TESTING AND IMPROVING EDUCATIONAL SOFTWARE

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Abstract

The Homework Laboratory® (HWL) is a CD-based educational tool for use in fundamental science and engineering courses. Capable of being used with virtually any quantitative course of study, it is intended to help students learn the course material in a more effective manner and to make the administration and presentation of the course easier for the instructor. The National Science Foundation sponsored a program for testing the software (using control and experimental groups of students) to assess its effectiveness at improving student understanding. The test program was conducted over a three-year period in engineering mechanics classes at The University of Texas at Austin (UT) and Tennessee Technological University (TTU). Also, in order to assess the modularity of the HWL (that is the ease with which new courses may be implemented) the software was modified and implemented in a high school statistics course.

This paper explores the implementation of the software in engineering mechanics courses at UT and TTU as well as in a high school statistics course. The use of the software and its effect on student tests scores are also discussed.

Introduction

Over the last decade, computer technology has been shown to be capable of effectively teaching, grading, and coaching students. For example in the early 90’s, the University of Pittsburgh in conjunction with the U.S. Air Force developed a successful and well-documented computer-based tutor for training electrical maintenance engineers[8]. By using hi-fidelity multimedia to present systematic, real world malfunctions, trainees were able to accelerate the building of expertise. Evaluation of the program indicated that 25 hours of training produced a level of expertise equivalent to a journeyman grade mechanic with four years of field experience.

Clearly, budgetary constraints as well as improvements in multimedia have been pushing universities toward more reliance on technological approaches[5, 6, 12]. Thus, the apprenticeship methodology for learning, emphasizing practice and often involving commercial software and other tools, has been shown helpful for students in fundamental engineering and/or science courses[11,7]. These courses typically involve the analysis of a process or system that is clearly defined and analytically repeatable. Therefore, an opportunity exists to test a student's ability to accurately demonstrate an analysis task, assess his/her mistakes, and provide pertinent instruction using an array of multimedia techniques. That is, the computer is capable of functioning as a tutor – constantly available – with the potential to increase the speed of the learning process and lengthen retention time.

The Homework Laboratory® (HWL) is a multimedia software package designed to implement the apprenticeship concept. As shown in Figure 1, the program randomizes the variables for each student's homework so that every problem set is different, grades each problem, coaches the student as necessary, and averages the grades for the professor at the end of the semester. The software also creates randomized and timed practice tests for the student based on the pertinent chapters of the

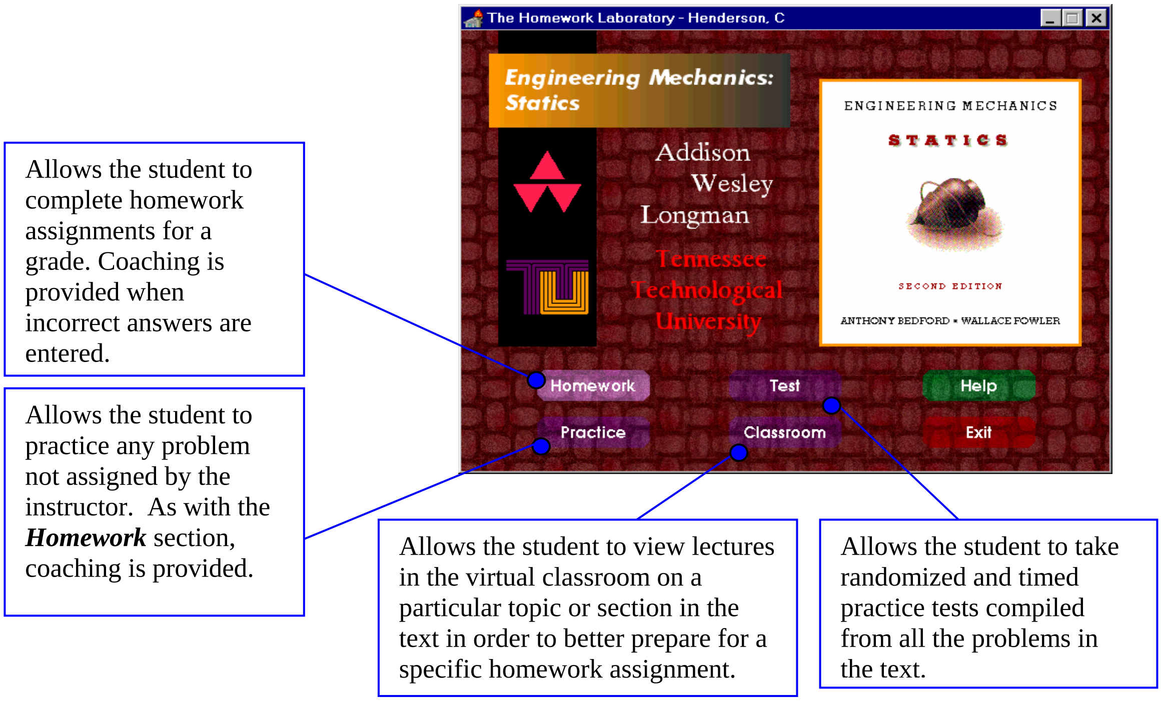


Figure 1. Student Version Main Screen.

assigned text and instructs the student in the virtual classroom.

