

Automated Homework in Electrical Engineering Technology

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Abstract

The purpose of this study is to analyze the effectiveness an Asynchronous Learning Network (ALN) approach to homework has on student performance by providing immediate feedback. Providing immediate feedback is an important part of reinforcing desirable behavior³. This project replaced the manual homework in the first semester Electrical Engineering Technology circuits course with problems generated, administered, checked, and immediately graded over the World Wide Web. The results were displayed on the student's screen allowing drill and mastery learning in a non-judgmental mode.

There is an increasing amount of research directed at the affects of interactive web-based learning. The ALN teaching method provides the students with access to the assignments at any time. This allows students to work at their own pace, on their own time, and to receive instant feedback about their understanding of the subject matter. This study assesses the effects of students' overall performance, when using an interactive homework web site as compared with traditional manually performed and manually graded homework.

I. General Background

All students entering Electrical Engineering Technology at West Lafayette and each of the five Purdue State Wide Technology locations take EET 107, Introduction to Circuit Analysis, the first semester. It lays the technical and instructional foundation for a tightly integrated series of six courses, involving at least twelve faculty across the state. It establishes the foundation of information and expectations upon which all remaining courses rely. Students must finish with a high level of knowledge, good work habits, self-confidence and an excitement for the material. Failure often means that the student decides to leave both the department and the university. For these reasons it is paramount that every effort be made to make the students successful, day-by-day.

II. The Instructional Problem

Traditional methods of assigning and completing homework do not provide immediate feedback to the students. Complete and rapid feedback is critical for students new to college, approaching a highly computational subject that is considerably different from material studied in high school. Immediate feedback allows instant correction of mistakes and it reinforces the correct techniques that the student is using, building success upon

success¹. It motivates the learner to try more and harder problems. It fosters the “I can do this!” attitude that is critical to keep new students in class and at Purdue.

However, the best traditional approach is to assign homework on Tuesday, the student works it late Wednesday night (long after any help is available), submits the work on Thursday, it is *sampled* by a student grader and returned the following Tuesday (or later). *If* a mistake is even discovered, the fact that there was an error is not returned to the student for at least a week. During that intervening week, the student has continued to apply the incorrect technique to subsequent problems. This wrong practice has just made the learner good at doing it wrong. Or worse, the young student has decided that he or she cannot work those problems and becomes discouraged about the course, the curriculum, college, etc⁴.

III. The Instructional Solution

The traditional, end-of-the chapter, paper-and-pencil problems were replaced by a data bank of problems administered over the World Wide Web by one of the School of Technology’s web servers. The questions may include traditional word problems supported by schematics done in Visio™ and photographs taken with a digital camera. Central to this project is that the questions contain randomly generated, realistic *numerical* problems, with answers that the server *computes*. When a student logged onto the WWW site, and requested to work a particular homework set, a *unique* set of problems was created for each person.

Once the student solved a set of problems and entered the solutions, the work was immediately evaluated and the results printed on the student’s screen. Since the numbers in the problems are variable, the student was able to try other versions of the missed problem by requesting a new set of homework problems. Each time, the server created a new set of problems with new solutions, allowing drill and mastery learning. Final scores were submitted to the course instructor.

IV. Implementation

IV. i. Software

The software used for this project was Test Pilot™; a Java based authoring program developed at Purdue University. Figure 1 shows the opening page for the Test Pilot™ software. (Note: Test Pilot is currently in use at over 175 institutions worldwide. They range from commercial use in training to K-12 schools, community colleges and major universities in addition to Purdue. For information about purchasing Test Pilot you may e-mail the author Malcolm Duncan at wmd@Virtual-Indiana.com or go to the Test Pilot home page on the web at <http://www.clearcutsoft.com/TestPilot/>.)

Figure 1. Test Pilot™ opening page.



Test Pilot™ was selected because, at the time, it was one of only a few authoring programs that could handle real time numerical computation. Test Pilot™ offered many other features that were deemed necessary for this project. For example Test Pilot™ supports most forms of web based media. This is not to say that Test Pilot™ is the only or best program on the market. It was the most attractive at the time this project was initiated.

IV. ii. Approach and Start-up

There were two divisions of EET 107 offered on the West Lafayette campus during the Fall 1998 semester. One division was required to complete their daily homework exercises on the WWW site. The other division continued to complete their homework manually.

