TEACHING WITH TECHNOLOGY:

DOES ACCESS TO COMPUTER TECHNOLOGY INCREASE STUDENT ACHIEVEMENT?

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INTRODUCTION

Computers and modern technology have been widely touted as the next important step in education. Schools are spending a great deal of money on computers, and government leaders are championing their use. Corporations and individuals are being asked to donate towards more technology in the classroom. Little work has been done, however, to examine the effectiveness of technology [Katz and Becker, 1999], which would seem to be an essential consideration given the enthusiasm technology has inspired. This paper offers a step towards correcting that deficiency by examining whether using computer technology as a supplement to classroom activities actually enhances student achievement in introductory economics. The results suggest that using course web pages and online, multiple-choice quizzes does not increase student scores on their final exam or on subsets of multiple-choice questions included as part of the final exam.

The literature that describes how to integrate technology into economics courses is quite extensive. Leuthold [1998] describes quite specifically how to construct a home page for economics courses and gives many suggestions for using it effectively. Also, an online journal, entitled *Computers in Higher Education Economics Review,* is devoted almost entirely to reviewing and describing new technological tools as well as explaining how to use them in teaching economics. In one such article, Judge [1999] discusses how to produce and use online web quizzes for economics so that students would receive immediate feedback on their understanding. Judge's paper is primarily descriptive in nature. It gives a summary of online quizzes in economics that exist on the web (which he says are limited compared to other disciplines), a description of what kinds of online quizzes and types of quiz questions that can be created, and an inventory of what tools are currently available for producing them. He also discusses the benefits

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to students and instructors of using online quizzes. According to Judge, one of the primary benefits to students of using online quizzes is immediate feedback on understanding of course material. He cautions that students could mistake good performance on objective, online quizzes for sufficient depth in understanding of the material but says students can be advised to use the quizzes only to reveal areas of weakness. Of course, another benefit to online quizzes, and attending feedback, is their accessibility anytime and anywhere students choose.

At the University of California at Irvine, several courses in the Graduate School of Management use web-based tests. According to Public Policy Professor Peter Navarro who uses online quizzes in his macroeconomics course, "[the] lack of rapid feedback in the traditional classroom is one of its most significant drawbacks" [*T.H.E. Journal*, 1999]. He reports that his students have benefited from the instantaneous feedback of online quizzes. One of the benefits to instructors from using online quizzes is that they can minimize work associated with grading by allowing instructors to use technology to compile the grades and track students' progress throughout the course. Procedures for tracking and analyzing responses can also provide instructors with useful information about students' performances. Our analysis of the benefits of online quizzes focuses on less-formal quizzes than Professor Navarro discusses. While these quizzes can ease the workload for instructors, our paper looks at whether the quizzes benefit the students.

A few works test whether technology enhances student learning. Agarwal and Day [1998] find that internet use positively affects both Test of Understanding College Economics III (TUCE) [Saunders, 1991] scores and final grades in introductory economics. Rankin and Hoaas [2001] study whether computer-assisted instruction improves student performance and find no such improvement. They also find no effect on student attitudes and teaching evaluations.

Our paper differs from these two because it looks at how effective new applications, such as online quizzes, are in increasing student performance in economics. Agarwal and Day [1998] uses e-mail and a class discussion list for communication and conferencing and the World Wide Web for the access, retrieval, and use of information in two sections of undergraduate economics (one micro and one macro) while the same instructor also teaches two other sections (one micro and one macro) where no internet tools are utilized. Rankin and Hoaas [2001] tests the effects of computer-generated slides within the classroom setting, whereas the online quizzes our paper uses are outside-the-class options.

The rest of the paper is organized as follows: the data collection process and outcomes are described in the next section followed by a presentation of the results. The final section concludes.