The process of developing useful learning software consists of cyclic and interdependent phases, one of the most important of which is testing[9]. The National Science Foundation (NSF) funded a three-year research program to determine (and improve) the effectiveness of the HWL as an educational tool. Though the software is capable of being used with virtually any quantitative course of study, engineering mechanics was chosen for this research along with the textbook *Engineering Mechanics – Statics*[2]. The purpose of this paper is to document the results of the study based on four pedagogical objectives for the software:

1. **Versatile and easy to use:** Does the software provide intuitive navigation where required training is minimized and the subject matter is the focus? This objective was measured through student surveys.
2. **Effective at encouraging student learning:** Does the software improve student performance as measured by comparing test scores between experimental and control groups of students?
3. **Effective at helping the instructor teach:** Does the software provide a valuable system for the management (i.e., grading, coaching, and teaching) of a course for the instructor. This objective was measured qualitatively through instructor surveys and suggestions from study participants.
4. **Easily modified for new subjects:** Does the software effectively use modular construction techniques such that new subject areas may be incorporated easily? This objective was evaluated by a case study where the software was modified for statistics.

Ultimately, the intent of the research was to assess the degree to which the above objectives were accomplished. In order to create a meaningful assessment of any learning tool, cyclic implementation and assessment in a broad setting, consisting of diverse user groups, is required[1]. For this reason, the HWL was investigated at a moderate-sized university (Tennessee Technological University — TTU), a large university (the University of Texas at

Austin — UT), and in a high school setting (Monterey High School — MHS).

Software Implementation and Administration

The first step in the assessment process was successful implementation and administration of the software such that each course participant and the instructor were able to use it successfully and efficiently. The HWL was developed for the Windows operating system and was intended for use over a campus network as well as on individual PCs. The following is a description of the implementation and administrative process at each of the three participating institutions.

Tennessee Technological University: TTU has approximately 9,000 students with 1600 in engineering. There are six undergraduate programs in engineering and all except one requires students to take engineering mechanics. Most students take this course the first semester of their sophomore year. Generally, to accommodate the demand, three sections of engineering mechanics per semester are offered with up to 50 students each. A setup and installation protocol was developed using Install Shield® such that the network administrator at TTU could load the software from a central location for use in any of approximately 30 campus computer labs. Install Shield® was also used to allow students to install the software on their own computers. Delphi (Visual Pascal) was the programming language used to develop the HWL[3].

Before the student could access the program on the network or individual PC, the instructor distributed a file to the students containing the homework assignments. This file, called a student data file (SDF), was created using the instructor version of the HWL and was modified by the student version (i.e., updated to include worked assignments) each time a student used the software. At TTU, this file was posted on the instructor's web page and was downloaded by the students at the start of the semester.

As students completed their work (e.g., homework problems as shown in Figure 2, practice problems or practice tests), the instructor would periodically require the

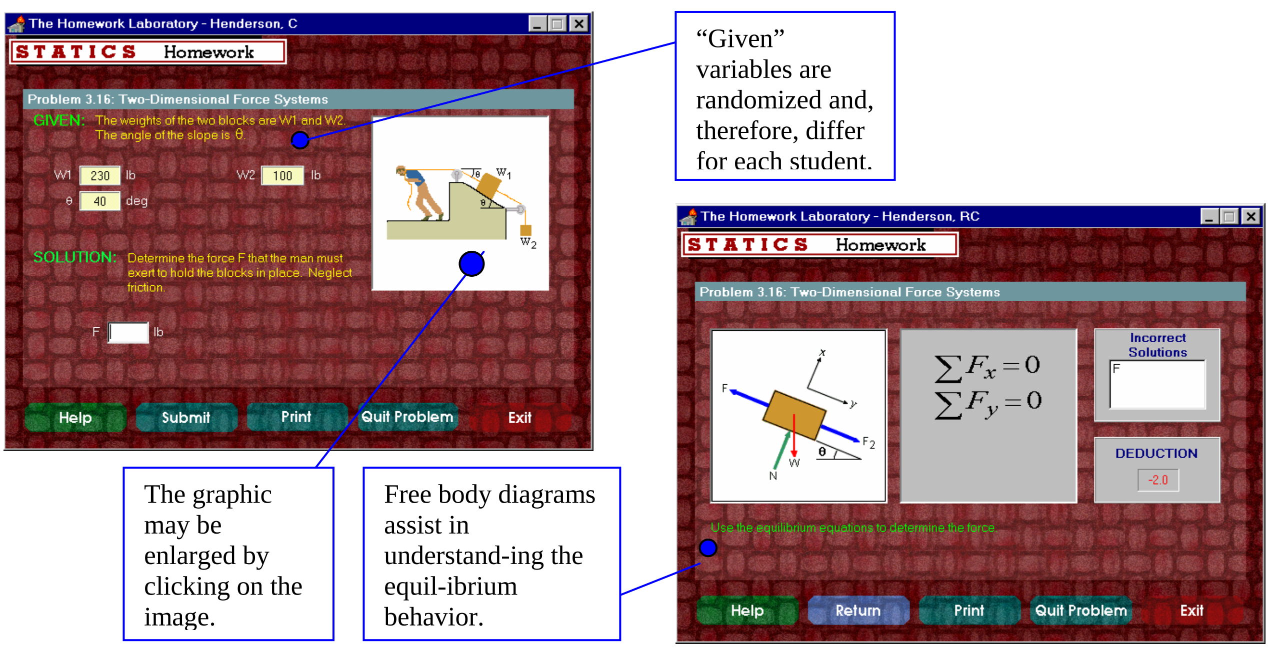


Figure 2. Homework Problem and Coaching Screen.

students to electronically submit their SDF by placing the file in a secure network location created by the network administrator upon installation of the HWL. The instructor would then use the instructor version to access the file and monitor student progress and grades either for an individual or an entire class.

