# Efficacy of Interactive Internet-Based Education in Structural Timber Design

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## ABSTRACT

**While traditional teaching methods (e.g., real-time, synchronous lectures) have proven effective for training future engineers, the Internet provides an avenue to reinforce the material and augment student learning, comprehension, and retention of material. This paper presents the integration and assessment of a library of interactive instructional modules specifically for a senior-level undergraduate elective course in civil engineering. An ongoing, comprehensive assessment process was implemented in the fall 1999 semester. The results of this quantitative assessment indicate that the use of well designed and pedagogically sound Internet-based supplemental modules provide students with a better understanding of course material. However, when Internet-based content does not promote critical thinking, little increase in the student performance and understanding of the material is realized. Interactive Web-based instruction should not be viewed as a "replacement" to traditional instruction, but rather a tool that provides a broader and more dynamic environment for students with a variety of learning styles.**

## I. INTRODUCTION

The evolution of the Internet has created a paradigm shift in post-secondary education. Until recently, the primary method of teaching engineering has been through the traditional use of lecture, laboratory, and homework. In the past five years, educators have begun to take advantage of the opportunities provided by electronic media and the Internet. The use of Web pages in college curricula grew 500 percent between 1995 and 1998 [7]. As the Internet evolves in complexity and usability, instructors are finding that it presents new avenues to reach students both synchronously and asynchronously.

The Internet has provided a natural environment for learning to take place. Since its conception, it has been an information infrastructure made up of interconnected computers for the purpose of exchanging information [10]. The development of new software and programming languages has given life to original static text Web pages. In the multifaceted environment of the Internet, material can be presented in static or dynamic form, as images and graphics, with animations, video and audio, or with any combination of these. Rather than the mundane act of taking lecture notes, the Internet provides an interactive environment that requires active student participation in the learning process.

An additional advantage of the Internet is that it allows instructors to effectively convey course material to a student population with a wide variety of leaning styles. The Keller Plan [9] outlines essential features of a personalized course that promotes a learn-at-your-own-pace curriculum. Information on the Internet may be tailored to follow the Keller Plan or other similar teaching philosophies to reach a greater audience.

It is hypothesized in this research that the Internet is a valuable tool for the instruction of engineers. Its interactive environment permits students to conduct virtual laboratory tests, see sample problems worked for them, solve problems on their own and take quizzes to test their knowledge, all with immediate feedback. The Internet environment is not conducive to comprehensive design problems and essay questions, and the types of problems that can be asked of students are limited at this time to short answer and multiple choice. However, these types of questions can be very useful in teaching the basic concepts that are needed in engineering design. Additionally, carefully crafted short answer and multiple choice questions can be used to test advanced design and engineering theory.

An important part of learning is developing critical thinking skills. One way to aid students in developing these skills is by fostering discussions on course related topics. Through the use of electronic bulletin boards and Internet chat-rooms discussions concerning homework, lecture topics and applications of learned material can be initiated.

## II. BACKGROUND

Many of the early educational uses for the Internet consisted of posting the course syllabus, topic schedule, and homework assignments. The most effective tool for asynchronous learning was e-mail, increasing the student-teacher interaction [4]. As the Internet has developed, more creative uses of this dynamic media have been devised to aid and enhance student learning.

Several models have been developed for Internet-based engineering courses [3, 4, 8, 16]. Each model maps the traditional engineering education paradigm to network-based learning. The models call for a high degree of student interactivity and the ability for the student to learn at his/her own pace and style. Some of the models duplicate lectures in on-line presentations, provide asynchronous discussion and use virtual or remote laboratories to replace the traditional hands-on experiments. Each of these models makes the assumption that a well-designed Internet-based course can be as effective as, or even replace, a traditional lecture style course of the same material.