The overall approach was to author and publish on the web homework questions for the computerized homework section. These questions could be accessed from any computer with a modem and an Internet connection. The students accessed the homework, completed all the problems, and submitted their answers. Test Pilot™ graded their answers and returned their grade. Figure 2 shows the question and answer page for one of the homework sets.

Figure 2a. Example of a homework question as generated by Test Pilot™.

Homework #5: Introduction to Series Circuits (Practice)

The diagram shows a series circuit with a 15V DC voltage source on the left. Five resistors are connected in series: R1 (2.5KΩ), R3 (1.5KΩ), R5 (4KΩ), R4 (11KΩ), and R7 (11KΩ). An arrow labeled 'I' indicates the direction of current flow from the positive terminal of the source through the resistors.

1. Given the following resistor values for the circuit above:
R1 = 9k ohms, R3 = 10k ohms, R5 = 4k ohms, R7 = 11k ohms,
what is the total resistance?

Figure 2b. Example of answers to the homework as generated by Test Pilot™.

Test Pilot
Scored Responses

Thank you! Your test responses were successfully recorded by Test Pilot.
The following is an evaluation of your responses:

Tim Paull

Submitted on Tue Dec 29 10:26:21 EST 1998 from 128.210.138.249

Given the following resistor values for the circuit above:
R1 = `R1,2,15,1` k ohms, R3 = `R3,2,15,1` k ohms, R5 = `R5,2,15,1` k ohms,
R7 = `R7,2,15,1` k ohms,
what is the total resistance? (1)
42000 is correct.

It was first thought that limiting the submissions to five and selecting the best score would give students an opportunity to determine their weaknesses and rework the problems but not be penalized for learning the system. Due to limitations in Test Pilot™ and potential administrative nightmares, it was decided, at the final hour, that two separate pages be developed. One web page would have links to the practice homework sets and the other web page would have links to the recorded homework sets. With very few exceptions, both the practice and recorded homework sets had the exact same questions. There were several ways to accomplish this. First, Test Pilot™ has the capability of generating random numbers so even though the questions are the same, the students were given a unique set of questions each time they requested a new set of questions.

Another method of randomization was to develop several versions of a multiple-choice question and have Test Pilot™ pick only a few of the questions every time homework was requested. Figure 3 shows an example of the Test Pilot™ question design screen.

Figure 3. Test Pilot™ Question Design Screen.

TEST Pilot™

Design Prefs Pick Style Security Export New Delete

Response Type:

- Yes or No
- True or False
- Multiple Choice
- Text Box
- Formula
- Section Break

Text:

For the circuit above, what is the power dissipated by R5 if
R1 = 1k ohms, R3 = 1k ohms, R5 = 1k ohms, R7 = 1k ohms?

Group: 1 Check here to override default formatting: HTML

Media Image (Filename or URL) Supported: .au, .mid, .mov, .gif, .jpg

<http://www.tech.purdue.edu/Eet/Courses/eet107/TPJPEGs/HW5/6seriescircuit12>

Formula: $(\text{Math.pow}(15/((R1)E3+(R3)E3+(R5)E3+(R7)E3+14E3), 2)) * (R5)E3$

Points: 1

Precision: 1 margin of error percentage permitted from the correct answer

In the formula box, enter variable references in the following format:

The practice sets were setup to allow the students unlimited access. This means the students could work the problems until they felt they had mastered them. Then they could go on to the recorded set. As stated earlier, the recorded set of homework questions had the same problems as the practice page. However, the students could only submit their answers to the recorded set one time. The use of two separate web pages with recorded and practice homework questions turned out to be an excellent way to allow students the

practice they wanted while keeping the administrative problems to a minimum. The reason administrative problems were lessened is that the results could be downloaded from the WWW into a spreadsheet program for manipulation. The information given included but was not limited to time the homework was accessed, time it took to complete the homework, both the correct answers and the answers given by the student, the number correct, and the percentage.

There was a fair amount of up front time needed to get the project going. A graduate student worked full-time in the summer. Most of that time was spent learning the software. The rest was spent writing homework problems and preparing a set of instructions for the students on how to access and complete the computerized homework. There was quarter-time work scheduled for the fall. This turned out to be more like full time. However, this was a one-time investment. Most of the time was spent discovering and fixing problems with the software and answering students' questions. As the semester got under way it became obvious that the students needed a way to communicate their problems in addition to e-mail. A problem survey page was developed, using Test Pilot, so that the students would have a uniform method of reporting problems and so that the graduate student would have the information to answer their questions.