The approach for testing the HWL was to have the same instructor teach one or more experimental classes and one or more control classes. Both the experimental and control classes had identical formats (i.e., same text, coverage, assignments, grading, lecture format, etc.) except that the experimental classes fully utilized the HWL for submission of homework (the virtual classroom, practice problems, and practice test functions were also available and encouraged), and the control classes followed a traditional homework approach (i.e., submission of problems on paper). Students in both classes were given similar tests (four per semester) including an identical fully comprehensive final exam. At the end of each semester, test scores and final grades for the experimental and control populations were compared. Modifications to the HWL were implemented each semester based on the overall findings, including student scores, student surveys, and instructor surveys. At the end of the test program, overall results were evaluated.

The evaluation of the software began with a pre-experimental group of students in order to test the network installation protocol, identify errors in the programming or delivery for the CD or network versions, and record and respond to student reactions to the software before the full experimental system was implemented. Following the initial trial, the test program consisted of a single instructor teaching sets of control and experimental classes over a two-year period as shown in Table 1.

Each semester, the software was loaded onto the campus computer system using a Windows platform and was available in all campus computer rooms. CDs were also available to students who wanted to use their own computers. Every effort was made to produce random populations (as a function of student ability) in all of the classes. This effort was later proven successful by the statistical comparison of entering grade point averages and pretest scores for each classroom population.

Table 1: HWL Implementation at TTU

Semester	Description	No. Of Students
Fall	Experimental 1	32
	Experimental 2	33
	Control 1	43
Spring	Experimental 3	20
Fall	Experimental 4	20
	Control 2	29
Spring	Experimental 5	16
	Total	193

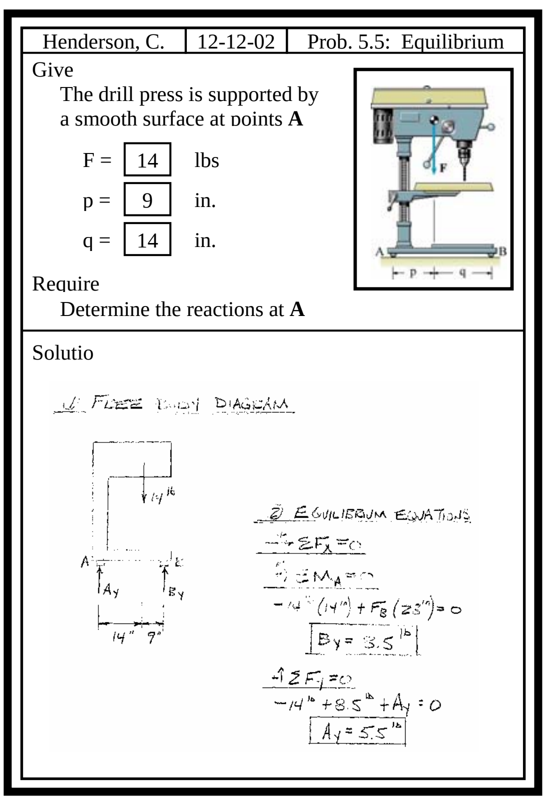
On the first day of each semester, the experimental classes were provided with a brief (15 minute) explanation of the HWL and were instructed to retrieve all remaining information about the process from the HWL web site (which contained step-by-step instructions and an interactive demonstration). The second day of classes a pretest was given in both the experimental and control classes covering a range of concepts in geometry, trigonometry, vectors, and calculus in order to assess incoming ability. By the third day, students were to have:

1. downloaded the generic SDF (Student Data File —created by the instructor using the instructor version; contains all assigned homework) from the HWL web site;
2. worked the first set of homework; and
3. placed the modified copy of their SDF (which included grades for the first worked assignment) in the "homework drop" location set up by the network administrator. [This network folder was accessible to each student for placement of a file, but only to

the instructor for copying or deleting files.]

Usually, after the first full week of classes, the experimental group was generally comfortable with using the software for each of its four main functions (see Figure 1). [Control classes submitted the same set of homework (from the text) on paper, and therefore, a similar initial learning curve was unnecessary.]

Although the HWL checks the numerical accuracy of the student's answers, hand calculations were also required of all students in the study. Figure 3 shows an example of the problem printout and a typical student response. The purpose of this submission was to allow the instructor to efficiently check the process. For example, enhanced proficiency and accuracy in the working of equilibrium problems is achieved by requiring each student to draw complete free body diagrams and solve the equilibrium equations in an orderly fashion, showing all units and clearly designating answers. The HWL affords the instructor a venue for quickly checking the student's work and supplies the student with a neat and organized set of worked problems at the end of the semester. [Student comments indicated that this feature was a favorite part of the software.] Every end-of-chapter problem in the text[2] was included in the software either in the homework section or the practice section (See Figure 1). [Any problem that was not assigned by the instructor appeared in the practice section. Coaching and grading in the practice section were identical to that for assigned problems, but did not affect the students' homework average. In the study, the instructor gave a list of acceptable practice problems to the students, and extra credit was given for each problem worked with a perfect score.]


Henderson, C. | 12-12-02 | Prob. 5.5: Equilibrium

Give
The drill press is supported by a smooth surface at points **A**

F = 14 lbs

p = 9 in.

q = 14 in.