Due to the rising costs of education at some institutions, it has become increasingly difficult to provide students with extended laboratory time. To this end, on-line laboratory experiments have been developed to provide students with hands-on, albeit virtual, learning experiences. Virtual experiments have been used with success at Northwestern University [1], the University of Texas at Austin [17], and Purdue University [12] to name but a few.

## III. Objectives

There are many different examples of World Wide Web-based or Internet-based courses. The Timber Design course at Washington State University (WSU) utilizes a comprehensive Web site for instructing students in the theories and concepts of wood and timber engineering. For this purpose, a suite of interactive modules was developed to supplement the lecture material of this senior-level design class. These modules include behavioral topics such as moisture effects, load duration, and dowel bearing strength. In addition, they also cover contemporary design issues such as allowable stress design (ASD) verses load and resistance factor design (LRFD), design adjustment factors, connection design, and shearwall design. Modules are both theory based and teach practical applications.

The principal objective of this research is to quantitatively assess the efficacy of the on-line modules for student comprehension and understanding of the course material. Although the previous five years have seen a large increase in the development of on-line course material, a literature review of such courses reveals surprisingly few quantitative assessments of the effectiveness of on-line materials. Evans et al. [4] and Wallace and Mutooni [16] are two exceptions. Most of the current published work utilizes student surveys and focus groups to obtain qualitative feedback from students about their use of on-line material [1, 11, 12].

## IV. Methodology

Similar to traditional lecture-type courses within most civil engineering departments, the Internet-enhanced *Timber Design* course requires students to purchase a textbook and current design manuals. Traditional lectures are held at regularly scheduled times and follow a logical progression of topics in wood engineering, including the use of the design manuals. All of the information necessary to successfully fulfill the objectives of the course is provided within these traditional sources.

The World Wide Web home page for the *Timber Design* course is located on a dedicated Internet server within the Department of Civil and Environmental Engineering at WSU. The Web site was designed using Microsoft FrontPage® Web design and publishing software. The home page includes links to the course syllabus, course objectives, announcements and news items (updated regularly), homework assignments, student scores, class bulletin board (updated daily), and the suite of supplemental instruction modules.

The supplemental modules were also created using Microsoft FrontPage®. The modules present information in the form of static text and graphics and demonstrate difficult concepts with animations developed using Flash 3™. The animations play like short video clips and allow the user to stop, start, and repeat them at any time. Additional interactivity comes through online quizzes that require students to select or input definitive answers to questions or design scenarios. The students' responses are given immediate feedback upon submission. This is achieved using VBScript, which is imbedded in the HTML code, and through Web pages composed using active server pages (ASP).

Asynchronous student-student and student-instructor interaction is promoted through the use of e-mail, the announcements and news Web page, and through the bulletin board discussion list. The bulletin board utilizes the server-based Ultimate Bulletin Board™ software from Infopop™. It provides a forum for ongoing discussions of course related topics including lectures, homework and projects, the online material, and general wood engineering issues. Students are encouraged to post questions about class material on the bulletin board where other students, the instructor, graduate students and corporate sponsors can asynchronously respond.

The discussion list and the library of supplemental modules are the two primary educational tools used to convey material and promote critical thinking. Several assessments have been done to determine the effectiveness of bulletin boards and discussion lists in engineering education [4, 13]. Therefore, this research will not assess this medium again but rather rely on the findings of previous research. Suffice it to say, both Patterson [13] and Evans et al. [4] documented that bulletin board type discussion lists foster discussion of course topics and promote critical thinking. The focus of the assessment in this research was therefore directed toward the library of learning modules.

### *A. Research Model*

The *Timber Design* course is an upper level baccalaureate structural engineering elective. The majority of the students enrolled in this course were seniors in their last year of the undergraduate civil engineering program. The remainder of the class consisted of junior-level and graduate-level civil engineering students. A total of 37 students were enrolled in the course during the fall 2000 semester at the time this study took place.

