-based hypertext materials effectively. Both Recker and Pirolli (1995) and Shute and Gawlick-Grendell (1994) showed ATIs using measures of cognitive abilities in the learning of specific material. They did not examine learning in an entire course. Yet the application of Web-based learning to college classrooms calls for the redesign of entire courses. Stu-

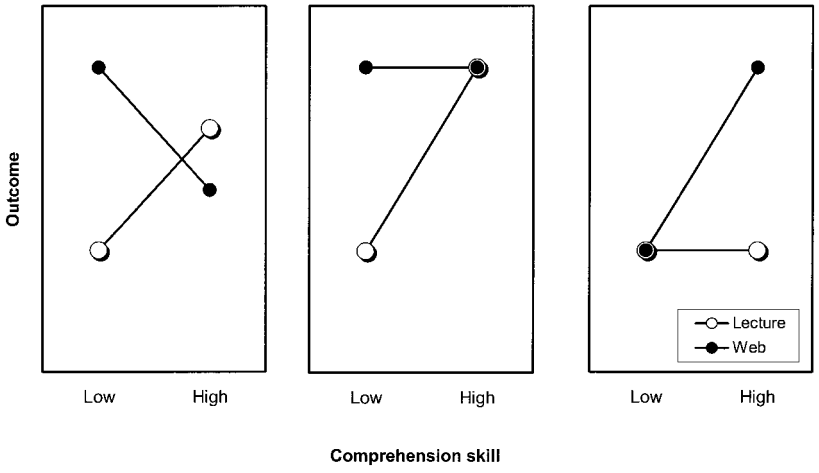


Figure 1. Hypothetical aptitude-treatment interactions (ATIs). The left panel shows an ATI in which the effects of instructional format (Web-based vs. lecture) are reversed at different levels of skill. The middle panel shows an ATI in which the Web-based course compensates for low comprehension skill. The right panel shows an ATI in which the Web-based course selectively improves performance of students with high comprehension skill.

dents of lower ability may be disadvantaged by such course redesign, whereas students of higher abilities may be given an advantage. This possibility is consistent with Snow and Yalow's (1982) hypothesis that measures of cognitive abilities "relate more strongly to learning outcome as instructional treatments appear to place increased information processing burdens on learners" (p. 531).

We designed this study to determine whether students with different levels of comprehension skill are affected differently by Web-based and lecture versions of an introductory psychology course. If such differences were obtained, then we were interested in determining which of the ATIs shown in Figure 1 would produce them.

Overview

Our Web-based course was the same as that described by R. H. Maki et al. (2000). Lectures were replaced by other activities that we expected to facilitate learning. Chapter previews included study of definitions, chapter outlines, and answers to frequently asked questions, followed by a short quiz over the preview materials. Such activities have been shown to facilitate learning from text (Mayer, Dyck, & Cook, 1984; Rothkopf & Bisbicos, 1967). Weekly computerized assignments involved active learning, including demonstration experiments and information seeking on the Web. Each of these was followed by a quiz with immediate feedback on performance. Students also took mastery quizzes consisting of randomly selected multiple-choice questions, and they received immediate feedback on their performance along with explanations about why answers were correct or incorrect (W. S. Maki & Maki, 2001). Weekly deadlines for each of these activities ensured distributed practice that, although helpful for learning (Bahrick, Bahrick, Bahrick, & Bahrick, 1993), is not typically done by students unless deadlines are in effect (Taraban, Maki, & Rynearson, 1999). In addition to the Web-based activities, students met once a week with a graduate student teaching assistant, either to participate in an activity related to the week's course material or to take a midterm examination.

As in R. H. Maki et al.'s (2000) study, we compared three kinds of outcomes (learning, performance, and student perceptions) for these Web-based sections with standard lecture–test sections taught by the same graduate student instructors. In the lecture sections, students met three times a week. The instructors lectured on textbook material, encouraged discussion, and used some demonstrations. In both Web-based and lecture sections, students read the same textbook, covering approximately one chapter per week. All students took the same examinations.

We used a measure of comprehension skill as our cognitive ability measure. The levels of comprehension skills of students in both types of courses were inferred from scores on the laboratory-based Multi-Media Comprehension Battery (MMCB) developed by Gernsbacher and Varner (1988). We selected the MMCB because it is a measure of general comprehension skills, derived from comprehension of auditory, written, and pictorial material. It also allowed us to examine the hypothesis that students who excel in different types of comprehension (auditory, written, or pictorial) would perform better in classes that emphasize different media. That is, lectures require auditory comprehension, but learning from Web-based material requires comprehension of written and pictorial materials.

We hypothesized that students who differ on the MMCB would differ in terms of outcomes of the Web-based and lecture courses. Students from Web-based and lecture sections were invited to come to the laboratory and participate in the MMCB. We then used students' levels of comprehension skill to predict their learning from, performance in, and perceptions of the two course formats.

Method

Design

We used a quasi-experimental nonequivalent-groups pretest–posttest design. Students selected the lecture sections or the Web-based sections of introductory psychology during each semester for 2 academic years (1999–2000 and 2000–2001). Across the 2 years, three different instructors taught both the lecture and Web-based courses. During the fall and spring semesters of 1999–2000, each of two instructors taught two Web-based sections (of about 25 students each) and one lecture section (of about 50 students). In 2000–2001, one of those instructors taught Web-based and lecture sections in the fall, and a third instructor taught both types of sections in the spring. All instructors were doctoral students at Texas Tech University.

Procedure

Web-based versus lecture format. The primary material to be learned in all sections of introductory psychology was taken from a standard introductory psychology textbook (Kalat, 1999). Students read approximately one chapter per week. The main difference between the formats was in the activities designed to supplement learning from the textbook. In the lecture sections, the supplement was three weekly class periods in which the graduate student instructors gave lectures or engaged the students in discussions or demonstrations. The graduate instructors offered review sheets and review sessions for examinations in their lecture sections.

In the Web-based sections, the supplement consisted of activities delivered via the Web, plus one weekly class session. Each week, students participated in four types of required activities. Each of these activities carried course points and, hence, participation was reflected in the final course grade. First, students were asked to preview the week's chapter by studying a chapter outline, reading answers to frequently asked questions, and exploring definitions of terms in the Web-based glossary related to the chapter. This was followed by a 5-item quiz over the material that was due on Sunday of each week. Points were given for correct answers on the quiz.

Second, students took Web-based, interactive multiple-choice mastery quizzes. These were created from the test bank provided by the publisher. With the publisher's permission, we placed about one half of the total test item pool (about 100 questions for most chapters) online. We augmented the online test bank with reasons why each alternative was correct or incorrect. When students requested a quiz over a chapter, 15 questions were randomly selected for the student. A database kept track of which questions the student had seen before and the accuracy of his or her answers to those questions. When students repeated a quiz for a chapter, they were presented with new questions, or, if they had seen all the test questions for a chapter, they were presented with those they had answered incorrectly. Students received immediate feedback on each quiz that indicated whether they were correct on each question and provided the reasons for why answers were correct or incorrect. Students could take as many quizzes as they liked over a chapter, but they had to pass two quizzes at 80% or better each week to receive the maximum course points. Quizzes were due on Mondays.

