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Online Homework for Agricultural Economics Instruction: Frankenstein's Monster or Robo TA?

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This paper describes the programming required for online homework, evaluates its use, and presents methods for student identification and for processing student input. Online homework applications were evaluated in a real class setting. Generally, online homework is cost effective for large classes that have numerous assignments and repeated usage. Online homework appears to increase learning through increased student study-time allocations. Students felt that online homework made course website interaction more productive. They also indicated that online homework increased their perception of the value of lectures and that its use in other courses would be welcome. All findings were highly statistically significant.

Key Words: computer-aided instruction, economics teaching methods, instruction cost effectiveness, online homework

JEL Classifications: A220, G130, Q100

Agricultural economics instruction is under stress. Connor identified some sources of this stress, including the continual tightening of instructional budgets, pressure to shorten graduation time, larger classes, a reduced faculty base, and stress on graduate programs resulting in fewer graduate teaching assistants. As a result, instructors are being asked to do more with fewer resources. This general tightening of available instructional resources, and, in particular, the reduced availability of graduate teaching assistants, has created pressure on instructors of large classes to utilize fewer graded homework assignments. Using the Internet to automate homework is one way to ameliorate the impact of declining instructional support.

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This automation is easily envisioned because it requires interactions similar to those which occur when the Internet is used for shopping, making airline reservations, or renewing professional association memberships. While envisioning is easy, implementation is difficult. Developing online homework is technically demanding, and it requires the developer to learn several different programming technologies and new programming languages.

This paper reports on the development and use of online homework in real class settings, and it has two objectives: The first is to describe the programming required to implement online homework. This description will provide an overview of the programming strategy, define and describe the programming technologies employed, and provide references to useful development materials. The intent is to give those with potential interest in developing their own online homework applications direction to the technologies and an assessment of the magnitude and complexity of the programming task. The second objective of this paper is to report students' evaluations of interactive online homework used in my courses. This evaluation will be based on student survey responses and on examination performances. The intent of this evaluation is to estimate the expected benefits from online homework in terms instructional time savings, more positive student attitudes, and enhanced learning.

Literature Review

Economics instruction has a tradition of utilizing the lecture format in what has been described as "chalk and talk" (Becker; Becker and Watts 1995, 1996; Vachris). Agricultural economics instruction also relies on the lecture format, although websites supplement nearly half of the undergraduate agricultural and resource economics courses taught in the western United States. (Dahlgran 2003). Half of these websites contain only course syllabi and instructor contact information, while the other half convey subject matter. The potential benefits of more sophisticated course websites include increased student learning and retention, increased perceptions of instructor effectiveness, more positive student attitudes toward the subject matter, and promotion of active student learning (Agarwal and Day; Simkins; Stephenson et al.), as well as instructional cost effectiveness (Dalgaard, Lewis, and Boyer; Lewis, Dalgaard, and Boyer).

Despite these benefits, many instructional applications of the Internet go unused (Goffe and Soskin; Ramstad; Vachris), most likely because of the time or technical expertise required for implementation (Molnar and Fields). Interactive online homework is one such underutilized application. It involves students accessing homework problems and submitting responses via the Internet. The server evaluates the responses and provides immediate feedback. While such interactive Internet applications are widely used, they were rarely found on agricultural and resource economics course websites (Dahlgran 2003).[1]

One obvious advantage of online, as opposed to traditional, homework is the reduction in the grading workload. More subtly, online homework permits beneficial instructional practices that are too costly to implement under traditional methods. For example, online homework can tutor the student when, based on feedback, the student is given the opportunity to refine his/her thinking and continue working on the problem. This application appeals to students' active experimentation learning-style preferences (Kolb). Another advantage of online homework is that each student can receive a unique problem set that is generated by invisible rules. This increases the likelihood that each student submits original work and shifts the focus from "the correct answer" to the correct solution process. A fourth advantage of online homework is that submission deadlines, required primarily for efficient grading of traditional assignments, can be relaxed, thereby permitting each student to choose his/her pace for study.

These pedagogical differences confound comparisons of online versus traditional homework and have led to a "groceries versus delivery trucks" analogy in the educational technology literature (Clark; Kozma; Ross). If traditional and online homework have identical pedagogical features, then the comparison of learning outcomes reflects the advantage of the Internet for materials delivery (i.e., better delivery trucks). However, if online homework has pedagogical features that are absent from traditional homework, then the comparison reflects differences in both the presentation medium and the pedagogy (i.e., better delivery trucks and/or better groceries).