Require
Determine the reactions at **A**

Solutio

Figure 3. Typical Problem Printout.

The University of Texas at Austin: UT is one of the largest universities in the nation, with approximately 5000 undergraduate engineering students and a total university population of approximately 50,000 students. There are five undergraduate programs in engineering, each of which requires students to take engineering mechanics during their sophomore year. Faculty in the Aerospace Engineering and Engineering Mechanics (ASE/EM) Department teach the course, and sections typically have between 120 and 160 students. Classes meet three times a week for a one hour lecture from the professor in charge and then the large class is broken into 4 separate discussion sections that meet two hours per week with a graduate student for discussion, problem solving, and quizzes. The HWL was used for four semesters in engineering mechanics with 440 students participating (Fall – 35; Spring – 120; Fall – 160; Spring – 125).

UT, like TTU, used the HWL web page as the primary vehicle for training students to use the software. An approximate one week introductory period was established where students would familiarize themselves with the approach, work some homework problems and submit them to the instructor. A pretest was given on the second day of classes. Following this, both hand solutions and electronic submission of the SDF were required on a weekly basis. UT used the same text and covered the same material as at TTU.

Primary variations between the two schools included choice of homework problems, grading scale, test content, and presentation format. Though the administration of the software at UT was, ultimately, very similar to that of TTU, differences in the two universities (e.g., class size, network setup, classroom procedures and schedule, etc.) made it necessary to transition into the most appropriate administrative approach over the course of the two-year project. Therefore, the software study at UT was by nature more qualitative than at TTU; yet, it provided essential data related to the applicability, efficiency, and functionality of the software for the large school environment.

Monterey High School: The HWL was used in an Honors Statistics classroom at Monterey High School (MHS). MHS is a rural public school in Monterey, Tennessee. The school teaches grades 7 through 12 with an enrollment of approximately 500 students. The purpose of the high school portion of the study was two-fold: 1) to determine the ease with which a new subject area (i.e., other than engineering mechanics) could be implemented and (2) to investigate how amenable a high school setting is for using the HWL as a learning tool.

In addition to the HWL staff of programmers, two high school teachers, two student teachers and one high school student were involved in the preparation and planning that preceded the implementation phase. The navigational and administrative portions of the switch involved replacing the problems database and modifying the graphical user interface (GUI) for both the student and instructor version. Fourteen students in the honors statistics course participated in the program during the final spring semester of the project.

Though the "look" and use of the software (from the students perspective) was very similar at MHS (as compared to UT and TTU), administration of the HWL was inherently quite different than in the two university settings. This was due in large part to the differing environments (local in-class machines vs. network installation), subject matter (statistics vs. engineering mechanics), and pedagogical approaches (small classroom vs. large lecture approach).

Results and Conclusions of the Study

As mentioned the purpose of the study was to investigate whether the software was:

1. versatile and easy to use;
2. effective at encouraging student learning;
3. effective at helping the instructor teach; and
4. easily modified for new subjects.

The results and conclusions for each of the stated pedagogical objectives are examined below.

Assessment of Versatility: Inherent in the success of any computer-based learning instrument is the ability of the target population (in this case students and teachers) to use the software in an effective/efficient manner. Over 600 students, six instructors, four network administrators, and a staff of approximately 25 graduate and undergraduate students were involved to some degree in direct and extended use of the HWL during the study (additional students and personnel on a more limited basis).

Near the close of each semester, an "end-of-experience" questionnaire was given to students attempting to qualitatively assess their experience using the HWL. Fifteen questions (covering such topics as software appeal, navigation, network problems, suggested fixes/additions, etc.) were presented to the students each semester. The three questions that were the most informative throughout the study were as follows:

1. Describe your overall impression (both positive and negative) of the software and concept as compared to the traditional way of submitting homework and preparing for tests.
2. If you had a choice from the instructor of using the HWL or submitting homework traditionally, which would you choose? Why (be specific and complete)?
3. If in the above question you chose the traditional method, how would you change the software or concept (if possible) for you to prefer it to the traditional approach?

Often, student reactions to a learning instrument provide clear indications as to the success of its implementation. In general students had fairly strong opinions about the HWL and computer-based learning approaches in general. Overall, students took their response to the questionnaire quite seriously, providing valuable feedback – both negative and positive. Negative aspects of the software, gleaned from student reviews over the two-year test period, include:

1. The HWL grades are based on correct answers with not enough credit given for the correct method.
2. The time required in learning to properly use the software at the first of the semester is exorbitant.
3. Weekly (rather than daily) submission of homework (SDF and hand calculations) may cause students to procrastinate.

Interestingly, in response to Question 2 (above), one student (who made an "A" in the class) responded:

> "[I would choose] submitting traditionally because in the case when I didn't have time to do the homework, I could always copy someone else's and not have to spend time teaching myself the material (Sorry, just being honest)."

The overall findings of the survey at TTU (conducted over the full two year test period) indicate that 67% of the respondents favored using the software over the traditional approach and 79% would favor the software if certain outlined modifications were incorporated. As expected, survey results improved over the course of the test period (most likely due to improvements to the software). The last semester had 75% of the students favoring the software without necessary changes and 83% favoring the software with modifications. The following student comments are indicative of some of the more positive aspects of the software:

> "I feel much more comfortable with the material after using it [the HWL], and the practice tests and problems were helpful. Also, the little bits of information provided after you initially got a problem wrong were excellent. The entire idea of being able to redo homework until you got a hundred on it was fabulous."