The third required activity each week was participation in an interactive experimental demonstration or a search of the Web for chapter-related material. For example, for the chapter on memory, students were given a

memory-span test in which increasingly long strings of digits were presented for memory. For the chapter on biopsychology, they worked with a diagram of the brain in which different parts were highlighted when different functions were selected. For some chapters, such as the introductory one, we asked them to look for information on the Web. They were asked to find a large psychology department and classify the psychologists in the department according to the scheme given in the textbook (which included areas such as clinical psychology, biopsychology, and cognitive psychology). These exercises were followed by a short quiz, and course points were given for correct answers on the quiz. This was normally due on Tuesday each week.

For the last activity of each week, students were required to attend a class meeting on each Wednesday led by the graduate instructor. Students were usually required to bring in a worksheet from the Web-based exercise for the week so that data from the week's assignment could be pooled and discussed. The graduate student instructor taught this in-class portion of the Web-based course. The instructor also graded the worksheets from the weekly assignment and communicated with students about their grades.

Lecture and Web-based students followed the same course calendar and took the same examinations, based on the same textbook material, on the same days. Examination questions were taken from the half of the test bank accompanying the textbook that had not been presented as quizzes on the Web. Questions were nominated by the graduate student instructors and selected by the faculty instructor. Graduate student instructors were asked to suggest questions that were related to material they had covered in their classes in their lecture sections.

MMCB. The MMCB contains written, auditory, and pictorial components. Gernsbacher, Varner, and Faust (1990) reported that the measures from different media were highly correlated (.72–.92), and a factor analysis showed that there was one main factor extracted from the scores. However, R. H. Maki, Jonas, and Kallod (1994) found that the written and the auditory components were correlated (r = .63), but neither of these correlated significantly with the pictorial component (rs = .16 and .27, respectively). To demonstrate validity of the MMCB, Gernsbacher et al. reported that written, auditory, and pictorial MMCB scores correlated with verbal SAT scores at rs = .64, .57, and .45, respectively. They also showed that individuals with higher MMCB scores were able to more efficiently suppress irrelevant meanings in sentence comprehension tasks. R. H. Maki et al. (1994) reported that the MMCB written component and the MMCB auditory component correlated with the comprehension portion of the more commonly used Nelson–Denny Reading Test (Brown, Nelson, & Denny, 1973); (rs = .46 and .42, respectively), although scores on the pictorial portion of the MMCB did not correlate significantly (r = .15) with the Nelson–Denny comprehension test.

We administered the MMCB in our laboratory. Students in the Web-based and lecture courses indicated that they were willing to participate in a laboratory experiment by noting their telephone number on a survey given during the first week of classes. They were called and scheduled to come to the laboratory in groups of 6. On arrival at the laboratory, students signed a consent form to participate for course credit. Each participant was shown into a small experimental cubical containing a computer. The materials and procedures were identical to those used by Gernsbacher et al. (1990). The stories were children's stories modified by Gernsbacher and Varner (1988) for use in the MMCB. Participants were instructed to study the stories carefully so that they could answer questions about them. All participants read two stories containing 636 and 585 words, presented line by line on the computer monitor until 24 lines were presented and the screen was filled. After a short pause, the display was erased, and the second part of the story was presented line by line. Lines were presented at a rate of 185 words/min. After each story was read, participants answered 12 open-ended questions that were presented on the computer screen. The participants were allowed 20 s to write an answer to each question on numbered answer sheets. Next, participants heard two stories containing 958 and 901 words, read at a rate of 215 words/min on a tape recorder. Again, after each story, participants saw 12 questions on the computer screen, and they wrote their answers on an answer sheet. Finally, they saw two picture stories containing 31 and 32 pictures with no words, presented using a slide projector at a rate of 7.75 s/slide. Participants moved from their cubicles and sat in a hallway so that they could see the screen displaying the slides. After each story, they moved back into the cubicles and wrote answers to questions presented on their computer screens.

We scored the MMCB using the criteria developed by Gernsbacher and Varner (1988). Gernsbacher et al. (1990) had reported that their scoring procedure for the MMCB produced a high correlation of interjudge agreement (r = .99). In our study, about one third of the participants' responses were scored independently by two scores. The Pearson correlation coefficient for total scores assigned by each rater was .98, so we also had high interrater reliability.

Self-rated comprehension ability. Students in both the Web-based and lecture courses completed surveys in class during the first week (precourse survey) and last week (postcourse survey) of classes. On the survey at the end of the semester, we asked students to rate their comprehension ability on a 7-point Likert scale that ranged from (1) *very poor* to (7) *very good*. We were interested in whether this simple measure would discriminate among students as well as the more time-consuming MMCB measure.

Dependent Measures

The dependent measures and response scales are listed in Table 2.

Learning. We measured students' subject-matter knowledge on both the precourse and postcourse surveys. The questions were selected from the practice test for the Psychology GRE (Educational Testing Service, 1994). There were 3–4 questions related to each chapter covered in introductory psychology. These questions are publicly disclosed questions from previously administered GRE tests, so they have adequate validity and reliability according to the Educational Testing Service's criteria for GRE tests.

Performance. In each lecture and Web-based section, students took four midterm examinations, each covering about three to four textbook chapters. During each semester, the examinations were the same for lecture and Web-based students. Examination questions were mostly selected from the test bank associated with the textbook. None of the questions used on examinations had occurred in the mastery quizzes for Web-based sections, although those questions were selected from the same test bank that accompanied the textbook.

Perceived learning, workload, and satisfaction. In Table 2, the questions posed to our students regarding their perceived learning and perceptions of workload are listed. The workload measures were included because Greenwald and Gillmore (1997) reported that workload, mediated by expected grade, is an important factor in student ratings of course instructors. We also collected measures of expected satisfaction and interest in psychology on both the precourse and postcourse surveys (see Table 2 for details).

Participants

All participants were enrolled in General Psychology at Texas Tech University. Across the 2 years, a total of 297 students originally enrolled in the lecture sections, and 288 originally enrolled in the Web-based sections. In general, students did not know that the course used a Web-based format when they enrolled, although the Web-based course was marked in the schedule as using assignments on the World Wide Web. Only 8 of the 95 (8.42%) students signed up for the course because they knew it was mostly Web based. Most students in the Web-based section selected it because the time was convenient (74.74%), although some students reported that their advisors had recommended it (14.7%). Students selected the lecture course because of a convenient time (62.76%) or because their advisors had recommended the course (31.91%).