[1] One exception is reported by Barkley and Haycock. Barkley also reports on online examinations. Homework-related Internet applications uncovered by the Dahlgran survey typically used the Internet to make assignments available to students, and responses were collected via e-mail. From the standpoint of programming, features, and capabilities, our model is more sophisticated and interactive than this.

Instructional cost effectiveness (Dalgaard, Lewis, and Boyer; Lewis, Dalgaard, and Boyer) is a more general method for evaluating online homework because it compares the delivery costs and total benefits of online versus traditional homework. Its applicability can be demonstrated with an example. Suppose we find that homework in general creates learning, but the increments from online and traditional homework are the same. Hence, there is no apparent benefit from online homework. However, if resource constraints mean fewer traditional assignments can be administered, then the online homework would have the advantage because of its greater usage. This example is most applicable to instructors with large classes, limited teaching support, and a desire to enhance student learning with supplemental activities. The important point is that instructional cost effectiveness considers resource costs and constraints as well as learning increments in evaluating instructional innovations.

Instructional support software such as Blackboard (Blackboard 2007a), Desire2-Learn (Desire2Learn), WebCT, or a locally developed template (O'Kane and Armstrong) can be used as the presentation medium for online homework. These solutions work well for grading multiple choice and true/false problems and for submitting essay and short answer problems to the instructor for grading. However, the general applicability of these systems constrains the tailoring of assignments to precisely fit specific instructional tasks (such as automated grading of numerical answers). These systems also require additional effort when shifting institutional support or market forces call for migrating materials to a different system.[2] To incorporate unique features, the instructor will have to write his/her own programs. The difficulty with this approach is that the computer programming is complex, requiring, like Frankenstein's monster, the stitching together of concepts from several bodies of programming. Hypertext markup language (HTML), JavaScript, the common gateway interface (CGI) specification, server-side scripting, structured query languages (SQL), the open database connectivity (ODBC) standard, and object linking and embedding (OLE) might all be required. Most instructors do not have ready access to knowledgeable computer programmers, and the time required for learning the programming concepts and writing the code is substantial.

However, once the programs are developed, their utilization resembles a robotic teaching assistant (Robo TA), one who endlessly grades homework and provides feedback, costs little to maintain, patiently accommodates active experimentation by many students, and generates individualized problems according to predetermined assumptions. Also, once developed, assignments are easily replicated because the core programs can be reused for additional homework assignments and other interactive instructional applications such as grade reporting to students, simulations, and online testing. Finally, the Robo TA can be precisely programmed to accomplish specific tasks.

Methods

Table 1 compares the traditional and online homework processes and shows that with online homework, server-side processing replaces the instructor's involvement. While the traditional process is well understood, online homework methods require additional explanation.

Each online assignment is presented to the student as an HTML document that includes a form (a section of HTML code that contains input fields for text or numbers, or other input devices such as dropdown menus, radio buttons, check boxes, or submit buttons). An example assignment is shown in Figure 1.[3] The student records responses in the input

[2] For example, Blackboard acquired WebCT in February of 2006 (Blackboard 2007b). While WebCT remains intact and supported, product development is under the Blackboard brand (Blackboard 2007c).

[3] Other assignments are available on the author's course websites (Dahlgran 2007a,b). Computer code that generates assignments is available upon request.

Table 1. Process Comparison: Traditional versus Interactive Online Homework

Traditional Homework	Interactive Online Homework
1. Student comes to class	1. Student logs on to course web site
2. Instructor distributes assignment	2. Student retrieves assignment from web site
3. Student composes and records answers	3. Student records answers in input fields
4. Instructor collects answers	4. Student submits answers via Internet
5. Instructor grades assignment	5. Server extracts responses and compares them to "correct" answers
6. Instructor records scores	6. Server records score
7. Instructor returns papers	7. Server communicates results back to student
	8. Student can return to step 3

fields. When completed to his/her satisfaction, the student passes the homework to the server by clicking the form's save/submit button. Submission runs a program on the web server (a.k.a. a server-side program), which extracts the student's responses, records them, computes a score based on discrepancies between the student's responses and the correct answers, and records the student's score in the course grade book. The results are communicated back to the student as an updated HTML document that shows the student's responses, indications of correctness, and the score attained. The student can revise and submit answers as many times as desired. This feedback makes the assignment interactive and corresponds to step eight under interactive online homework (Table 1). Grading-time requirements make this interaction infeasible under the traditional approach, while costless grading makes it feasible under the online approach.