VI. iii. Pedagogy

There was intensive consultation among Professor Jacob (the lead faculty for the project); Professor Herrick (coordinator of EET 107) and the graduate student during May 1998 to establish the pedagogy; technical content, presentation style, and other problem set administration details. Items decided on were question structure, division of homework sets, length of homework sets, and how to handle the manual submitted supplemental homework sets.

IV. iv. Structure of Homework Sets

For continuity, it was decided to have the computerized homework question sets follow the syllabus that the manual homework students follow. Under that format, there was a set of homework due each class period that there was not an exam. For the most part, the homework sets coincided with the chapters in the text that was used². This was done to try to maintain as much continuity with the book homework students for accurate comparison at the end of the semester. Figure 4 shows the opening web page where the students selected a practice set of homework problems went to the recorded problems web page went to the problem survey to report a problem, or back to the 107 homepage.

Figure 4. Practice homework selection web page.

EET 107 Computerized HW Problems (Practice Only)			
Go To Recorded Homework Problems		Back to EET 107 Home Page	
Problem Survey			
	Monday (HW Due)	Wednesday (HW Due)	Friday (HW Due)
Week 1		Number Notation	Voltage Sources
Week 2	MLK Jr. Birthday	Resistance & Conductance	Power and Energy

Length of Homework

It was decided that each homework set should take the average student approximately 45 minutes to complete. This meant that the super bright students could be done much sooner, while others may struggle. This was about half the time the manual homework for that topic should take. The reason for the difference is that the computerized homework had to be completed all at once as opposed to the manual homework which could be worked on in pieces. Also, this allowed the computerized students to complete at least one set of practice homework before trying the recorded version. Since they had unlimited tries at the practice set without a grade being recorded, the students could even try a few questions at a time, working on individual problem areas.

IV. v. Question Structure

The question structure seemed simple at first. The earlier material was mostly foundation and required drill. Most questions were either theory, which lends itself to multiple choice, or simple one step calculations. However, as the semester went on, the material obviously got more intense. The biggest difficulty arose when it was required that students work on problems that had multiple steps. To handle this it was decided to set up a series of questions that was equal to the number of steps to an individual problem. For example, four questions were written for a four-step problem. The first question required the first and easiest step be performed. The next required that the first two steps be performed and so on. Since Test Pilot™ has the capability to generate random numbers, each question, while having the same look, was actually a new and unique problem meaning that the student needed to recalculate the first step to get to the next one. The biggest difficulty with writing these questions came when trying to determine a single formula to calculate the final answer to a multiple step problem. This took time reducing several formulas into one.

IV. vi. Supplemental Homework

There were several sets of supplemental homework that were written by Professor Herrick (course coordinator). Most of these did not lend themselves to being put on the computer. Also, it was felt that there was value in having the computerized homework students complete some pencil and paper homework. For this particular course the students need practice in drawing and modeling circuits. So, for all supplemental homework sets, the computerized students completed the exact same assignments as the book homework students. This accounted for 9 out of 35 homework sets or 25.7%.

V. Results and Analysis

Numerical data was collected throughout the semester plus a student survey administered at the end of the semester. The numerical data consists of the test grades, homework grades, and the final grades for both the manual and computerized homework sections. That data was then statistically analyzed using the two-sample t test based on the following hypothesis:

H_0 : Computerized Homework Mean (X) - the Mean of the Manual Homework Section (Y) = 0

H_a : Computerized Homework Mean - Manual Homework Mean \neq 0.

Table 1 shows the results followed by a discussion. The student survey will be summarized near the end of this paper.

	Computerized X BAR	S _X	Manual Y BAR	S _Y	Test Statistic	t Critical**	Significance
	BAR		BAR				
All Tests	84.12	4.667	80.24	5.5	1.423	\cong 1.62	No
Test 1	80.76	18.49	72.36	21.53	2.01	\cong 1.62	Yes
Test 2	84.76	17.46	75.04	22.59	2.32	\cong 1.62	Yes
Test 3	83.48	16.17	83.47	13.79	0.00	\cong 1.62	No
Test 4	90.87	12.71	85.90	14.34	1.71	\cong 1.62	Yes
Test 5	89.78	11.79	87.07	13.38	1.00	\cong 1.62	No
Test 6	79.68	16.89	79.36	19.45	0.08	\cong 1.62	No
Final Test	79.51	15.89	78.46	16.66	0.30	\cong 1.62	No
Homework	68.30	22.82	77.88	17.70	-15.58	\cong -1.62	Yes
Final Grade	84.92	11.38	84.75	11.15	0.07	\cong 1.62	No

Table 1. Statistical analysis of homework data collected for EET 107.