DATA AND VARIABLES

The data we use were collected during four semesters from Fall, 1997, to Spring, 1999, in an undergraduate Elements of Economics course. This is a one-semester survey course of microeconomics and macroeconomics, with sections taught each semester. The same instructor taught all of the sections during the period of this study. The students in the classes were primarily Caucasian sophomores (19-20 years old) who

lived on campus. Most of the students in the course were pharmacy majors who were taking the class as a required part of their program of study. All of the sections were taught in 50-minute periods at 9:00 AM, 10:00 AM, or 11:00 AM on Mondays, Wednesdays, and Fridays. The class sizes during the period of study varied from 39 to 48 with averages of 47.5 for the control group and 43 for the test group.

Beginning in the Spring 1998 semester, the instructor created a web page for the class that contained homework assignments, practice exams (which were exams given in the same course in previous semesters), answer keys, and interactive quizzes.[1] The interactive quizzes consisted of multiple-choice questions with four possible answers. The student could select a set of questions based on chapter number and concept. Questions answered correctly were followed by a brief explanation about why they were correct. More importantly, questions answered incorrectly were followed by more in-depth explanations about why the answers were not correct. The student could answer the question again. We wrote all of the questions, answers, and explanations. These online quizzes were provided only as a supplemental study aid for the students.[2] The instructor did not monitor students' performances on the quizzes or incorporate them into course grades.

Students were given access to the web pages and encouraged to use them. The instructor had previously placed old exams on reserve in the library. While we do not have data describing how many students used the sample tests in the library, anecdotal evidence suggests that the students felt they gained tremendously from this practice. That practice continued, but the web page expanded the locations where these exams could be found. Information obtained from end-of-the-semester course evaluations for two of the three semesters in the test group indicate that over 70 percent of the students used the web pages during those semesters. The addition of the web pages with the interactive quizzes was the only significant change in teaching practice or course materials that the instructor made during the four semesters of this study. The textbook and supplements available to students were the same each semester, and the teaching style of the instructor did not change.[3]

To test the effectiveness of the new web pages, the students were tested on basic economic concepts. Eleven multiple-choice exam questions were chosen to be representative of the important concepts covered and were included in the final exams for all four semesters.[4] Four of the questions came from the TUCE III exam; the authors wrote the remaining seven. These questions were not available to the students prior to the final exams, which were retained by the instructor each semester. The questions themselves remained the same over the four semesters, although we varied their order and placement in the final exam.[5] The final exam for each semester consisted of 60 percent multiple-choice questions and 40 percent essays or problems.

During the first semester (Fall 1997) of using these questions, the web pages were not in place. This semester is used as the control group. During the next three semesters, the web pages were used. The students' answers for the eleven common questions were recorded as well as their overall grades on their final exams. These questions were asked on the final exam during four separate semesters (8 different class sections total). From class rosters and university officials, data were also gathered on the students' gender, grade point average, chosen school (business, pharmacy, and so on), and verbal and mathematical scores on the Scholastic Aptitude Test (SAT).

TABLE 1
Variable Definitions

Variable Name	Variable Definition
TUCE	Number of student's correct responses on 4 multiple-choice questions that came from the TUCE III exam and were given every semester
MULTCHOICE	Number of student's correct responses on 11 multiple-choice questions that were given every semester
FINAL	Student's score on final exam out of 100 possible points
FEMALE	Dummy variable = 1 if student is female
SATV	Student's score on verbal section of Scholastic Aptitude Test
SATM	Student's score on math section of Scholastic Aptitude Test
GPA	Student's grade point average (out of 4.0)
PHARMACY	Dummy variable = 1 if student is majoring in pharmacy
COMPUTER	Dummy variable = 1 if student was enrolled during a semester where internet applications were available and use encouraged

TABLE 2
Descriptive Statistics

	Control Group			Test Group		
Variable	**n**	**Mean**	**Std. Dev.**	**n**	**Mean**	**Std. Dev.**
TUCE	91	2.68	1.04	244	2.70	1.12
MULTCHOICE	91	8.22	2.05	244	8.27	2.04
FINAL	91	79.19	12.11	244	81.76	11.60
FEMALE	91	0.62	0.49	244	0.63	0.48
SATV	91	531.98	96.15	244	548.20	79.36
SATM	91	555.82	93.98	244	573.61	74.86
GPA	91	3.09	0.49	244	3.20	0.49
PHARMACY	91	0.76	0.43	244	0.78	0.42