A total of 189 students (94 lecture and 95 Web) came to the laboratory to participate in the MMCB. Other students were either not interested in

Table 2
Dependent Measures

Measure/item	Response scale
Content questions	40 multiple-choice questions from practice GRE
Examination scores	40 multiple-choice questions from publisher's test bank
How much did you learn in this class relative to your other college courses?	5-point scale: 1 = *much less than average*, 5 = *much more than average*
My psychology course was a better learning experience than my other courses.	5-point scale: 1 = *strongly disagree*, 5 = *strongly agree*
Hours spent on your psychology course each week	5-point scale: 1 = *less than 2*, 2 = *2–4*, 3 = *4–6*, 4 = *6–8*, 5 = *more than 8*
My psychology course was more work than my other courses.	5-point scale: 1 = *strongly disagree*, 5 = *strongly agree*
I [will like/liked] my psychology class.	5-point scale: 1 = *strongly disagree*, 5 = *strongly agree*
Psychology is an interesting subject.	5-point scale: 1 = *strongly disagree*, 5 = *strongly agree*
After you finish this class, how likely are you to take more psychology courses?	5-point scale: 1 = *not at all likely*, 5 = *will surely take more psychology courses*

Note. GRE = Graduate Record Examination.

participating in the laboratory experiment or could not be contacted by telephone. The mean MMCB score for students in the Web-based sections was 113.6, and the mean score in the lecture sections was 109.1. The difference was not significant, $F(1, 187) = 1.56$, $MSE = 630.82$, $p > .05$ (the level of significance used for all analyses to be reported). Of the 189 who participated in the MMCB, 155 (74 lecture and 81 Web) also participated in both the precourse and postcourse surveys from which we obtained the measures of content learning, comprehension ability, perceived learning, workload, and satisfaction. For each analysis described subsequently, we used the data from all participants for whom we had complete data for that portion of the study.

Background Variables

The strength of the nonequivalent-groups, pretest–posttest design is that it allows determination of the equivalence (or nonequivalence) of groups by pretest measures. The pretest information we collected was used in two ways. First, as reported in the *Regression Analyses* section, we imposed statistical control by removing the variance due to these potentially confounding background variables. Second, we compared some characteristics of our participants directly as a check on the equivalence of the Web-based and lecture groups. Students' majors were identified from the official class lists. Majors were classified into six categories: science and technology (including biological and physical sciences, engineering, math, and computer science), preprofessional (including premedical, predental, prephysical therapy, other health professions, nursing, architecture, and prelaw), social sciences (including psychology, political science, mass communication, exercise and sports science, human development, and elementary education), humanities (including English, history, and philosophy), business (including all majors in the College of Business Administration and majors from Agriculture, including agribusiness and agricultural economics), and undecided. Table 3 shows the distribution of majors for the two course formats. A chi-square test showed that the distributions of majors were not significantly different, $\chi^2(5, N = 189) = 2.70$. Students were also classified into freshmen and sophomores and above, as shown in Table 3. We used only two categories, because there were relatively few students who were above the sophomore level. The distributions of year in college did not differ statistically for the two course formats, $\chi^2(1, N = 189) = 1.76$.

Results

Descriptive Statistics

Means for lecture and web-based courses. Table 4 shows the number of participants, mean scores, and standard deviations for the predictor variables (MMCB scores and self-rated comprehension ability) and the outcome variables for the Web-based and lecture sections. In addition, we report Cohen's *d* to show the effect size for the difference between the Web-based and lecture courses. We used two measures of learning: percentage correct on the GRE content questions at the end of the course and mean percentage correct on the four in-class examinations. Percentage correct on the GRE questions at the beginning of the course are also reported. Students' perceptions of learning are shown as means on the 5-point scale (with 5 reflecting more positive perceptions) for the quality of the learning experience and for perceived amount learned, both relative to other courses. Two workload measures—(a) mean hours spent on the course per week, as estimated from the mean intervals on rating scale and (b) workload relative to that of other courses—are shown. Finally, the table includes the three measures of satisfaction collected both at the beginning and at the end of the course (liking the course, interest in psychology, and likelihood of taking more psychology courses).

Correlations with comprehension ability. We computed Pearson correlations among the components of the MMCB, self-rated comprehension ability, and performance on in-class examinations.

Table 3
Characteristics of Students in the Lecture and Online Courses

	Section	
Characteristic	Online	Lecture
Gender		
Female	65	69
Male	30	25
Major		
Business	13	10
Humanities	4	3
Preprofessional	29	32
Science/technology	18	12
Social sciences	19	25
Undecided	12	12
Year in college		
Freshman	58	66
Sophomore, Junior, Senior	37	28

Table 4
Number of Participants and Means and Standard Deviations of Predictor and Dependent Variables for the Lecture and Web-Based Courses

	Lecture			Web based			
Variable	*M*	*SD*	*n*	*M*	*SD*	*n*	*d*
MMCB	109.29	25.15	94	113.62	25.02	95	.173
Self-rated comprehension	3.64	0.84	74	3.76	0.90	81	.138
Content scores							
Precourse	25.47	6.97	84	26.33	7.66	89	.117
Postcourse	30.67	9.66	74	36.48	13.39	81	.494
Examination scores	69.72	11.37	94	73.99	11.89	95	.367
Learning experience	3.47	1.05	74	3.02	1.20	81	−.398
Perceived learning	3.55	1.01	74	3.25	1.02	81	−.296
Hours per week[a]	3.71	1.57	74	4.08	1.66	81	.229
Relative workload	2.63	1.13	74	3.18	1.13	81	.487
Liking for course							
Precourse	4.56	0.72	84	4.19	0.70	89	−.521
Postcourse	4.28	0.94	74	3.73	1.26	81	−.498
Interest in psychology							
Precourse	4.56	0.68	84	4.31	0.70	89	−.362
Postcourse	4.27	0.98	74	4.14	0.98	81	−.132
Take other psychology courses							
Precourse	3.13	1.50	84	2.79	1.46	89	−.230
Postcourse	2.92	1.54	74	2.30	1.48	81	−.411

Note. MMCB = Multi-Media Comprehension Battery.
[a] Only 2 students rated time spent as "8 hours or more," so the influence of this open-ended category is minimal. We estimated time per week as 9 hours for these 2 students.

These correlations are shown in Table 5. As can be seen in the table, there is no evidence that the various components of the MMCB differentially predicted Web-based and lecture performance in any way that was different from the composite MMCB score, so we added the three MMCB scores together and used the more stable composite MMCB score in all analyses. The MMCB scores produced moderately high correlations with measures of learning and performance in the Web-based course (bottom half of the table), but the MMCB produced low correlations with learning and performance in the lecture course (top half of the table). Self-rated comprehension ability correlated positively with the MMCB scores, with examination performance, and with final scores on the difficult content (GRE) questions, and the patterns were similar in the Web-based and lecture courses.