### *B. Assessment Design*

A battery of quizzes was implemented in the normal course curriculum to assess the efficacy of the Internet-based modules on student understanding and comprehension of timber engineering. In addition to the quizzes, a series of on-line surveys was placed at the end of each on-line module to solicit subjective feedback on the module.

The *Timber Design* course has six related but individual topics that are covered over the course of the semester. Of these six topics, five have one or more corresponding on-line supplemental modules. "Pre-quizzes" were administered after the last lecture on a topic. The scores on the pre-quiz served as a baseline for measuring student comprehension. The students were then assigned homework and were informed whether or not a corresponding Internet module was available. The use of the modules was made strictly voluntary, although students were encouraged to use them.

On the day the homework was due, a second, more challenging "post-quiz" was administered. The post-quiz was a measure of student development that had taken place since the administration of the pre-quiz. The post-quiz also solicited a response regarding the amount of time the student spent using the online material. In order to obtain a valid response, it was important to stress to the students that it would not directly affect their grades if they did not utilize the on-line material.

The structure of the quizzes followed Bloom's taxonomy for categorizing the level of abstraction of questions used in education [2]. Pre-quizzes consisted predominantly of level-one and level-two, knowledge and comprehension questions that required little higher order thinking. The post-quiz questions consisted of level-four and level-five, analysis and synthesis questions that required students to draw their own conclusions and construct ideas based on given information. A cognitive effort was made to keep the difficulty levels of the pre-quizzes and post-quizzes consistent throughout the course. Each of the quizzes consisted of five questions; each question was given zero, half or full-credit. The questions were worth one point apiece for a total of five possible points. One individual graded all quizzes to provide consistency of grading. Five level-four and level-five questions were included on the mid-term exam to provide additional data on student retention of material. These questions were similar to the post-quiz questions asked on previous quizzes.

In order to determine the efficacy of the Internet modules, students were separated into two groups: Group A being those students who made use of the modules and Group B being those students who did not use the modules. The assessment came through the following seven comparisons of quiz performance:

1. the average pre-quiz score of the entire class to average post-quiz score of the entire class;
2. the average pre-quiz score of Group A to the average Group A post-quiz score;
3. the average pre-quiz score of Group B to the average Group B post-quiz score;
4. the average pre-quiz score of Group A to the average pre-quiz score of Group B;
5. the average post-quiz score of Group A to the average post-quiz score of Group B;
6. the average GPA of Group A to the average GPA of Group B, and
7. The average grade in the prerequisite class* for Group A to average grade in the same class for Group B.

The first three comparisons are global observations that examine the general trend in performance of the class as a whole and of the two groups from the pre-quiz to the post-quiz. The fourth comparison is a baseline observation that compares the performance on the pre-quiz by the two groups. If their performance is statistically similar, then both groups can be considered to have started at the same knowledge level. Number five compares the post-quiz performance of the two groups. If the pre-quiz analysis identifies the two groups to be similar, then any difference between the two groups can be attributed to the gain in knowledge and understanding through completion of the homework and the use of the Internet-based modules.

*CE 330: *Introduction to Structural Engineering* is the only direct prerequisite *course for CE 436: Design of Timber Structures.*

The final two comparisons were made in order to determine the academic similarities and/or differences between the two groups. In order to draw conclusions based on the first five comparisons, it had to first be determined if Groups A and B were statistically the same or if one had an academic advantage over the other. The importance of these final two comparisons is evident when it is realized that the members of the two groups would not necessarily remain constant from topic to topic.

The quiz schedule also included topics that did not have corresponding supplementary Internet-based modules. An analysis was made of the same comparisons outlined above. In this case however, Group A was comprised of students who had used the modules at least three out of four times in previous topics (there being a total of four modules with pre-/post-quiz sets). Group B was made up of the remainder of the students. In this way, Group B became a conservative baseline from which to gauge the effect that the homework alone had on the development of student knowledge and understanding of the material. The results from the comparisons made between groups A and B were then used in conjunction with the results from the module analysis to estimate the relative efficacy of the modules.