Like traditional homework, online homework requires the submitter's identity. Rather than relying on a student-supplied identity with each submission, the user identification (ID)/password method is used because of its increased accuracy, its provision of access to all identity-dependent pages after identity is established, and students' intolerance of primitive Internet solutions. Identity checking occurs when a student clicks a link to any identity-dependent document and also occurs in each assignment to thwart anonymous access through the homework's Internet address.

Clicking a link to an identity-dependent document triggers a JavaScript subroutine that checks whether the student has logged on to the course website. If the student has logged on, then the document is loaded. If the student has not logged on, then the subroutine opens a window that prompts for the student's user ID and password. These are passed to a server-side program that queries the database of registered users. If the user ID and password match those in the database, then a log-on cookie is installed in the student's browser.[4] The cookie is identified by its name and contains the log-on status, the student's name from the users' database, and the user ID. Goodman provides JavaScript routines for manipulating cookies.

After log-on success, the homework assignment is generated by a server-side script that performs several tasks. First, the student's user ID and name are extracted from the cookie. Second, the student's current session responses are retrieved.[5] If current session responses are not available, then a database of previously submitted answers is queried for the current user and assignment. If a record is

[4] Cookies are small text files that a web browser writes and reads. Flanagan provides greater detail.

[5] The server's environmental variables are used to pass data between an HTML form and the web server. If these variables contain data, then the student has submitted the form in the current session. These values must be inserted in the proper fields if responses are to persist after submission.