> "I think that the HWL is more efficient and (if used correctly) can save the students time and stress. I would choose for the instructor to use the HWL because I enjoy being able to do my homework at my house at 10:00 at night if I need to … it gives you feedback the moment that you submit your answer."

And one of the more interesting comments:

> "My impression of how the software was used was that I didn't like it, but it was good for me. It was kind of like that terrible tasting cold medicine … you have to take it to feel better. I would choose the HWL because I learned more from all my little mistakes than what I learned from practicing from the book. In the book, I could look up the answers, but in the program I had to figure out what I did wrong."

Assessment of Student Use: In addition to functionality, ultimately pedagogical tools must adequately convey the principles of the course material such that real learning occurs. The adequacy of the learning experience was measured in this study by comparing test scores (particularly the identical comprehensive final exam scores) and final averages for experimental and control groups of students at TTU. [The experimental group refers to those students using the HWL during this study. The control group refers to those students using the traditional approach.]

To thoroughly compare the response of the experimental and control groups (hereafter referred to as the treatment groups) to the corresponding learning approaches, the following questions were investigated and are answered herein:

1. Were the treatment groups originally equivalent in ability (entering GPA) before any treatment was administered?
2. Is there a difference in achievement (final examination scores and course grades) between the experimental group and the control group overall (i.e., regardless of GPA level)?
3. To what extent is achievement (without regard to treatment group) a function of ability (entering GPA)?
4. Is the difference in achievement between the experimental group vs. control group the same for students in different entering GPA groups or levels? In other words, does the HWL have a more significant effect on certain ability levels?

In Table 2 and Figure 4, the results of a one-way analysis of variance of entering GPA's are presented. The difference in GPA's between the experimental and control groups had a probability of .59 of occurring by chance. Therefore, the difference is not statistically significant. In fact, Figure 4 shows clearly that the GPA means for the experimental (homework group 1) and control (homework group 2) groups were very similar. Clearly, the experimental and control groups were equivalent at the beginning of the study. This answers question number one above and strengthens the remainder of the analysis considerably because it establishes that the groups, while not randomly assigned, were very similar before they received the statics course and homework treatments. Therefore, if they are different after a treatment is administered, it is safe to say the homework treatment caused the difference.

TABLE 2: ANALYSIS OF VARIANCE (Entering GPA)

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Homework	0.102	1	0.102	0.285	0.594
Error	66.494	185	0.359		

Note: Dep Var: GPA N: 187
Multiple R: 0.039
Squared multiple R: 0.002

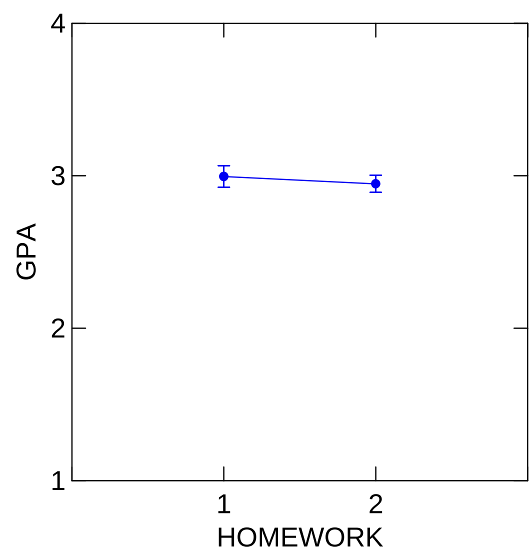


Figure 4: Least Squares Means for Treatment vs. GPA.

Table 3 shows the results of a two-factor (2 x 5) analysis of variance for final exam scores in the engineering mechanics classes. The results of the analysis for the course grades were almost identical to the results for final examination scores; thus, only the results for the comprehensive final examination are presented in this paper. The two factors were homework treatment (experimental or control) and entering ability (GPAGROUPS) from low to high. In addition to presenting the main effects of the treatment and ability, Table 3 presents the interaction effect of the combinations of treatment with ability that cannot be explained by either factor alone. There was not a significant main effect due to the HWL (P = .543), thus the answer to question number two for the study. A very significant main effect (P = .000) due to ability or entering grade point average (GPAGROUP) was found. This answers question number three for the study. Finally, Table 3 shows a significant (P = .043) interaction effect on final exam scores for homework method with ability and answers question number four.

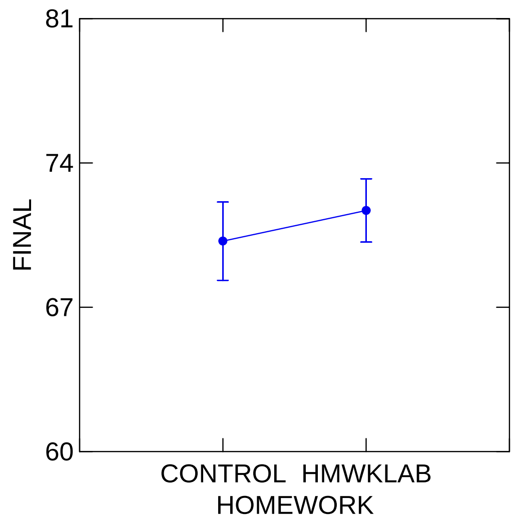
TABLE 3: ANALYSIS OF VARIANCE (Final Exam Scores)					
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Homework	86.567	1	86.567	0.372	0.543
GPAGroups	21926.132	4	5481.533	23.546	0.000
Homework-GPAGroups	2341.183	4	585.296	2.514	0.043
Error	41205.968	177	232.802		
Note: Dep Var: FINAL Multiple R: 0.608 Squared multiple R: 0.369				N: 187	