The comparisons described above were made by performing an analysis of variance (ANOVA) on the mean scores for the entire class and each group. The resulting $F$ distributions were compared to the critical value $F_\alpha$ with a significance level of $\alpha = 0.05$. All data was assumed to follow a normal distribution with a small sample size.

The Timber Design course is made up of six general topics. Of these six topics, five included one or more supplemental modules. Pre- and post-quiz sets were administered for each topic with a module save one: *Design Loads*. This was because the *Wind Loads* module was a practical demonstration of the development of wind loads and contained no material specific to wood or the design of wood structures; therefore, this topic was excluded from the assessment. *Member Design* is the most extensive topic in the curriculum and does not have any corresponding modules. Therefore, two quiz sets were administered on this material to provided data for topics without on-line modules. This data served as the control group and provided the baseline from which assessments can be made regarding the efficacy the modules on student learning and comprehension. Table 1 outlines the course topics and their corresponding module(s) and quizzes.

### *C. Research Considerations*

There were several factors that were considered in this research to have a potential effect on the overall results. The first of these was the honesty of the students reporting the amount of time they spent using the modules. It is possible that students may have indicated that they used the module when in fact they had not. The question soliciting this information was crafted in such a way as to promote an honest response from the students by stating they would not be penalized if they did not use the Web material. Students also signed a consent form in full knowledge that this research effort was in progress. Thus, they should not have had any false perceptions as to the intent of this question and would have felt free respond truthfully. Based on these factors, the assumption was made that all students would report their Web usage truthfully.

Another consideration was that the academic demographic of the two groups would not be a constant. This concern was two

| *Topic* | *Module(s)* | *Quiz* |
|---|---|---|
| Physical and Mechanical Properties of Wood | Moisture Content | Pre- and Post-Quizzes |
| Design Loads | Wind Loads | None |
| Structural Wood Products | Adjustment Factor Quiz<br>Adjustment Factor Scenarios<br>Duration of Load | Pre- and Post-Quizzes |
| Member Design: | | |
| Beams | None | Pre- and Post-Quizzes |
| Tension Members<br>Compression Members<br>Combined Loading Members | None<br>None<br>None | Pre- and Post-Quizzes |
| Connections | Connections | Pre- and Post-Quizzes |
| | Dowel Bearing Strength | None |
| Assemblies | Shearwalls | Pre- and Post-Quizzes |
| | Diaphragms | None |

***Table 1. Course topic and quiz schedule.***

pronged. First, although the modules were not mandatory, it was theorized that only students that are considered "over-achievers" would take the initiative to use the modules. Simply by their nature, these students would outperform other students in the class who did not use the modules and thus skew the results of the assessment. A contradictory hypothesis assumed that the above average students who felt confident in their study skills would not take the extra time to use the modules. In contrast, below average students would dominate usage of the modules and thus skew the assessment results. It was felt that both of these were valid predictions and as a result, they could tend to negate themselves. However, in an effort to gauge the academic demographic of the groups the additional ANOVA of the grade point average (GPA) and prerequisite course grades was added.

Finally, the design content of the module itself was considered. Each module was developed to help students with topics that have proven difficult for previous classes. Although careful thought went into the planning and design of each module, not all of the modules contain the same level of theory and practical design material. This is partly due to the different topics covered by the class and the Web site. The *Moisture Content* module, for example, is a relatively short module that has an approximately equal mix of theory and practical information. The *Adjustment Factors* module, on the other hand, contains very little theory, but rather provides students with repetitive practice of applying adjustment factors to given design scenarios. It was a goal of this research to determine the level of efficacy for each of these types of modules have in order that future modules could be developed that would maximize student learning.

## V. Assessment Results

The objective of this assessment was to determine if the Internet-based material developed for the *Timber Design* course enhanced student understanding and comprehension of the course material. In order to make this determination, it was first verified whether or not the two groups of students were academically similar. In other words, confirmation was needed that the academic demographics of each group mirrored the demographics of the class as a whole.