The data set contains 335 observations with 91 in the control group and 244 in the test group. Table 1 defines the variables, and Table 2 provides descriptive statistics for the control group and the test group. Observations with missing data were omitted. From the descriptive data, we can see that the students in the test group have higher SAT scores and grade point averages than students in the control group, but the differences are not statistically significant.

The descriptive statistics for the variable *COMPUTER* are not reported in Table 2 because the mean value for the control group is 0, and the mean value for the test group is 1. When combining the two groups, the mean value for *COMPUTER* with 335 observations is 0.73 with a standard deviation of 0.45.

EMPIRICAL ANALYSES

In our analysis, we estimate three models: one with the score on the four TUCE questions that appeared in common on the final exams for all of the sections as the dependent variable, one with the score on all eleven of the multiple-choice questions that appeared in common on the final exams for all of the sections as the dependent variable, and one with the overall score on the final exam as the dependent variable. We test whether the supplemental web pages affect student learning by including a dummy variable (COMPUTER) equal to 1 in the semesters where students had access to the web pages and were encouraged to use them. Our model is based on the one used by Agarwal and Day [1998]. A primary difference is that the internet variable in their model reflects student use of email and the World Wide Web while our focus is on online quizzes and practice exams.[6]

We expect that student characteristics, such as score on the math section of the Scholastic Aptitude Test (SATM) and grade-point-average (GPA), will be positive predictors of students' scores while *FEMALE* is likely to be a negative predictor.[7] We expect that being a pharmacy major (*PHARMACY*) will also be a positive predictor of student performance since this program is more competitive and rigorous than others at the institution where the study took place. Even after controlling for student ability, the pharmacy students may be more committed to doing well or may have better study skills.

Table 3 presents the results of the ordinary least squares (OLS) estimation on the TUCE questions, Table 4 presents the results of the OLS estimation on the full set of common multiple-choice questions, and Table 5 presents the results of the OLS estimation on the final exam.[8] Our results show that the web pages are not a significant determinant of student performance on any of the test instruments. This raises the question whether using technology is worthwhile. We should be careful, however, because the students in our sample were generally academically stronger students—with statistically significantly higher GPAs and SAT scores than a similar sample of business majors at the same university during the same time period. These students may have already had relatively good study skills without the technology, so the marginal benefit from the technology was lower for them than it might have been for students who were not as good academically.

As expected, student abilities as measured by the score on the mathematics section of the Scholastic Aptitude Test and by grade point average as well as a major in pharmacy are the strongest predictors. Using a one-tailed test, all three of these variables are significant at the .05 level in all of the models except in the TUCE model where *PHARMACY* is significant at the .10 level. Interestingly, being female negatively impacts performance and is significant at the .05 level in the TUCE model but not in the other two models. Although we have used only four questions from the TUCE and cannot draw a strong conclusion, the finding that females perform worse on TUCE questions is consistent with those of Agarwal and Day [1998], but not Ziegert [2000], where she finds that the gender gap in performance on the TUCE exam disappears after taking students' personality types into account.