To adequately understand these results, especially the interaction effect of method and ability, the means for the analysis have been computed and plotted and are presented in Figure 5. Figure 5a shows that the experimental group did better on the final exam than the control group, but not significantly. Figure 5b demonstrates that the final exam performance is highly related to the previous GPA of the students. Figure 5c compares the final exam performance of the experimental group to the control group students by each ability (entering GPA) group. This plotted interaction is significant and shows that for those 34% of students whose GPA is either below 2.24 or above 3.50, the conventional method of instruction produces better final examination scores. For those 66% of students whose GPA is between 2.25 and 3.49 (the three middle GPA groups) the HWL produces better final exam scores. In other words Figure 5c shows that the exam scores are significantly better for the 2.25-3.49 group when they receive the HWL treatment. This illustrates what was presented in a previous paragraph where the interaction effect for homework method and entering ability was described as having a significant probability of P = .043, smaller than the conventional standard of $\alpha = .05$.

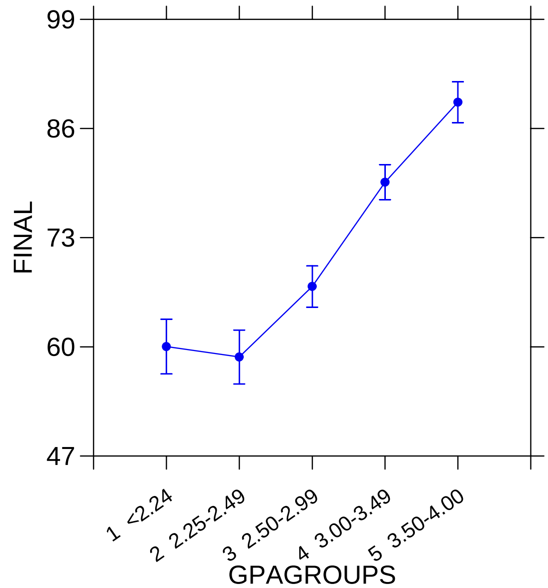
Assessment of Instructor Use: During the HWL's beta-development, the software was reviewed by professors at various universities, including the U.S. Naval Academy, Northern Arizona University, Texas A&M University, and the University of Illinois. The review process was initiated at the request of TTU's sponsoring publisher (Addison Wesley Longman – AWL), and the positive comments of the reviewers regarding the concept and approach initiated a partnership between AWL and TTU for development of the software. During the three-year evaluation of the software, a primary and a secondary instructor at UT, TTU, and MHS used the software. In addition to these participants, graduate assistants as well as "help desk" staff used the instructor version of the software to assist students on a weekly basis during the testing period. Though the number of instructor participants was insufficient to provide a quantitative statistical evaluation of the instrument, it may be concluded that an overwhelming majority of the reviewers found the HWL to be both beneficial for the student and helpful for the instructor. As a result of these reviews, both internal and independent, numerous valuable suggestions as to software modifications and usage techniques were implemented throughout the project.

The following software features were initiated directly as a result of instructor input and have been found to be the most helpful in the management of a course.

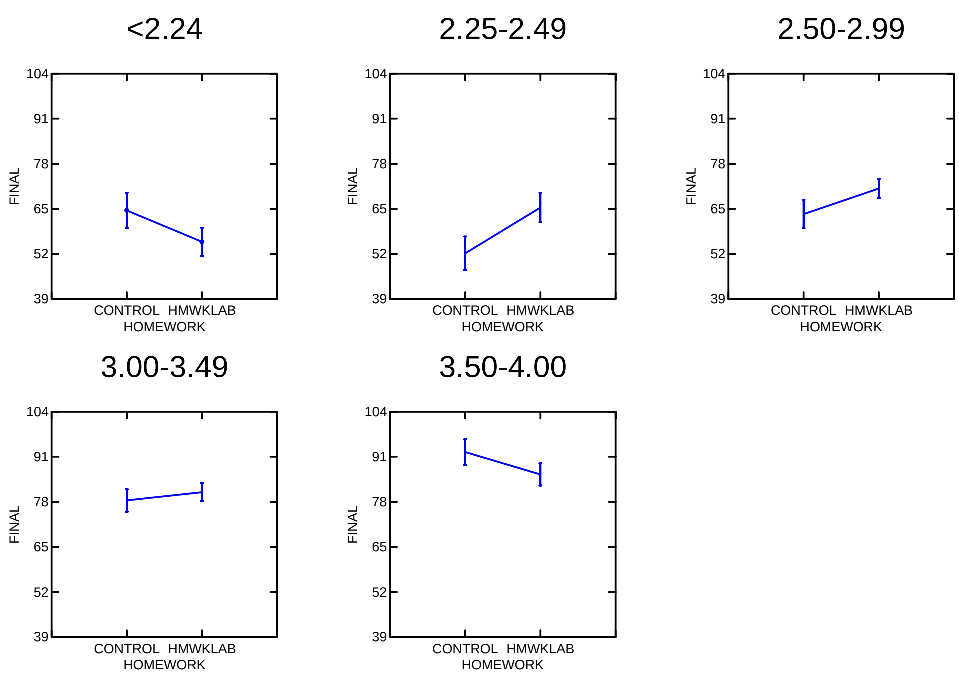
1. Student Summary Data: This feature (as shown in Figure 6) provides the instructor with summary information regarding student usage including number of homework problems completed and homework average, number of practice problems and practice tests completed, as well as a break down of student time (in minutes) spent in each section of the HWL. This information is



(a) Treatment vs. Final



(b) GPA Groups vs. Final



(c) GPA Treatment vs. Final for GPA Levels

Figure 5: Least Squares Evaluation.

available for individuals as well as the whole class and helps the instructor assess topics of particular difficulty.