To do this, Figure 1 presents the pre-quiz scores of Group A (who used the modules) and Group B (who did not use the modules) for topics that had on-line modules. An analysis of variance (ANOVA) indicated that the pre-quiz scores of Groups A and B were statistically similar. The same result was obtained for the pre-quiz comparison between Groups A and B for topics that did not have modules associated with them (Figure 2). Therefore, it can be concluded that both groups started out at the same performance level prior to working through homework problems or using the on-line modules.

The results of the post-quiz comparison of topics without modules are presented in Figure 3. The ANOVA indicated that the two groups performed equally on the post-quiz for the Beam Design topic and for the Combined Loading topic. This indicates that working through the homework problems did not have a greater influence on one group versus the other. To confirm that Group A did not have an academic advantage over Group B, an analysis of the students' cumulative GPAs and prerequisite course grades was performed. Figure 4 presents the average GPA for each group. The statistical analysis showed the GPAs of the two groups to be statistically equivalent for each set of pre-/post-quizzes, with the exception of the *Shearwall* topic. A similar analysis of the prerequisite course grades indicated the same trend. Given this, the assumption that the two groups were academically equivalent is valid. The next step was to determine if the modules enhanced student performance.

The student performance on the post-quizzes for topics with modules is summarized in Figure 5. The ANOVA results of the post-quiz comparison of Group A and B indicate that the students who used the on-line material performed better than those students who chose not to use the modules. The only exception to this is the *Adjustment Factors* modules. It was observed that the *Adjustment Factors* modules improved the performance of Group A with respect to Group B, but only to the point where their performance was statistically equivalent on the post-quiz.