Table 6 shows the correlations among the MMCB and the outcome measures for the lecture and Web-based courses. Although the MMCB was correlated with examination and content question scores and with workload, especially so in the Web sections (see bottom half of Table 6), the MMCB generally was not related to other outcome variables. Table 6 also shows the correlations among the outcome variables. Examination scores were related negatively with perceived workload in both types of courses. They were also related positively to perceived learning and to course satisfaction. The measures of course satisfaction, including the perceived quality of the learning experience, perceived learning, liking for the class, interest in psychology, and intention to take other psychology courses, were generally interrelated in both types of courses.

Table 5
Correlations Among Predictor and Performance Variables for the Lecture Course (Above Diagonal) and the Online Course (Below Diagonal)

Variable	1	2	3	4	5	6	7	8
1. Beginning content scores	—	.44*	.36*	.23*	.28*	.37*	.09	.27*
2. End content scores	.52*	—	.53*	.16	.16	.20	−.04	.40*
3. Mean exam scores	.36*	.72*	—	.46*	.35*	.32*	.18	.49*
4. MMCB	.22*	.48*	.53*	—	.85*[a]	.86*[a]	.68*[a]	.31*
5. MMCB—Visual	.21*	.32*	.47*	.83*[a]	—	.59*	.46*	.35*
6. MMCB—Auditory	.26*	.49*	.52*	.87*[a]	.60*	—	.31*	.26*
7. MMCB—Pictorial	.04	.31*	.27*	.72*[a]	.42*	.43*	—	.13
8. Rated comprehension	.22	.36*	.37*	.26*	.34*	.23*	.05	—

Note. MMCB = Multi-Media Comprehension Battery.
[a] Correlation of a component of the MMCB with the entire scale (i.e., a part–whole correlation).
* $p < .05$.

Table 6
Correlations Among Multi-Media Comprehension Battery (MMCB) and Dependent Measures for Lecture Courses (Above Diagonal) and for Online Courses (Below Diagonal)

Variable	1	2	3	4	5	6	7	8	9	10
1. MMCB	—	.16	.37*	−.08	−.22	−.09	−.06	.04	−.01	.11
2. Postcourse content scores	.48*	—	.53*	.03	−.22	.25*	.20	.21	.24*	.16
3. Exam scores	.53*	.72*	—	−.02	−.39*	.36*	.21	.29*	.26*	.26*
4. Time spent	−.19	−.10	−.24*	—	.23	.31*	.03	.26*	.13	.13
5. Workload	−.24*	−.12	−.28*	.48*	—	.10	.03	.03	.10	.13
6. Experience	−.05	.16	.26*	.18	.05	—	.50*	.55*	.58*	.26*
7. Perceived learning	.14	.32*	.36*	.19	.01	.05	—	.41*	.30*	.36*
8. Liked class	.04	.13	.32*	.07	−.12	.67*	.63*	—	.51*	.41*
9. Interest	.06	.22*	.33*	.14	.06	.47*	.38*	.62*	—	.41*
10. Take other psychology courses	.11	.10	.13	.22	.18	.29*	.26*	.29*	.38*	—

* $p < .05$.

Regression Analyses

We analyzed the data in separate regression analyses for six dependent variables. For each regression, variance related to background variables that may confound or obscure the differences between lecture and Web-based courses was removed first. For the dependent variables related to learning and performance, background variables included scores on GRE questions about psychology measured at the beginning of the course. For the measures related to satisfaction, background variables included ratings of expected course satisfaction, interest in psychology, and intention to take more psychology courses at the beginning of the course. For all regression analyses, variance associated with year in college (coded as "freshman" or "other") and variance associated with major were included in the group of background variables. Major was classified into six levels, and the variance was removed with five dummy-coded vectors. Major and year in college were included in the regressions because there were some differences in the distributions for the Web-based and lecture courses (see Table 3), although the differences were not significant. After removing variance related to the background variables, variance associated with the three instructors was removed with two vectors.

The two major predictor variables—course format and scores on the MMCB—were entered next into each regression equation. Finally, the interaction of these two variables was entered. MMCB scores were centered around zero to allow interpretation of the interaction (see Aiken & West, 1991). If MMCB predicted variance differentially for the lecture and Web-based courses, we expected to find that the interaction between course format and MMCB scores produced a significant increment in R^2.

Learning predicted by the MMCB. Learning of course material was measured by increased performance on the difficult-content (GRE) questions. The results of the regression analysis predicting scores on the practice GRE questions at the end of the semester are shown in Table 7. This regression was based on 151 students who had scores on content questions at the end of the semester. Background variables accounted for significant variance, but the instructor vectors did not increase R^2 significantly. However, both course format and the MMCB increased predictability. Finally, there was a significant interaction between course format and the MMCB. This interaction is depicted in Figure 2. For each participant, we calculated residual scores after variance related to the background variables and instructor was removed. We then added

Table 7
Regression Analysis Predicting Test Performance From Course Format and Multimedia Comprehension Skill

	Content performance				Examination performance		
Variables	R^2	ΔR^2	*b*	*df* change	R^2	ΔR^2	*b*
Background	.296	.296*		7	.203	.203*	
Instructor	.320	.024		2	.206	.003	
Course format	.350	.030*	2.106	1	.229	.023*	1.628
MMCB	.387	.037*	0.096	1	.354	.125*	0.178
Format × MMCB	.433	.046*	0.109	1	.374	.020*	0.069

Note. In this table, *b* values rather than *betas* are given because *beta* is not interpretable when variables are centered for interactions, as they were here; *b* is not given for the initial variables and for instructor because these were coded with multiple vectors. A positive *b* for course format indicates higher performance for the online course; a positive *b* for the interaction indicates a larger difference between the two course formats with higher Multi-Media Comprehension Battery (MMCB) scores. Background variables included beginning knowledge, major, and college classification. Degrees of freedom for the increments in R^2(*df* change) were the same for both regression analyses.
* $p < .05$.

the mean for the posttest content scores to each residual. These are the data points shown in the left side of Figure 2 for the Web-based and the lecture courses. The black line is the best-fitting regression line for the Web-based course, and the gray line is the best-fitting regression line for the lecture course. As can be seen in Figure 2, performance increased more in the Web-based course with increases in comprehension skill than it did in the lecture course.

We calculated regions of significance as described by Aiken and West (1991). Performance in the Web-based course was significantly higher than in the lecture course for students whose MMCB scores were at or above 111.68; that is, from just above the mean MMCB and upward. (The beginning of the upper region of significance is marked by the vertical line in Figure 2.) At the lower end, performance would be theoretically better in lecture courses than in the Web-based courses for students having the impossible MMCB score of −49.85 or lower. Thus, the pattern of learning that we observed is most similar to the third ATI shown in Figure 1; that is, students with greater comprehension skill benefited from the Web-based course more than did students with lesser skill.