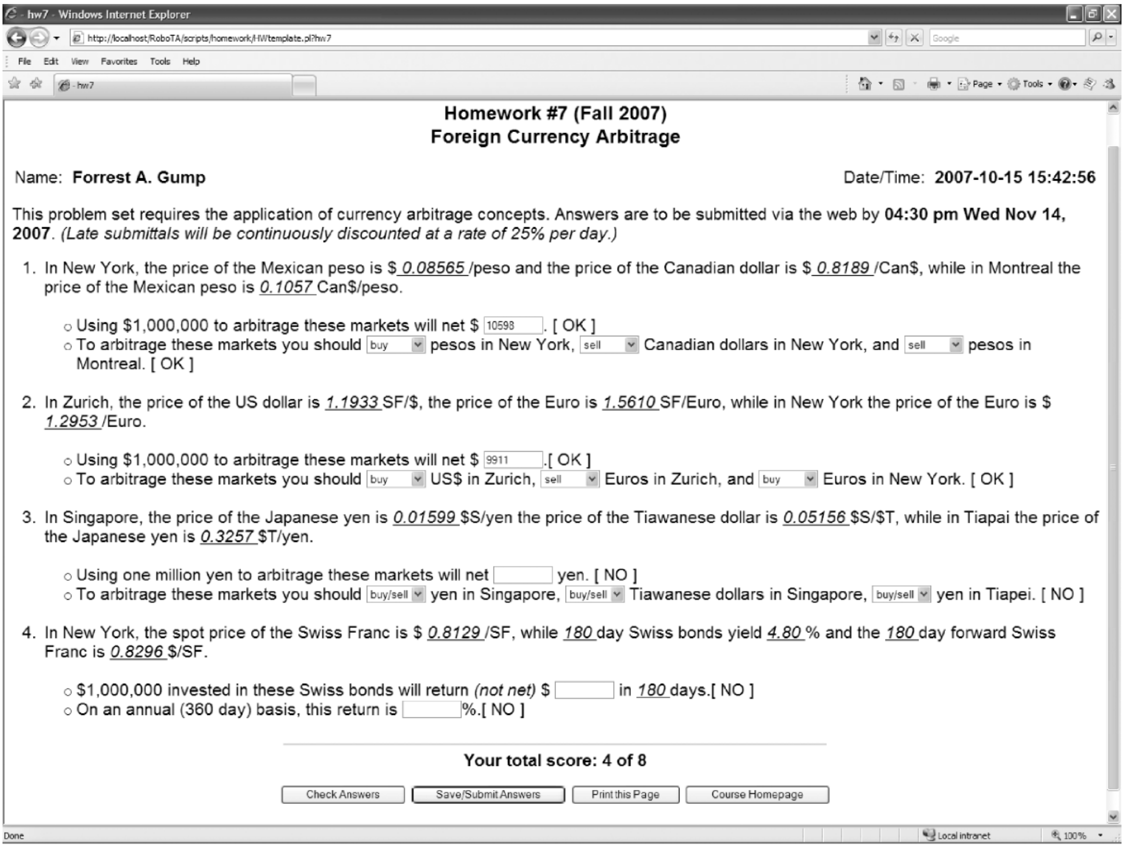

Figure 1. Example Interactive Online Homework Problem Set

found, then previously submitted responses are extracted for insertion in appropriate fields. Third, initial assumptions, correct answers, and the current score are computed. Finally, the assignment showing the student's name, previously submitted answers, and current score, is generated (Figure 1).

The student responds to the homework's input mechanisms (text fields, dropdown menus, etc.). The "Check Answers" button (Figure 1) allows the student to test responses for correctness, while the "Save/Submit Answers" button saves the work to the homework database. The submission process queries the homework database for a record matching the user and assignment IDs. If a record is found, then it is updated with the submitted answers. If no record exists, then a new one containing the user ID, assignment ID, score, time stamp, and submitted responses is created.[6] Submission also records the student's score in the course grade book.

Assignment development is expedited by the use of a template to perform operations common to all assignments (identity checking, loading previous responses, recording submissions, etc.). Individual assignments are contained in separate files and plug into the template as two subroutines. One generates

[6] Submitted answers are stored as a character string of the form var1 = val1&var2 = val2&var3 = val3 . . . . This general format accommodates any type and amount of form data and is easily administered because assignment-specific tables with unique fields for each variable are not needed. If the student later resumes working on an assignment, then previously saved values are retrieved by querying the homework data table for the user and assignment IDs, retrieving the character string, and splitting the string first on the '&'s, then splitting each item in the resulting list on the '='.

the assignment's HTML document, while the other scores the assignment. This design allows assignments to be composed with an HTML editor. The resulting document is captured for output by the assignment-generating subroutine.

Interactions between the student's browser and server databases require two interfaces: first, data are passed from the student's browser to a server-side program, and then the data are passed from the server-side program to the database. Data are passed from the student's browser to the server-side program through the common gateway interface (CGI) specification (Castro; Meltzer and Michalski). Server-side programs can be written in Perl, PHP, Microsoft Visual Basic, or Microsoft Visual C#, since all have modules for accessing CGI data. Perl and PHP are public domain scripting languages that are widely used for web applications (ActiveState; Perl; PHP). They are versatile, easy to learn, and well documented (Schwartz and Phoenix; Wall, Christiansen, and Orwant). The Microsoft languages are part of the free Microsoft Visual Web Developer 2005 Express Edition (Hart et al.; Lowe; Microsoft). My programs use Perl.

The general form of the server-side program database interaction consists of a server-side program that connects to the database then manipulates it with structured query language (SQL) commands. These commands use the value of variables in the server-side program to select, add, delete, or update database records. Data can be extracted from the database by selecting records and then assigning the values of the fields to program variables. The specific commands depend on the combination of the server-side program's language and the relational database management software (RDBMS).[7] For example, Microsoft Access data are accessed using the Perl Win32 ODBC (open database connectivity) module or the Win32 OLE (object linking and embedding) module (Dubois; Roth), while MySQL data are accessed using the Perl DBI (database independent interface) module.[8]

Finally, the web server must be configured to grant Internet users permission to read from and write to databases and to execute the server-side programs.

Evaluation

The previous section focused on how online homework works. The normative issue of whether online homework should be used is examined here by considering its costs, benefits, and changes in learning performance and student attitudes. This evaluation is based on my use of online homework in an upper-division undergraduate course on the economics of futures markets and an introductory graduate-level course on econometrics. Recent average enrollments in these courses are 100 and 22 students, respectively. The courses incorporate fourteen and ten online homework problem sets, respectively. These problem sets are well suited to Internet submission and grading because correct numerical answers indicate mastery of price relationship concepts (futures markets) or computational procedures (econometrics).

Cost effectiveness of online homework is evaluated by comparing instructional time requirements for online versus traditional homework. Online homework requires additional development time when compared to traditional homework. This report and its cited references might reduce development time but development time for online homework will exceed that for traditional homework. This additional development time must be incurred either directly by an instructor or indirectly by an instructor/programmer team. The primary benefit of online homework is the elimination of grading time. For traditional homework, grading time is directly related to class size, the number of assignments, the length of the assignment, and the type of the

[7] I have used both Microsoft Access and MySQL. Access is part of the Microsoft Office (Professional) suite, and MySQL is a public domain RDBMS application (MySQL).