2. Spreadsheet Transfer: Student grades may be viewed directly in the HWL or may be exported as a text file, a CSV file, or directly into an MS Excel® spreadsheet (see Fig. 7).

3. Syllabus Printing: After the instructor creates the original student data file (assigning homework for the semester), the HWL will assist the instructor in the creation of a syllabus for the class.

4. Answer Mode: Since every student's problems have randomized variables,

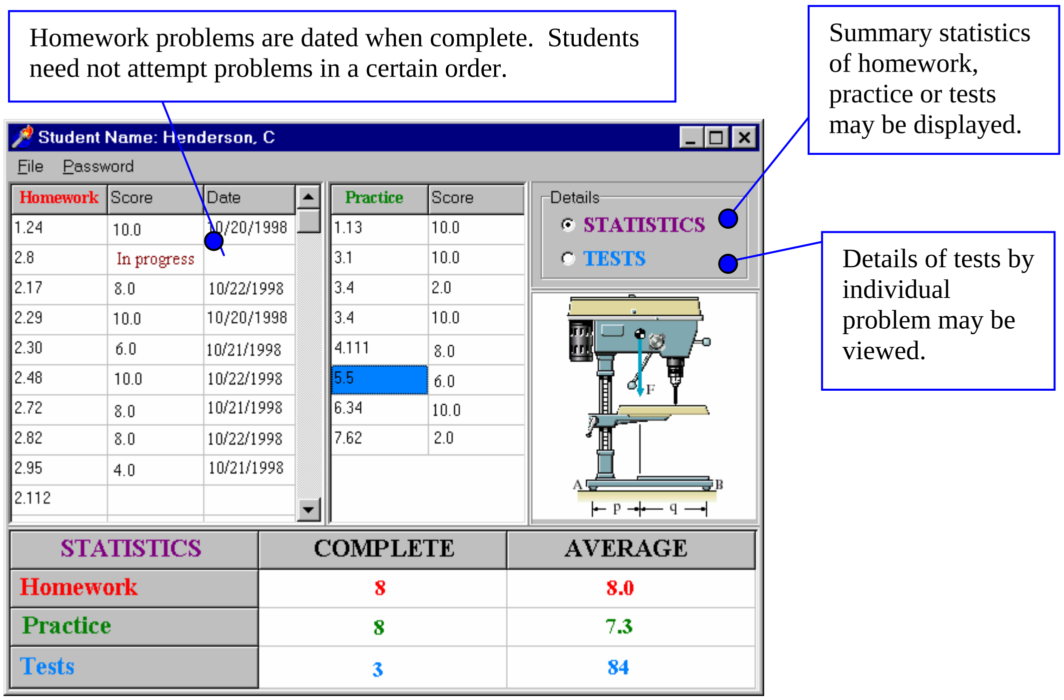
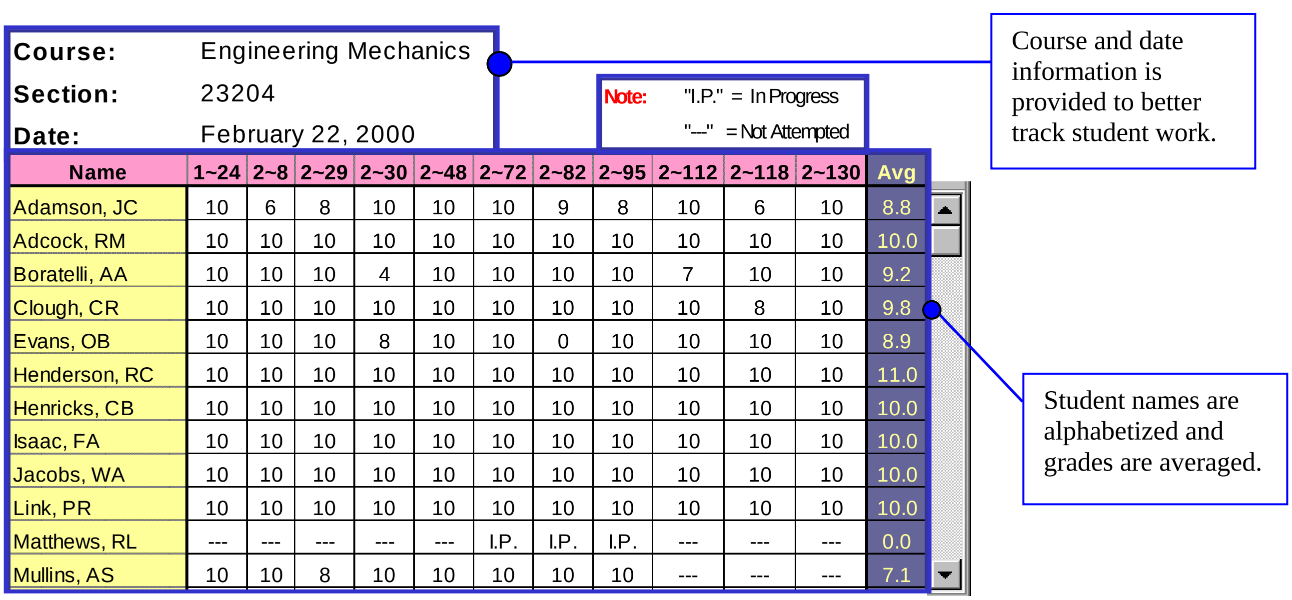


Figure 6. Summary of Scores and Results.