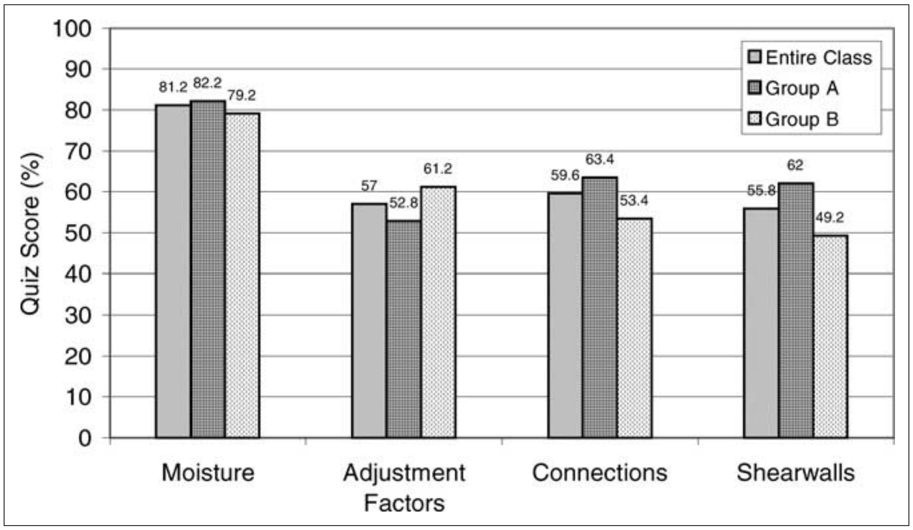


*Figure 1. Pre-quiz performance for topics with on-line modules.*

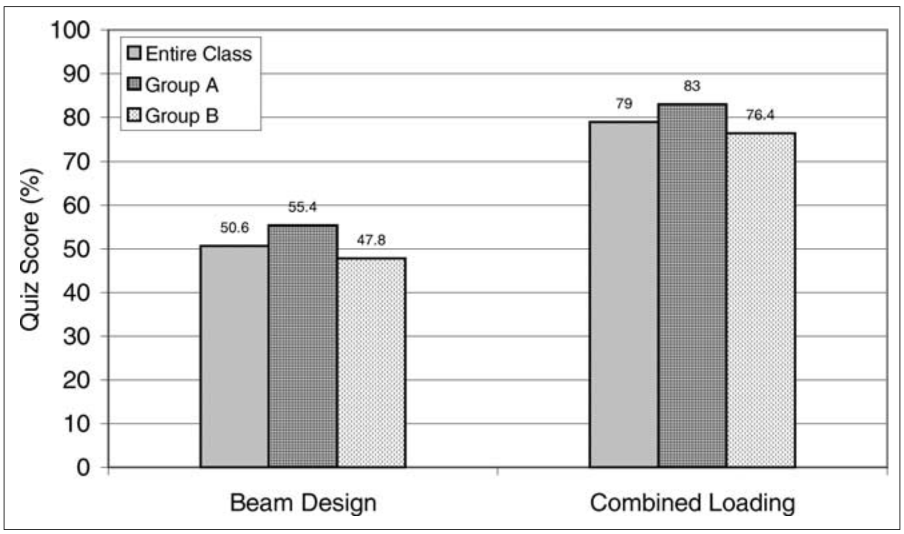


*Figure 2. Pre-quiz performance for topics without on-line module.*

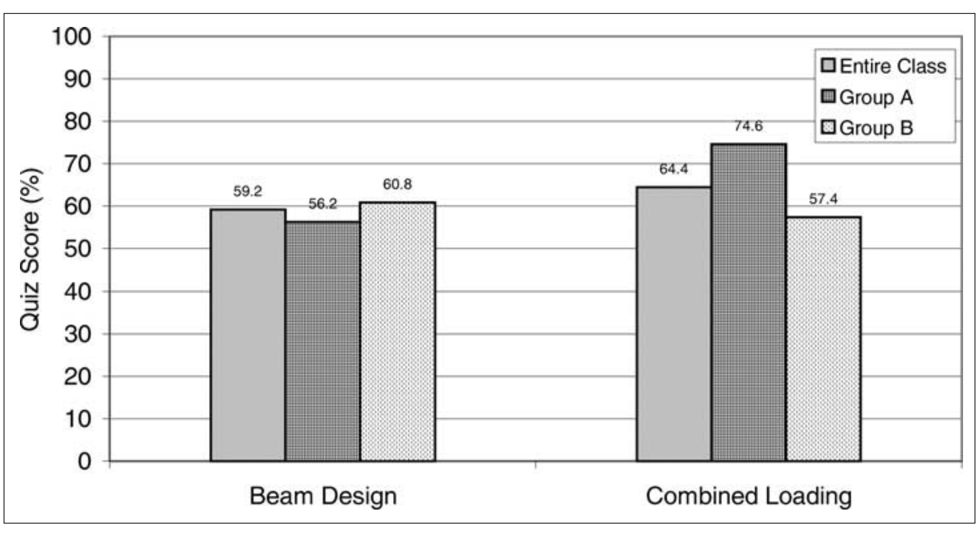


*Figure 3. Post-quiz performance for topics without on-line modules.*

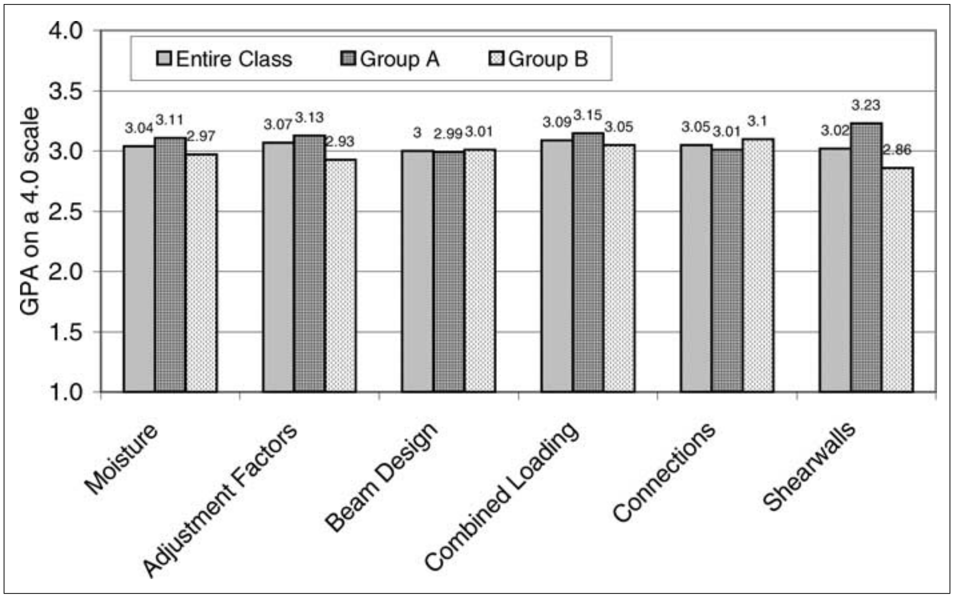


*Figure 4. Relative cumulative Grade Point Averages of module users and non-users.*

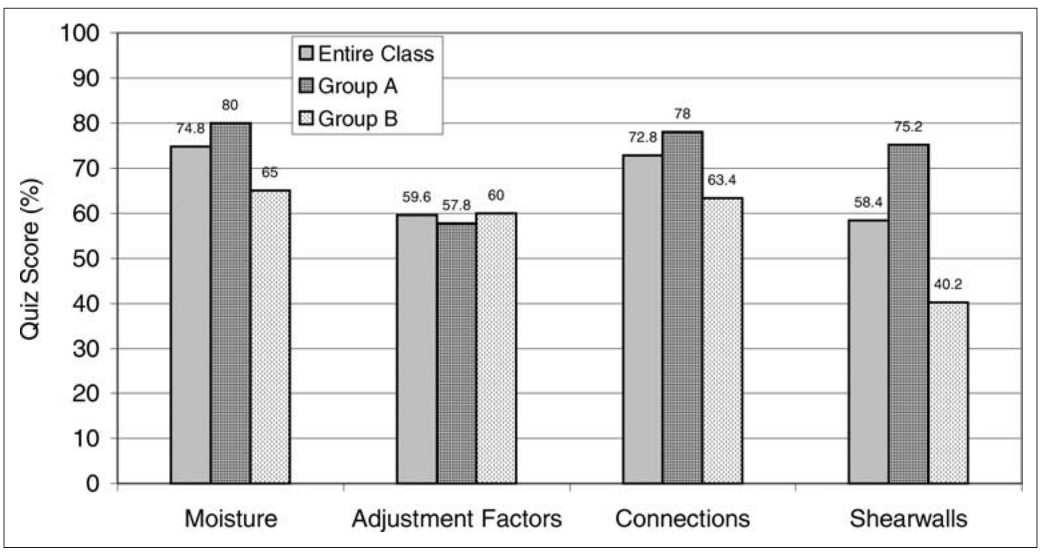


*Figure 5. Post-quiz performance for topics with on-line modules.*

To obtain direct user data as to the effectiveness of the modules, electronic surveys were placed at the end of each module. The surveys were tailored to solicit information about student time on task, student perceptions of learning and applicability of on-line material. The results of the surveys indicated that the modules were generally well received (c.f., Table 2). Students indicated that the modules helped them better understand and visualize the material. They also indicated that they were more likely to discuss the concepts presented in the modules with other students or the instructor and felt that they could immediately see the results of their time spent with the modules.

In addition to the performance questions asked in the surveys, the following quotes were selected from the comments made by students.

- "The Web really helped in visualizing parts of the course which I found tricky."
- "The Internet modules both increased the requirement of time for studying and increased understanding."
- "Greatly helped visualize the concepts."