[8] These modules are available for free download from the Active State website.

assignment. To illustrate, assume the following:

1. An initial time investment (Π_0) is required to learn the programming concepts and develop an overall programming structure that includes top-level web pages, databases to contain results, database query routines to store and retrieve data, and a template for the assignments.
2. Development time for assignment i is incurred only once and is Π_i if the assignment is presented online versus π_i if the assignment is presented by traditional methods.
3. Grading online homework requires no time, while grading assignment i presented by traditional methods requires γ_i minutes per student, and N_t students are in the class offered at time t.

Under these assumptions, the comparison of instructional time required for online versus traditional homework becomes

$$(1) \qquad \Pi_0 + \sum_{i=1}^{n} \Pi_i \text{ versus } \sum_{i=1}^{n} \pi_i + \sum_{t=1}^{m} \sum_{i=1}^{n} \frac{N_t \gamma_i}{(1+r)^t},$$

where n is the number of online homework assignments developed, m is the time horizon for their use, and r is the instructor's discount rate. This comparison indicates that online homework is favored with lower instructional time requirements when class sizes (N_t) are large, grading a traditional assignment is time consuming (γ_i is large), assignments (n) are numerous, the instructor's discount rate (r) is small, and many uses (m) of the assignment are anticipated. For assignments with numerical answers, γ_i increases with the complexity of the formulae applied. The instructional time comparison capitalizes traditional homework grading-time costs over subsequent uses. Grading-time requirements are not capitalized for online homework because they are zero. This difference is important to younger instructors who have longer instructional time horizons (m).

To illustrate the magnitude of the time commitments involved, I estimate that eight weeks were required to master the programming concepts and develop the first online homework, two weeks were needed to develop the second homework, and one week was needed to develop each of the other twelve assignments used in my futures markets course. Thus, total development time was 880 hr. I have used these assignments for seven years (2000 through 2006) for classes of 100 students for a total of 9,800 assignments (7 yr $\times$ 14 assignments $\times$ 100 students). If we ignore the discounting, then we can conclude that, if on average, these assignments could have been collected, graded, recorded, and returned in 5.4 min or less per assignment (880 hr/9,800 assignments), then the traditional homework method has the advantage. Further break-even time reductions will occur with continued use of these assignments.

This analysis ignores pedagogical differences between online and traditional homework. For example, my econometrics homework requires students to compute numerous statistics including averages, variances, correlations, regression estimates, standard errors of regression estimates, predicted values, standard errors of the prediction, and confidence and prediction intervals for two variable and multiple regressions. Each student provides and analyzes his/her own sample data. This approach has the advantage that when students confer, attention is directed to the correct procedure, rather than the correct answer because each student's correct answer is different. Attention so directed by conferring students is beneficial because learning the procedure is the educational objective. Grading student-specific homework under the traditional method would require working each student's homework to determine the correct answers prior to grading the student's homework. This approach is clearly not feasible because of its computational burden. However, it is costless under online homework as each student's correct answers are computed by the server-side program prior to scoring the student's submission. Also, the quality of student learning derived from continued experimentation directed toward obtaining a correct answer likely exceeds the learning

Table 2. Relative Frequency of Student Responses to Evaluative Survey Administered in Economics of Futures Markets Course

2005 survey, 64 respondents	More	Responses No More/ No Less	Less	Chi Square[a]
The OLHW[b] assignments caused me to spend _____ total time on the course than I would have spent if they had not been used.	75.0%	21.9%	3.1%	53.38*
The OLHW problems caused me to learn _____ from this course than I would have learned if they had not been used.	71.9%	23.4%	4.7%	46.16*
The OLHW problems made class attendance ______ worthwhile than it would have been if they had not been used.	70.3%	25.0%	4.7%	43.34*
2001–2005 survey, 440 respondents		**Agree**	**Disagree**	
The HW assignments were made more difficult by the use of the Internet.		14.1%	85.9%	226.95*
The OLHW assignments helped me understand the material presented in lecture.		89.1%	10.9%	268.95*
OLHW assignments should not be used in any course.		11.4%	88.6%	262.73*

[a] The chi-square statistics test for a uniformity of responses.
[b] Online homework; not abbreviated on questionnaire.
* Indicates that the probability of a greater chi-square if responses are uniformly distributed is less than 0.0001. The chi-square statistic has two degrees of freedom for the first three items and one degree of freedom for the last three items.

derived from unknowingly submitting an incorrect answer under the traditional method.