Name	1~24	2~8	2~29	2~30	2~48	2~72	2~82	2~95	2~112	2~118	2~130	Avg
Adamson, JC	10	6	8	10	10	10	9	8	10	6	10	8.8
Adcock, RM	10	10	10	10	10	10	10	10	10	10	10	10.0
Boratelli, AA	10	10	10	4	10	10	10	10	7	10	10	9.2
Clough, CR	10	10	10	10	10	10	10	10	10	8	10	9.8
Evans, OB	10	10	10	8	10	10	0	10	10	10	10	8.9
Henderson, RC	10	10	10	10	10	10	10	10	10	10	10	11.0
Henricks, CB	10	10	10	10	10	10	10	10	10	10	10	10.0
Isaac, FA	10	10	10	10	10	10	10	10	10	10	10	10.0
Jacobs, WA	10	10	10	10	10	10	10	10	10	10	10	10.0
Link, PR	10	10	10	10	10	10	10	10	10	10	10	10.0
Matthews, RL	---	---	---	---	---	I.P.	I.P.	I.P.	---	---	---	0.0
Mullins, AS	10	10	8	10	10	10	10	10	---	---	---	7.1

Figure 7. Display of Grades for a Class.

assisting a student was difficult without reworking the problem. The HWL was modified to include an answer mode that would provide correct answers for any inserted variables.

Assessment of Subject Area Modularity: Modular programming refers to software construction techniques that deliberately separate or isolate portions of code in order to more easily add, delete, or modify sections of the program. One of the goals of the HWL was to be able to extract that portion of the code pertaining to a particular subject and efficiently replace it with material for another subject.

To examine modularity, course material for engineering mechanics was replaced with that for high school statistics. In general, the switching of subject matter was performed efficiently as anticipated. The extraction of the engineering mechanics problem sets and the modification of subject related navigational features were completed by the HWL staff within about three weeks. [A functional version for statistics was actually completed in a single day with clean-up activities taking additional time. This includes the navigational and functional facets of the program – not the programming of statistics problems, which took about three hours per problem.]

In general, use of the software at MHS went well. Students enjoyed using the computers for their homework and particularly liked the immediate response that the computer gave instead of having to wait for the teacher to grade their work by hand. The statistics teacher felt that the two biggest advantages were the administrative aspects of the software (grading and coaching) and the fact that the HWL prevented plagiarism while allowing some group work.

Student input revealed several lessons learned from the high-school portion of the study. As with TTU and UT, instructor comments were important to increasing the usefulness of the software. Two of the primary recommendations from the study were:

1. In general, a Macintosh platform would be the most practical; few schools in middle Tennessee have a large number of PCs. This made implementation more difficult and extended the learning curve for some students.
2. Though workable, statistics is not the most appropriate subject area overall, and more thoroughly quantifiable courses will provide better results.

Summary and Observations

NSF's 1994 conference entitled "Project Impact: Disseminating Innovation in Undergraduate Education" outlined several important phases toward completing a particular education reform. These include: (1) pilot study, (2) revision and testing, (3) working with a publisher and (4) focusing on a national level [10]. This study has attempted to follow this course of action. The results of the study were positive in many ways. A significant majority of students preferred the software to the traditional approach and felt that they learned more using it, despite the additional up-front learning curve. The HWL was shown to produce slightly (though not significantly) higher test scores than the traditional approach for the test population taken as a whole. However, significantly higher test scores and final grades for the mid-range GPA levels were observed.

Ultimately, the software was dramatically improved by lessons learned throughout the study, particularly in terms of implementation and administration at UT and MHS. It would appear from this test project that the HWL and other learning instruments have the potential to perform as well (or out perform) traditional approaches while saving institutions time and money associated with grading and coaching. The choice of methods may be made based upon the ability level of the students, cost per student, convenience and other criteria. Given how labor-intensive conventional homework grading is, whether performed by a professor or a graduate assistant, the HWL and similar learning instruments provide effective alternatives.

Clearly, educational software is being shown to be efficient and cost effective[13]. However, despite the success of the software as a learning tool, two significant obstacles remain in terms of widespread dissemination. First, development of learning software is often programming intensive and may require significant initial expenditures[4]. For the HWL, a single problem takes an average of about 3 hours for a qualified student to fully complete (i.e., programming, art work transfer, help screens, database modifications, checking, etc.). If a text contains 1500 problems, this may amount to $30,000 or more for the programming costs alone. Management costs would add considerably to this figure. Even though these are essentially one-time expenses, publishers are reluctant to commit these funds. Secondly, the publishing industry is changing rapidly due to the advent of Internet publishing and other web-based teaching approaches. These rapid changes produce uncertainties in the publishing industry regarding its future role in print media as well as in the relationship supplementary pedagogical instruments will have with traditional textbooks. As a result, publishers may be apprehensive to invest in projects that will require long-term commitments or substantial upfront capital. Given the merit of the approach, however, it is felt that these obstacles will be overcome – particularly by using integrated teamwork approaches between the publisher and developer.

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