TABLE 3
OLS Estimation
Dependent Variable: *TUCE*

Variable	Coefficient Estimate	*t*-ratio	*p*-value
COMPUTER	−0.124	−1.058	0.2991
FEMALE	−0.218	−1.996	0.047
SATM	0.002	3.143	0.002
PHARMACY	0.221	1.692	0.092
GPA	0.827	6.549	0.000
CONSTANT	−1.294	−3.124	0.002

R^2 = 0.26
Adjusted R^2= 0.25
n = 335

TABLE 4
OLS Estimation
Dependent Variable: *MULTCHOICE*

Variable	Coefficient Estimate	*t*-ratio	*p*-value
COMPUTER	−0.275	−1.388	0.166
FEMALE	−0.184	−0.992	0.322
SATM	0.006	4.556	0.000
PHARMACY	0.459	2.077	0.039
GPA	1.829	8.557	0.000
CONSTANT	−1.074	−1.531	0.127

R^2 = 0.39
Adjusted R^2= 0.38
n = 335

TABLE 5
OLS Estimation
Dependent Variable: *FINAL*

Variable	Coefficient Estimate	*t*-ratio	*p*-value
COMPUTER	0.346	0.373	0.709
FEMALE	−0.446	−0.516	0.606
SATM	0.024	3.757	0.000
PHARMACY	4.941	4.789	0.000
GPA	15.134	15.150	0.000
CONSTANT	15.826	4.827	0.000

R^2 = 0.60
Adjusted R^2= 0.59
n = 335

CONCLUSION

The authors create and utilize web pages and online quizzes to facilitate learning in a one-semester introductory economics course. The main benefits of our web pages are two-fold: they provide opportunities for students to work independently outside of class with access to course material at any time of day, and they allow students to obtain additional feedback from their instructor through the explanations of correct and incorrect answers on the quizzes. The technology was provided to students as a supplemental study aid.

The results show that adding this type of technology does not increase student performance on multiple-choice questions on the final exam or on the overall final. A summary of results from using TUCE data by Becker [1997] reports that pre-course abilities are generally the only positive and significant predictors of student success. In this work, pre-course abilities seem to be the strongest predictors of students' scores. We find that out-of-class use of technology does not increase student scores. Our findings do not coincide with those of Agarwal and Day where using technology increases student grades overall but do complement Rankin and Hoaas, who find that in-class use of technology does not increase student scores. Even though access to technological study aids does not improve student performance, it is possible that it improves students' attitudes toward the course, the instructor, or economics, in general. The teaching evaluation form used during each semester of this study, however, does not suggest such a benefit. The survey does not ask specifically about student attitudes, but average scores on the questions do not differ noticeably among the semesters included in this study.

These results raise the possibility that using technology is not worthwhile (for the students) in spite of the money and time spent encouraging their use. Since three-fourths of the students in our sample were in a highly competitive program, however, they may have simply substituted web pages for other study aids without an overall gain. Future research should examine the effects of the technology on students with differing levels of abilities and preparation.

Our results do not suggest that all out-of-class, technological study aids will not improve student learning. An additional avenue for future research is to test the effectiveness of different methods of employing technology as a supplemental study aid.

NOTES

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1. The authors used AuthorWare by Macromedia to create the interactive quizzes. The financial assistance of a Hunkele Teaching with Technology Grant from Duquesne University is gratefully acknowledged.
2. These quizzes differed from the weekly, multiple-choice quizzes that were given in class during all four semesters of the study.
3. For each semester, there was a textbook (*Essentials of Economics* by Schiller [1996]) and an accompanying student study guide that were made available to students but not required. The

students were given the opportunity to purchase a course packet that contained copies of the instructor's transparencies. This was also not required.

4. Copies of the questions are available from the authors upon request.
5. The instructor made minor changes in the final exams in order to ask questions about the writing assignments which were different for each semester. However, the overall difficulty of the exams remained equivalent and no more than 10 percent of the questions were changed.
6. Another difference between the Agarwal and Day model and this one is that they included variables describing students' races and ages. We did not have these data available, but our classes were quite homogeneous with respect to these two variables—primarily Caucasian and 19-20 years old. These variables were not significant in the Agarwal and Day model.
7. See Becker [1997] for a discussion of the positive relationship between students' abilities and performance in economics and Dynan and Rouse [1997] for a discussion of the negative relationship between being female and performance in economics.
8. We included only SATM in the model because SATM and SATV were correlated, and SATM was a stronger predictor in our models.

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