To determine students' attitudes toward several course features, I administered an evaluative questionnaire in the futures markets course at the end of each semester.[9] Questionnaire items and responses pertinent to online homework are summarized in Table 2.

To assess the impact of online homework on the student's time devoted to my course, I included in the 2005 questionnaire the multiple choice item "The online homework problems caused me to spend (a) more, (b) no more/no less, or (c) less total time on this course than I would have spent if they had not been used." Three times as many students reported spending more time on the course than reported spending less or the same amount of time (Table 2). This difference is highly significant; the probability of a greater chi-square (two degrees of freedom) is less than 0.0001, so we conclude with 99.99% confidence that online homework causes students to spend more time on the course.[10] To ensure that students were using their online homework time productively, I asked for responses to "The homework problems were made more difficult by the use of the Internet." Eighty-six percent of the 440 respondents for the 2001–2005 courses disagreed with this statement. This level of disagreement is also statistically significant as the probability of a greater chi-square (one degree of freedom) is less than 0.0001.

Does learning increase because of students' increased allocation of time to the course? Examination results from my economics of futures markets course taught in the fall semesters of 2000 through 2005 are used to address this question. Each offering used three

[9] The evaluation survey uses many of the same procedures as the online homework assignments. It exemplifies the versatility of the procedures described.

[10] The methods for this and subsequent chi-square tests are presented in Snedecor and Cochran (pp. 228–56). The null hypothesis is that the data are distributed uniformly among the cells (i.e., that responses are unrelated to the classificatory variables).

Table 3. Homework Score versus Response on Related Examination Items, Fall Semesters 2000–2005[a]

Student Response to Examination Item:	Related Homework Assignment Score[b] 0%	1%–49%	50%–99%	100%	Total
Incorrect	56.3%	53.4%	47.8%	36.2%	45.0%
Correct	43.7%	46.6%	52.2%	63.8%	55.0%
Count	2,158	1,069	2,384	4,529	10,140

[a] Seven homework assignments, seventeen homework-related examination questions on three different examinations (depending on year), and approximately 100 students per offering.
[b] Percentages are of column counts.

multiple choice examinations with a total of eighty items. An average of seventeen of these eighty items related directly to concepts covered by online homework. Examination items were rarely duplicated for subsequent use. Table 3 relates each student's examination item performance (correct or not) to online homework performance. This table shows that students who did not participate in online homework were least likely to respond correctly to related examination items and that the likelihood of a correct response increased with the homework score. This relationship is statistically significant; the probability that a chi-square random variable with three degrees of freedom is greater than 291.47 is less than 0.0001. This indicates with 99.99% confidence that online homework participation is associated with learning the homework concepts.

To control for each student's grade point average, which is positively related to both the probability of correct examination responses and homework scores, a probit model was applied to the data summarized in Table 3. For each of the seven assignments, related examination item responses were combined to get an average score for each student for the examination items related to each assignment. Estimation results based on 3,514 available observations are

$$EXAM_{ijt} = \Phi\Big(\underset{(0.108)}{-0.745} + \underset{(0.040)}{0.216}HW_{ijt} + \underset{(0.029)}{0.394}CGPA_i + \sum_{j=1}^{7}\hat{\varphi}_j HW_j + \sum_{t=0}^{5}\hat{\delta}_t SEM_t\Big), \quad (2)$$

where Φ is the cumulative normal probability function[11], $EXAM_{ijt}$ is the proportion of the examination items relating to homework j correctly answered by student i during semester t, DHW_{ijt} is the proportional score attained by student i on homework j in semester t, $CGPA_i$ is student i's cumulative grade-point average, DHW_j is a dummy variable representing homework assignment j ($j = 1, 2, \ldots, 7$), $\hat{\varphi}_j$ is the estimated effect of homework assignment j on $EXAM_{ijt}$, SEM_t is dummy variable representing course offering (fall semesters, 2000 through 2005), $\hat{\delta}_t$ is the estimated effect of course offering on $EXAM_{ijt}$, and the estimated standard errors are in parentheses. As expected, we observe a positive relationship between exam scores and homework scores while controlling for *CGPA*. All effects are again significant at a 0.0001 probability level. These results indicate that, on average, across all assignments and semesters, the average student ($CGPA = 2.81$) who fully completed the online homework increased the probability of correctly responding to examination items related to that homework from 0.516 to 0.598.[12] This response is significant but smaller than that shown in Table 3 because Table 3 does not control for the relationship between *CGPA* and *HW* scores.