It was also determined through this study that not just any computer module aided student learning. It was evident through comparisons that modules that presented material in a concise manner and with a good mix of theory and practical material provided the best results. Modules such as the *Adjustment Factors,* which provided students an opportunity to apply adjustment factors with immediate feedback, did not promote critical thinking skills. It did, however, bring students who traditionally performed at below average levels, up to an average level. Although this is not a negative result, a better use of student time would be to design a module that also increased the overall critical thinking level of the user.

Think about a similar course you have taken that relied primarily on textbooks and paper and pencil exercises. Compared to that course, because of the way this course uses interactive Internet-based instructional modules:

| | | Select only one response per question | | | | | |
|---|---|---|---|---|---|---|---|
| ***How likely are you to:*** | | ***Much more likely*** | ***Somewhat more likely*** | ***About the same*** | ***Somewhat less likely*** | ***Much less likely*** | ***Not Applicable*** |
| 1 | …apply what you are learning to "real world" problems | 18.7% | 56.3% | 25% | 0% | 0% | 8% |
| 2 | …discuss ideas and concepts presented in the module with other students and/or instructor. | 6.3% | 50% | 31.3% | 6.3% | 0% | 0% |

Indicate how strongly you agree or disagree with the following statements:

| ***Because of the way this course uses Intern-based material:*** | | ***Strongly Agree*** | ***Agree*** | ***Disagree*** | ***Strongly Disagree*** | ***Not Applicable*** |
|---|---|---|---|---|---|---|
| 3 | …I am better able to understand the ideas and concepts taught in this course | 43.7% | 56.3% | 0% | 0% | 0% |
| 4 | …I am better able to visualize the ideas and concepts taught in this course | 63% | 37% | 0% | 0% | 0% |
| 5 | …I spend more time studying | 12.5% | 37% | 37% | 0% | 12.5% |
| 6 | …I am able to learn at my own pace. | 25% | 56.3% | 18.7% | 0% | 0% |
| 7 | …I can see the results of my work with module almost immediately. | 37% | 37% | 18.7% | 0% | 6.3% |

*Table 2. Sample electronic survey to solicit user feedback from Internet modules for Fall 2000—Results are from Moisture Content module.*

## VI. CONCLUSIONS

The results of this study are based on a single class taught by an individual instructor with seven years experience in teaching this course. It would not be appropriate to directly apply the results of this research to a different situation. However, the results do permit several general conclusions to be drawn about Internet-based teaching supplements in engineering courses. First, the students who made consistent use of the supplemental instructional modules exhibited a higher understanding and comprehension of the material be taught than did the students who did not use the modules. Second, the increase in student understanding and comprehension could be attributed directly to the usage of supplemental modules as was illustrated in comparison of the post-quiz results for topics with modules (c.f., Figure 5).

It should be noted that this research does not suggest that the Internet-based instructional modules be a substitution for traditional lecture classes. Rather this research has shown that Internet-based supplemental instruction can improve the performance level of students. It could be argued that these types of instructional tools simply provide redundant exposure to the course material and this accounts for the increase in student performance. This research shows, however, that the educational design of the modules has an effect on the performance of the students. The *Adjustment Factors* module does not promote critical thinking and the assessment of this topic shows little increase in the performance of the module users. In contrast, the assessment of the *Moisture Content, Connections,* and *Shearwall Design* modules, which provide a mix of theory and practical information, indicate that the students outperformed their peers who did not use the modules. Furthermore, the selected student comments are a testimonial to the effectiveness of the Internet-based modules for conveying difficult concepts.

In conclusion, a responsibility exists by instructors to provide students with the best learning tools that are available. Not all students learn in the same way, nor do all professors have the same teaching styles. The Internet provides a means to reach a wide variety of learning styles regardless of the instructor's teaching style. Internet-based supplemental education may not be right for every class, but it is another tool available to instructors for educating engineers.

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