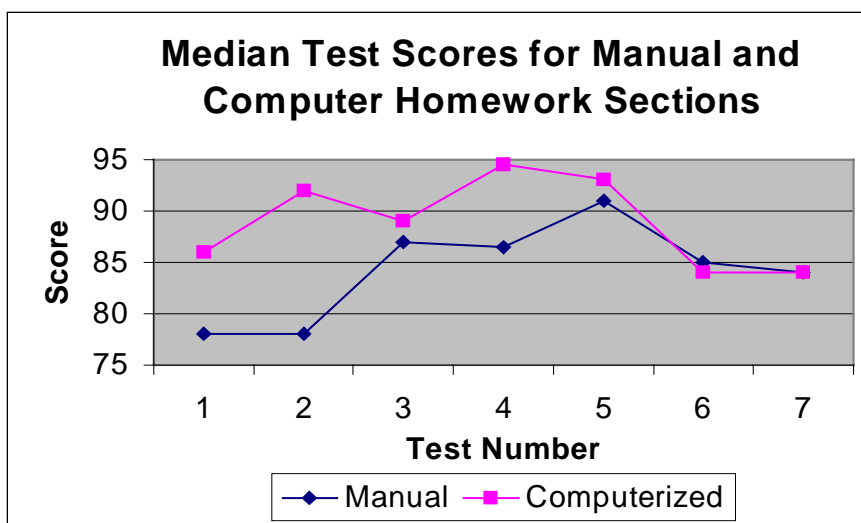
One thing we were looking for was if the computerized homework would improve the students overall grades. Since on the average the test grades were higher (this will be discussed in detail later) we felt that we should see some difference in their overall grades. This was not the case. As shown in the table above, the overall grades for the computerized and manual homework students were almost exactly the same. There was no statistical difference. Further study of the statistics reveals what we feel is the reason that the final grades were the same.

The computerized student's homework grades (X) were significantly lower than the manual student's homework grades (Y). The t score for the two sample t test was -15.58 putting it well into the critical area. The negative sign shows that the computerized homework grade was significantly *lower* than the manual homework grade. There is enough significance to reject the null hypothesis of computerized homework student's performance minus the manual homework student's performance is zero. The disparity in homework scores offsets the gains in average test score. There are two reasons for the disparity in homework grades. First, the computerized homework is 100% graded as opposed to the manual homework that is only spot graded. Second, there was no partial credit given on individual problems with the computerized homework.

There was some difference in the overall test grades for the two sections. However as shown in the table above, while the average test grade was higher for the computerized homework students than it was for the manual students, 84.12 vs. 80.24, they were not far enough apart to be considered statistically significant. That is, there is not enough statistical significance to conclude that doing computerized homework was any different than doing manual homework. Further study of the table shows that on the early drill and mastery type material, the computerized homework students performed statistically better than the manual homework students did. This is true for tests 1, 2, and 4 in particular. The other test grades were virtually the same for both the computerized and manual homework students. It should be noted that this is also the time that most of the supplemental homework sets were done. As stated earlier the supplemental homework was done manually by both the computerized and manual students. The trend in test scores also shows that as the material increased in difficulty, doing computerized homework as opposed to manual homework neither helped nor hurt the students.

The next question becomes, "Did the computerized students come down to the manual or the other way around?". Figure 5 below is a scatter plot of the median test scores for both the manual and computerized students for each test.

Figure 5. Median Test scores for both Manual and Computerized Homework Students.



For the first five tests the computerized scored better with the manual students catching up some each test. On test 6 both section scores went down. Since the students are allowed to drop one test, it has been Professor Herrick's (lead instructor for EET 107) experience that the scores for the last test are always somewhat lower than the other tests. A lot of students didn't study very much for it; they were gearing up for finals. If they were happy with the grade they had, they tended not to spend much time preparing for test 6. Finally, the scores for the final exam (test 7 in Figure 5) were almost exactly the same. It would appear that doing either computerized or manual homework had little impact on how students bring all the concepts together.