[11] Probit estimation is used because $EXAM_{ijt}$ is a proportion with frequent occurrences of both zeros and ones (Greene, pp. 662–71; SAS Institute, pp. 3225–316).

[12] Greene (p. 664) showed that for the probit model where $E[y|\mathbf{x}] = \Phi(\mathbf{x}\boldsymbol{\beta})$, then $\partial E[y|\mathbf{x}]/\partial \mathbf{x} = \phi(\mathbf{x}\boldsymbol{\beta})\boldsymbol{\beta}$, where Φ represents the cumulative normal distribution function, $\mathbf{x}$ represents explanatory variables, $\boldsymbol{\beta}$ represents unknow parameters, and ϕ represents the standard normal density function.

If students do not perceive a connection between assignments and learning, then they will view assignments unfavorably. Students' perceptions of the learning attributed to online homework was assessed by the 2005 survey item "The online homework caused me to learn (a) more, (b) less, (c) no more/no less from this course than I would have learned had the homework not been used." Seventy-two percent of the respondents believed they learned more because of the online homework. This proportion is significant beyond the 0.0001 probability level.

Favorable student attitudes toward online homework influence attitudes toward lectures as well. Two questionnaire items measured this effect. Eighty percent of the students who responded to the 2001 through 2005 surveys agreed with "The online homework helped me understand the material presented in lecture." This level of agreement is statistically significant beyond a probability of 0.0001. In addition, of the 64 students who responded to the 2005 survey item "The online homework made class attendance (a) more, (b) no more/no less, (c) less worthwhile than if they had not been used," 70% indicated that they felt that online homework made lecture attendance more worthwhile. Improved student attitudes toward lectures benefit both the instructor and the students.

As a final evaluative point, the surveys administered in 2001–2005 asked students to respond to the statement "Online homework should not be used in any course." Eighty-nine percent of the students disagreed with this statement. This level of disagreement is highly significant; the probability of a greater chi-square is less than 0.0001. These responses indicate the potential for increased use of online homework.

Summary and Conclusions

This paper describes the programming required for online homework and documents its benefits. The description of the programming is purposefully broad because a variety of programming languages can be used. Some alternatives are presented. The central challenges are accurately identifying the student in a network environment where users are by default anonymous and taking student responses from the browser to a permanent data repository. This discussion distinguishes between client-side (the student's web browser) and server-side (the web server) processing because this distinction is critical in the development process. Instructors can use this discussion to focus more quickly on the tools needed to develop online homework that fits their needs. Once mastered, the programming techniques described can be adapted for other interactive Internet-based instructional applications such as surveying, testing, creating simulations, and reporting grades or progress.

My second objective was to evaluate online homework as a teaching and learning tool. One possible evaluation compares online homework with traditional homework. If both approaches have identical features, then this comparison simply evaluates the Internet as a presentation medium. But, the online homework described in this paper performed tasks that were too costly to replicate with traditional homework. In this case, a comparison of online versus traditional homework reflects the combination of the medium and the additional capabilities of online homework. Further, mimicking the online homework capabilities with traditional homework is not feasible, and mimicking traditional homework in an online environment for the purpose of comparison is not interesting because such a comparison discards the most useful features of an online application. As a result, the comparison presented here best reflects differences between online homework as implemented versus no online homework.

The evaluative results demonstrate the potential cost effectiveness of online homework. In general, cost effectiveness requires the increase in development time to be offset by a reduction in grading time. This offset requires lots of student exposures, which are more likely to be available for large classes that have many homework assignments and many offerings of the same course. Online homework also works best when numerical or one-word answers are required. Student evaluations of online homework were favorable. These favorable evaluations were statistically significant. Students indicated that online homework caused them to spend more time on the course and that the use of the Internet did not hinder their efforts. The evidence indicates that online homework enhanced student learning, and students perceived likewise. Students also indicated that online homework increased their perceptions of the value of lectures and that the online approach could be applied profitably in other courses. All of these findings were unambiguous.

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