Performance predicted by the MMCB. We conducted a similar regression analysis for the average of four class examinations that were the same for the two course formats. This regression analysis was based on the 183 students who took all examinations. The results of this regression analysis can be seen in the right half of Table 7. Background variance related to scores on the pretest, college major, and college classification was removed first, followed by variance associated with instructor. Course format accounted for a significant increase in variance, with higher examination scores in the Web-based course than in the lecture course. Students with higher MMCB scores performed better than students with lower MMCB scores. The interaction between course format and MMCB scores was significant. This interaction is plotted in the right half of Figure 2. Again we obtained a residual score for each participant after removing variance related to the background variables and instructor and adding the performance mean to each residual score. The best-fitting regression line for the Web-based course (black line) and the best-fitting regression line for the lecture course (gray line) again show an interaction pattern.

We calculated regions of significance and found that students who scored above 133.13 on the MMCB (marked by the vertical line in Figure 2) had significantly better performance in the Web-based course than in the lecture course. At the lower end, students with MMCB scores of 6.59 and below would be expected to perform better in the lecture course than in the Web-based course. Because better performance in the lecture than in the Web-based course would occur only for MMCB scores that were below the range that we observed, we again concluded that the ATI is of the third type depicted in Figure 1. Only highly skilled students benefited more from the Web-based instruction than from traditional lecture-based instruction.

Learning and performance predicted by rated comprehension skill. We performed a second set of regression analyses on the learning measures, using as a predictor self-rated comprehension ability instead of the MCCB scores. This analysis was based on the 151 students for whom we had rated comprehension scores. The results of this regression are shown in Table 8. Background variance was removed first, followed by variance due to instructor. Course format predicted significant variance with higher scores in

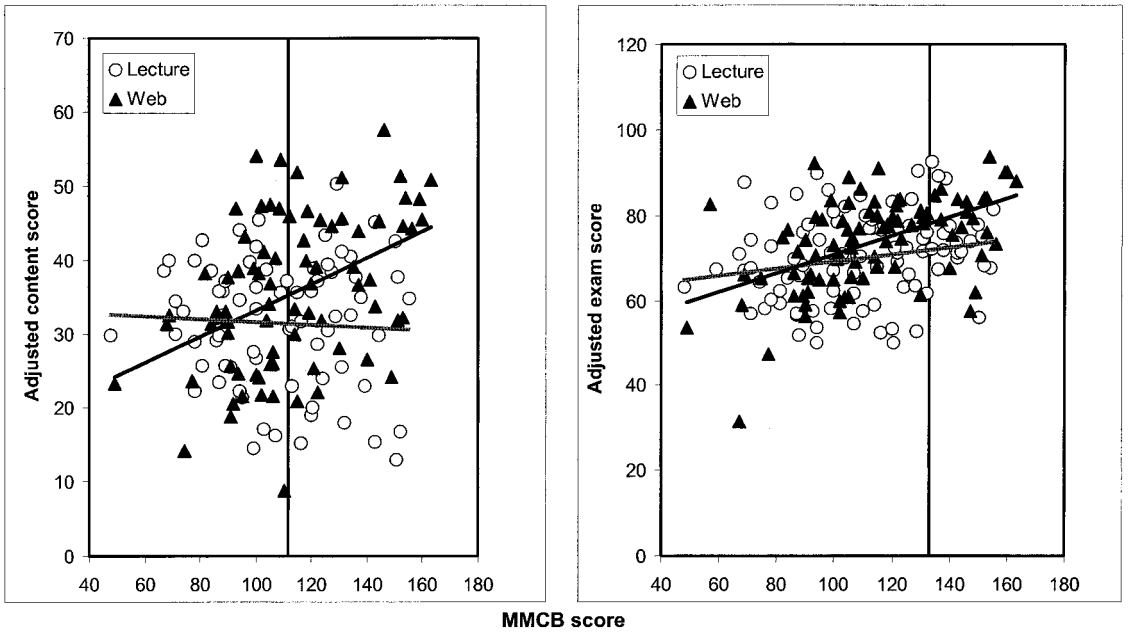


Figure 2. Residual scores (plus the grand mean) after variance related to the background variables and instructor was removed for the postcourse content measure (left panel) and for examination scores (right panel) as a function of Multi-Media Comprehension Battery (MMCB) scores in the Web-based (solid triangles) and lecture courses (open circles). The black line is the best-fitting regression line for the Web-based course, and the gray line is the best-fitting regression line for the lecture course. The vertical line marks the beginning of the upper region of significant differences between Web-based and lecture courses (Aiken & West, 1991).

the Web-based course, and rated comprehension was positively related to content knowledge. However, there was no hint of an interaction; the increase in R^2 was essentially zero when the interaction component was added to the equation. The left side of Figure 3 shows the residual scores plus the GRE posttest mean as a function of rated comprehension. The best-fitting regression lines are essentially parallel, showing no interaction. Students who rated their comprehension as higher scored better on the content knowledge questions in both the Web-based and lecture courses.

The right side of Table 8 shows the regression analysis for the classroom examinations with course format and rated comprehension as predictors. Background variance and instructor variance were removed first. The change in R^2 due to course format was not significant in this analysis, perhaps because we did not have comprehension ratings for all students, resulting in less power in this analysis. Rated comprehension ability accounted for significant variance, but the interaction between rated comprehension and course format was not significant. Residual scores plus the examination mean are plotted for the Web-based and lecture groups in the right half of Figure 3. The best-fitting regression lines for both the difficulty posttest questions and the examination scores show that the pattern for rated comprehension ability (Figure 3) is quite different from that obtained with empirically determined comprehension skill (Figure 2).

Perceived learning. At the end of the semester, students were asked to rate their perceptions of learning in the Web-based and lecture courses (see Table 2). For one measure of perceived learning, the students rated the learning experience relative to other courses. In the regression analysis shown in Table 9, we first removed background variance associated with major and year in college, and then we removed variance related to instructor. Instructor produced a significant increment in variance. Course format also predicted variance, with higher ratings related to the lecture course than to the Web-based course. MMCB scores and the interaction of MMCB scores and course format did not produce significant increments in R^2.

For a second measure of perceived learning, students rated the amount they had learned relative to other courses. The regression analysis shown in the right half of Table 9 produced a pattern that was similar to the learning-experience question. Instructor and course format yielded significant increments in R^2, but comprehension skill and the interaction of comprehension skill and course format did not. For both of the perceived-learning questions the lecture format produced higher ratings than did the Web-based format, even though learning was actually higher in the Web-based course.