One weakness that showed up was that the computerized homework students had difficulty with proper form in doing the manual homework. This is important because like mathematics and/or the sciences, electronics has its own nomenclature, both verbal and written. Students must learn early the proper way to draw a circuit and label values with the proper units. The computerized homework section had difficulty with form, which may be a partial explanation of why their homework grades, especially their supplemental homework grades, were lower.

One major concern was, "Were the two sections of equal capability going into the semester?". After the semester was over, the graduate student enlisted the help of the counselor and obtained the mean and standard deviation of the SAT scores for the two sections. The mean combined SAT score (verbal and math) for the computerized section was 1050 while the manual homework sections mean was 1067. With a difference of 17 points, it is safe to say that the two sections were of equal capability.

VI. Student Survey

The students were given the surveys to complete after taking their final exam. There were 11 questions that asked them to rate different aspects of the computerized homework versus manual homework. They were given a scale ranging from 1 to 7 with 1 being extremely detrimental (to their performance) to 7 for extremely beneficial. There were then four informational questions and two questions allowing open discussion.

Several interesting viewpoints came from the surveys. With any new software package there are problems. Test Pilot™ was no different. We asked the students how they felt about doing homework on the Internet first based on their experience and then if there were no software glitches. Based on the results 84% ($\mu = 5.98$, $\sigma = 0.90$) of the students felt that doing homework on the Internet would be beneficial. Also, 80% ($\mu = 6.16$, $\sigma = 1.36$) felt that the practice page was beneficial.

There were some problems with Test Pilot™. For example, some students submitted correct answers but the formula handler in Test Pilot™ did not recognize their answers and counted them incorrect. All problem situations were handled on an individual basis and only accounted for approximately 1% of all responses. Given the early software problems, it's surprising that only 22.6% ($\mu = 3.75$, $\sigma = 1.64$) of the students felt that the software was detrimental. Finally 69% ($\mu = 5.00$, $\sigma = 1.99$) said that having done the

supplemental homework sets manually and the computerized homework, they would prefer to do the computerized.

In the comments section of the survey there were two items that showed up often. The student's biggest complaint was that the homework sets were too long. This is most likely because they were required to complete the recorded homework problems all in one sitting. Their major request for improvement was one-question-at-a-time capability. Since the newest version of Test Pilot™ will have one-question-at-a-time capability, the two main student concerns should have been addressed.

VII. Conclusions

The result we were looking for was that delivering homework via the Internet would improve student learning. For the drill and mastery material this was indeed true. And, while the other material did not yield the improvement in performance that we were hoping for, completing homework over the Internet did not hinder students learning. It is becoming absolutely imperative for universities to increase their distance learning capabilities. This study shows that the EET department at Purdue can provide the same quality homework to someone off campus as can be offered on campus. There is also evidence to suggest that if the supplemental homework sets could be spaced out, or computerized, there could be a real benefit to distributing homework via the Internet.

Finally, this study shows that students overall would prefer to do computerized homework, the results show that there is no detriment to doing computerized homework over manual, and there is a decrease in administrative time. As the software improves, the results should improve. With the decrease in administrative time, the instructional staff (professors, TA's, and graders) will have more time to work on improving the class.

VIII. Items for Further Study

There are several directions that this study will go. First, we will review what worked and didn't in EET 107 and make corrections as needed for the next semester. Also, there are currently four other courses in EET and two other School of Technology departments that plan to offer automated homework over the World Wide Web.

We have proven with this study that fundamentals can be effectively taught with the aid of on-line homework. The next semester will be spent identifying topics in other courses that can be put on-line. Next summer will be spent investigating ways to improve our effectiveness in the on-line multiple step problems. Also, during the summer of 1999, EET 257 (one of the courses in the same sequence as EET 107, the pilot course) homework will be put entirely on-line. As more testing software packages become available they will be evaluated to see if there is any benefit to changing software.

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Tim Paull has won the 1998 Outstanding Graduate Student Award for the School of Technology. He has also received the Outstanding Graduate Teaching Assistant award for the EET department at Purdue. While at East Tennessee State University working on his undergraduate degree, Tim was the Student Director of the Math Lab along with being presented several awards for academic performance.

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