Perceived workload. The left half of Table 10 shows the regression with time spent per week on the psychology course as the dependent variable. We estimated time in hours by using the midpoint of each rating interval (i.e., we used 3 hr for the 2– 4-hr interval). Background variance of major and year in college, removed first, was not significant. Instructor produced a significant increment in variance. Course format did not produce a significant increment in variance, although somewhat more time was reported for the Web-based course. Comprehension skill and the interaction between skill and course format did not account for significant variance.

The right half of Table 10 shows the regression predicting rated amount of work relative to other courses. Background variables did not account for a significant portion of the variance; however, students were more likely to agree with the statement that the course involved more work than other courses when they took the Web-based course than the lecture course. Students who were lower in comprehension ability were more likely to agree that their course involved more work, but course format did not interact with ability.

Course satisfaction ratings. Table 11 shows the regression analyses of three measures of satisfaction with the psychology course. For each of these ratings, we collected a precourse measure that was similar to the postcourse measure, and these were entered in the first step of the regression with other background variables. The regression for liking of the course is shown in the left side of Table 11. Background variables accounted for significant variance, and instructor added a significant increment in variance. Course format also accounted for significant variance, with students preferring the lecture course over the Web-based course. Comprehension skill and the interaction of skill with course format did not add significant increments in variance.

Two factors that are known to relate to satisfaction with courses are workload and scores on examinations (Greenwald & Gillmore,

Table 8
Regression Analysis Predicting Test Performance From Course Format and Self-Rated Comprehension Ability

	Content performance				Examination performance		
Variable	R^2	ΔR^2	*b*	*df* change	R^2	ΔR^2	*b*
Background	.296	.296*		7	.227	.227*	
Instructor	.320	.024		2	.232	.005	
Course format	.350	.030*	2.007	1	.250	.018	1.464
Rated comprehension	.430	.080*	4.133	1	.358	.108*	4.755
Format × Rated Comprehension	.430	.000	0.151	1	.361	.003	−0.776

Note. In this table, *b* values rather than *betas* are given because *beta* is not interpretable when variables are centered for interactions, as they were here; *b* is not given for the initial variables and for instructor because these were coded with multiple vectors. A positive *b* for course format indicates higher performance for the online course. Background variables included beginning knowledge, major, and college classification. Degrees of freedom for the increments in R^2(*df* change) were the same for both regression analyses.
* $p < .05$.

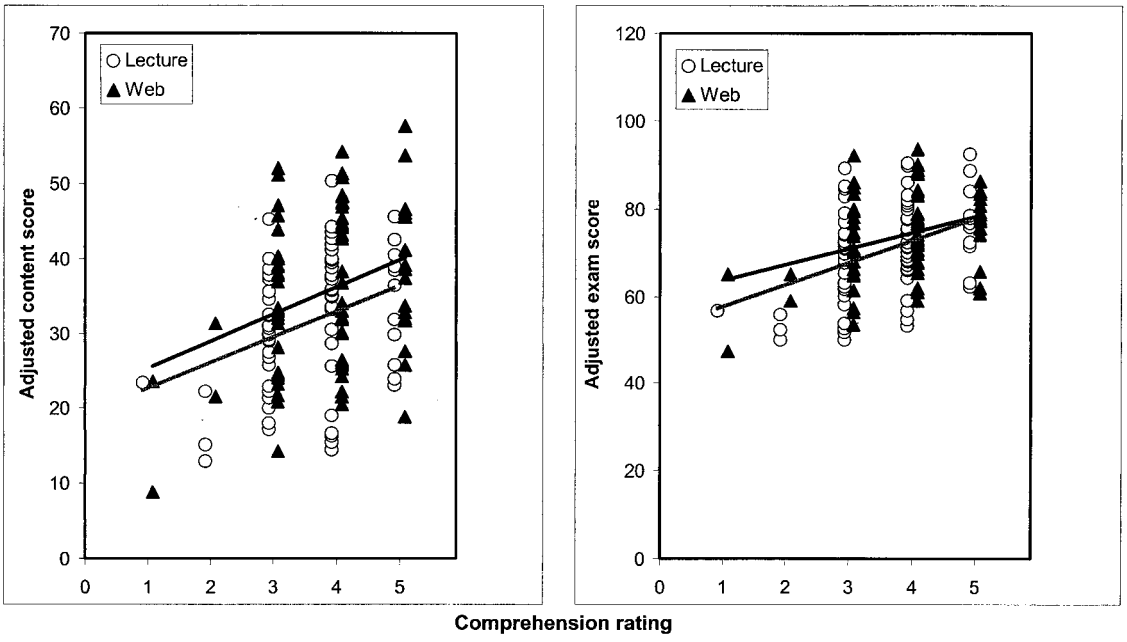


Figure 3. Residual scores (plus the grand mean) after variance related to the background variables and instructor was removed for the postcourse content measure (left panel) and for examination scores (right panel) as a function of rated comprehension scores in the Web-based (solid triangles) and lecture courses (open circles). The black line is the best-fitting regression line for the Web-based course, and the gray line is the best-fitting regression line for the lecture course.

1997). We conducted an additional regression analysis that removed these two variables from the "liked" question before variance due to course format was entered. Workload (entered as time per week in hours and amount of work relative to other courses) did not account for a significant increment in variance (R^2 increment = .025), but examination performance significantly increased the amount of variance explained (R^2 increment = .057). Better examination performance was related to greater liking for the course; however, the variance associated with course format was still significant after variance related to workload and examination performance had been removed (R^2 increment = .063). Thus, students liked their lecture classes more than their Web-based classes, and this advantage cannot be explained by workload or actual success.

The regression for interest in psychology is shown in the middle of Table 11. Only instructor significantly influenced students' interest in psychology at the end of the semester. The right panel of Table 11 shows regression results for students' intentions to take other psychology courses. Background variables, including the precourse measure of intention, accounted for significant variance. Instructor did not add a significant increment in variance. Course format added a significant increment in variance, with

Table 9
Regression Analysis Predicting Subjective Ratings of the Learning Experience From Course Format and Multimedia Comprehension Skill

	Better learning experience				Perceived learning		
Variable	R^2	ΔR^2	*b*	*df* change	R^2	ΔR^2	*b*
Background	.058	.058		6	.057	.057	
Instructor	.154	.095*		2	.133	.076*	
Course format	.185	.031*	−.199	1	.157	.024*	−.161
MMCB	.185	.000	−.002	1	.160	.003	.002
Format × MMCB	.188	.003	−.002	1	.169	.009	.004

Note. In this table, *b* values rather than *betas* are given because *beta* is not interpretable when variables are centered for interactions, as they were here; *b* is not given for the initial variables and for instructor because these were coded with multiple vectors. A negative *b* for course format indicates more positive ratings for the lecture course. Background variables included major and college classification. Degrees of freedom for the increments in R^2(*df* change) were the same for both regression analyses. MMCB = Multi-Media Comprehension Battery.
* $p < .05$.

Table 10
Regression Analysis Predicting Workload From Course Format and Multimedia Comprehension Skill

	Time spent				Relative workload		
Variable	R^2	ΔR^2	*b*	*df* change	R^2	ΔR^2	*b*
Background	.043	.043		6	.049	.049	
Instructor	.087	.044*		2	.062	.013	
Course format	.105	.019	.231	1	.128	.066*	.317
MMCB	.113	.007	.006	1	.163	.034*	−.009
Format × MMCB	.118	.005	.005	1	.163	.000	−.001

Note. In this table, *b* values rather than *betas* are given because *beta* is not interpretable when variables are centered for interactions, as they were here; *b* is not given for the initial variables and for instructor because these were coded with multiple vectors. A positive *b* for course format indicates that students perceived the online course as involving more work. Background variables included major and college classification. Degrees of freedom for the increments in R^2(*df* change) were the same for both regression analyses. MMCB = Multi-Media Comprehension Battery.
* $p < .05$.

students in the lecture sections indicating a greater likelihood of taking more psychology courses. Students with higher MMCB comprehension skill reported a greater likelihood of taking more courses than students with lower skill, but the interaction with course format was not significant.

Discussion

In our previous comparisons of the Web-based and lecture versions of General Psychology (R. H. Maki et al., 2000), we found three consistent effects: Students (a) learned more and (b) performed better in the Web-based version, but (c) they liked it less. The learning advantage was expressed in larger pretest–posttest gains on a set of (difficult) GRE practice questions. The performance advantage was shown by higher scores on in-class examinations. The satisfaction disadvantage was expressed in both lower ratings of the class and lower reported likelihood of taking more psychology courses. In this article, we have reported replications of all these effects. More important, however, we have presented evidence that advances our understanding of these effects in two ways. First, we discovered an individual-difference variable, measured (but not self-rated) comprehension skill, that appears to explain the source of the learning and performance advantage shown by students in the Web-based courses. Second, our analyses of variables mediating the course ratings act to limit the possible causes of the lesser satisfaction reported by those same students. We now explore and qualify each of these matters in turn.

Learning and Comprehension Skill

In this research, we used the MMCB (Gernsbacher et al., 1990) to measure comprehension skill. We originally thought that the MMCB might reveal differences between Web-based and lecture courses specific to one or more modalities (written, auditory, or pictorial); however, no such modality effects were found. Instead, we discovered that the overall MMCB score differentiated between the two course formats. Specifically, students with relatively

Table 11
Regression Analysis Predicting Course Satisfaction, Interest in Psychology, and Intention to Take Other Courses From Course Format and Comprehension Ability

		Liked class			Interest in psychology			Take other courses		
Variable	*df* change[a]	R^2	ΔR^2	*b*	R^2	ΔR^2	*b*	R^2	ΔR^2	*b*
Background	7	.091	.091*		.065	.065		.314	.314*	
Instructor	2	.134	.043*		.104	.039*		.338	.024	
Course format	1	.169	.035*	−.229	.106	.002	−.043	.358	.020*	−.235
MMCB	1	.173	.004	.003	.108	.002	−.002	.382	.024*	.010
Format × MMCB	1	.174	.001	−.001	.111	.003	−.002	.385	.003	.004

Note. In this table, *b* values rather than *betas* are given because *beta* is not interpretable when variables are centered for interactions, as they were here; *b* is not given for the initial variables and for instructor because these were coded with multiple vectors. A negative *b* for course format indicates more positive ratings for the lecture course than for the online course. Background variables included precourse rating, major, and college classification. Degrees of freedom for the increments in R^2(*df* change) were the same for both regression analyses. MMCB = Multi-Media Comprehension Battery.
[a] Degrees of freedom for the change in R^2 were the same for each regression analysis.
* $p < .05$.

high MMCB scores were those who benefited the most from the Web-based format; students with low MMCB scores appeared to accrue no benefit at all (Figure 2). Thus, it appears that good comprehension skills enable students to benefit from those features of the Web-based format that contribute to increased learning.

This research extends our knowledge of mediators of Web-based learning in two other ways. First, direct measurement of comprehension skill, although costly in terms of time and effort in a practical setting, is important. We found that measured skill predicts differences between Web-based and lecture courses (Figure 2) but that self-ratings of comprehension skill do not (Figure 3). Second, the results distinguish among the three possible ATIs depicted in Figure 1. Our results show that the highly skilled students benefit most from the Web-based format (see right panel of Figure 1). This finding invites the question of the circumstances that might realize the ATIs in the left and middle panels of Figure 1 in which students with lesser comprehension skill benefit from some instructional intervention. One possibility is suggested by Shute's (1995) work on intelligent tutoring systems in which low-aptitude learners showed large benefits of the tutor on learning of procedural skills but not on learning of conceptual knowledge. Our Web-based course, being basically a general survey course, taught and assessed mostly conceptual knowledge. According to this reasoning, the mix of procedural skill and declarative knowledge in a course may determine which of the outcomes shown in Figure 1 are obtained from instructional treatments like the Web-based course.

Our conclusions about the role of comprehension skill in Web-based learning and performance, however, need to be tempered for two reasons. First, the MMCB is correlated with the verbal SAT and thus may be measuring more general cognitive functioning (Gernsbacher et al., 1990). Second, the features of our Web-based course responsible for the learning and performance advantage are not known. For example, some combination of our interactive homework exercises, mastery quizzes, or group discussions may promote more active learning. However, the structure of the Web-based course, with its frequent and regular deadlines, is also a possible cause of the learning and performance differences. The general features of this structure, such as making the learners responsible for information processing, a relatively new curriculum, reliance on printed text for instruction, the relatively rapid pacing, and our advance organizers, are all instructional treatments that Snow and Yalow (1982, Table 9.2) would have expected to confer advantage on our high-ability students.

Satisfaction

In spite of the increased learning in the Web-based course, students liked it less. We can now discount two possible sources of their dissatisfaction. Students in our Web-based course rated the workload for the course higher than did students in the lecture course; however, the difference in satisfaction remained when variance due to workload was removed. Like workload (Greenwald & Gillmore, 1997), course grades influence satisfaction, and our students' liking of the course was related to their examination performance. However, removing the variance due to examination performance still left a difference in satisfaction favoring the lecture course.

We also do not believe that our technology (course components, user interface, etc.) was at fault. We believe, along with Shute and Gawlick-Grendell (1994, p. 185), that "learning environments [should] incorporate creative, hands-on problem solving scenarios to encourage learners to become actively involved in the learning process. This will not only improve learning outcome, but also enhance enjoyment of the learning experience." Current academic software (including our own Web-based course) could be so improved. However, the students in the Web-based course rated its components very highly (e.g., our quiz system; W. S. Maki & Maki, 2001).

What then might be the source of the relative dissatisfaction with the Web-based course? We offer three speculations. Williams and Ceci (1997) reported an instructor-enthusiasm effect. In their case study, an increased level of exhibited enthusiasm was accompanied by higher student ratings of satisfaction and learning. Something similar may have been at work in our lecture course, in which students met with the instructor many more times than did students in the Web-based course. Another function of the instructor may be to serve as a guide, selectively emphasizing some points and thus limiting the scope of material needing to be studied for an examination. Such guidance was minimal in the Web-based course. A third possibility lies in the structure of the Web-based course. We know from anecdotal remarks from students that at least some of them disliked the regular, weekly deadlines. Thus, the dissatisfaction may be less a matter of total work and more a matter of the distribution of that work.

In our discussion, we have tried to frame an agenda for future research to more precisely specify the components of Web-based instruction that are responsible for diminished satisfaction and the components that are responsible for the increased learning and performance that we reported here. Future research would also determine the kinds of course content that might be technologically enhanced to benefit low-skill as well as high-skill learners.

References

Ackerman, P. L., & Heggestad, E. D. (1997). Intelligence, personality, and interests: Evidence for overlapping traits. *Psychological Bulletin, 121,* 219–245.

Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions.* Newbury Park, CA: Sage.

Bahrick, H. P., Bahrick, L. E., Bahrick, A. S., & Bahrick, P. E. (1993). Maintenance of foreign language vocabulary and the spacing effect. *Psychological Science, 4,* 316–322.

Brown, J. L., Nelson, M. J., & Denny, E. C. (1973). *The Nelson–Denny Reading Test.* Chicago: Riverside.

Clark, R. E. (1994). Media will never influence learning. *Educational Technology Research & Development, 42,* 21–29.

Conklin, J. (1987). Hypertext: An introduction and survey. *IEEE Computer, 20,* 7–11.

Cronbach, L. J., & Snow, R. E. (1977). *Aptitudes and instructional methods: A handbook for research on interactions.* New York: Irvington.

Educational Testing Service. (1994). *GRE: Practicing to take the Psychology Test* (3rd ed.). Princeton, NJ: Author.

Gernsbacher, M. A., & Varner, K. R. (1988). *The Multi-Media Comprehension Battery.* (Tech. Rep. No. 88-3). Eugene, OR: Institute of Cognitive and Decision Sciences.

Gernsbacher, M. A., Varner, K. R., & Faust, M. E. (1990). Investigating differences in general comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 430–455.

Greene, S. L., Devlin, S. J., Cannata, P. E., & Gomez, L. M. (1990). No Ifs, ANDs, or Ors: A study of database querying. *International Journal of Man–Machine Studies, 32,* 303–326.

Greenwald, A. G., & Gillmore, G. M. (1997). No pain, no gain? The importance of measuring course workload in student ratings of instruction. *Journal of Educational Psychology, 89,* 743–751.

Hiltz, S. R. (1993). Correlates of learning in a virtual classroom. *International Journal of Man–Machine Studies, 39,* 71–98.

Kalat, J. W. (1999). *Introduction to psychology* (5th ed.). Pacific Grove, CA: Brooks/Cole, Wadsworth.

Landauer, T. K. (1995). *The trouble with computers: Usefulness, usability, and productivity.* Cambridge, MA: MIT Press.

Maki, R. H., Jonas, D., & Kallod, M. (1994). The relationship between comprehension and metacomprehension ability. *Psychonomic Bulletin and Review, 1,* 126–129.

Maki, R. H., & Maki, W. S. (in press). Prediction of learning and satisfaction in Web-based and lecture courses. *Journal of Educational Computing Research.*

Maki, R. H., Maki, W. S., Patterson, M., & Whittaker, P. D. (2000). Evaluation of a Web-based introductory psychology course: I. Learning and satisfaction in on-line versus lecture courses. *Behavior Research Methods, Instruments, & Computers, 32,* 230–239.

Maki, W. S., & Maki, R. H. (2001). Mastery quizzes on the Web: Results from a Web-based introductory psychology course. *Behavior Research Methods, Instruments & Computers, 33,* 230–239.

Mayer, R. E., Dyck, J. L., & Cook, L. K. (1984). Techniques that help readers build mental models from scientific text: Definitions pretraining and signaling. *Journal of Educational Psychology, 76,* 1089–1105.

McCrae, R. R., & Costa, P. T., Jr. (1987). Validation of the five-factor model of personality across instruments and observers. *Journal of Personality and Social Psychology, 52,* 81–90.

Recker, M., & Pirolli, P. (1995). Modeling individual differences in students' learning strategies. *Journal of the Learning Sciences, 4,* 1–38.

Rothkopf, E. Z., & Bisbicos, E. E. (1967). Selective facilitative effects of interspersed questions on learning from written materials. *Journal of Educational Psychology, 87,* 455–467.

Sankaran, S. R., Sankaran, D., & Bui, T. X. (2000). Effect of student attitude to course format on learning performance: An empirical study in Web vs. lecture instruction. *Journal of Instructional Technology, 27,* 66–73.

Shute, V. J. (1992). Aptitude–treatment interactions and cognitive skill diagnosis. In J. W. Regian & V. J. Shute (Eds.), *Cognitive approaches of automated instruction* (pp. 15–43). Hillsdale, NJ: Erlbaum.

Shute, V. J. (1993). A comparison of learning environments: All that glitters . . . In S. P. Lajoie & S. J. Derry (Eds.), *Computers as cognitive tools* (pp. 47–73). Hillsdale, NJ: Erlbaum.

Shute, V. J. (1995). SMART: Student Modeling Approach for Responsive Tutoring. *User Modeling and User-Adapted Interaction, 5,* 1–44.

Shute, V. J., & Gawlick-Grendell, L. A. (1994). What does the computer contribute to learning? *Computers in Education, 23,* 177–186.

Snow, R. E., & Yalow, E. (1982). Education and intelligence. In R. J. Sternberg (Ed.), *Handbook of human intelligence* (pp. 493–585). Cambridge, England: Cambridge University Press.

Taraban, R., Maki, W. S., & Rynearson, K. (1999). Measuring study time distributions: Implications for designing computer-based courses. *Behavior Research Methods, Instruments & Computers, 31,* 263–269.

Wang, A. Y., & Newlin, M. H. (2000). Characteristics of students who enroll and succeed in psychology Web-based classes. *Journal of Educational Psychology, 92,* 137–143.

Waschull, S. B. (2001). The online delivery of psychology courses: Attrition, performance, and evaluation. *Teaching of Psychology, 28,* 143–147.

Williams, W. M., & Ceci, S. J. (1997). "How'm I doing?" Problems with student ratings of instructors and courses. *Change, 29,* 13–23.

Received August 1, 2001
Revision received February 26, 2002
Accepted February 27, 2002 ■

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