On Development, Application and Effectiveness of a Computer Based Tutorial in Engineering Mechanics (Statics)

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Abstract

This paper describes a computer based tutorial for the first course in engineering mechanics taught at Mississippi State University. It gives an overview of the instructional materials that make up the Statics tier of the Virtual Laboratory for the Study of Mechanics (www.ae.msstate.edu/vlsm), and elaborates on the experience of using this tutorial as a supplemental teaching tool in one section of Statics during Fall 2000 semester. It also examines the effectiveness of this computer based instruction method in enhancing students' performance in the course, and reports on the students' evaluation of the tutorial.

I. Introduction

The use of computers in engineering education—especially in the area of engineering mechanics[1-3]— is not new, but a more recent development is the significant shift in technology implementations toward greater use of computers as *tools in the learning process* rather than as instructional delivery devices. This undoubtedly poses a considerable challenge to the developers of computer based instructional materials (CIMS) who must ensure the pedagogical value of the content while applying the pertinent computer technology. Additional challenges to those developing course specific CIMS are twofold: 1) making the content interesting to students; and 2) incorporating features that are very difficult or even impossible to demonstrate in textbooks or on the chalkboard.

The focus of this paper is on the CIMS developed for the first course in engineering mechanics, commonly known as Statics (EM 2413), taught at Mississippi State University. Of the nine different degree programs offered in the college of engineering, only students in Computer Science and Computer Engineering are exempt from taking Statics. Students in Chemical, Electrical, and Industrial Engineering take Statics without it being a prerequisite to any other course in their degree programs. However, for students in Aerospace, Biological, Civil, and Mechanical Engineering, this is the fundamental course on which many of the higher level courses are based.

With this constituency in mind, the CIMS for Statics were developed as part of a larger Internet based system known as the Virtual Laboratory for the Study of Mechanics (VLSM). The CIMS for Statics consist of five separate modules with each focusing on a particular set of topics taught in the course. The titles of the five modules are as follows: *Concurrent Force Systems*; *Non-Concurrent Force Systems*; *Trusses, Frames and Machines; Friction*; and *Geometric Properties of Shapes*. Although all modules have elements that can help with demonstration of concepts

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and solution techniques during classroom lectures, they are designed primarily to be used by individual students as a self-paced asynchronous instructional or tutorial tool outside of classroom.

With the significant portion of the contents in four of the Statics modules completed, VLSM was formally placed online at www.ae.msstate.edu/vlsm in Fall of 2000. In the same semester a study was conducted to determine if these CIMS have any noticeable impact on student learning. To establish any possible correlation between the use of VLSM and student performance, the author taught two sections of EM 2413. In one section, all students were issued individual access codes to the Statics modules with the instructor making a limited use of VLSM in classroom lectures. The author taught the other section without any reference to VLSM and without allowing the students any access to it.

In the next section of the paper, various features of CIMS for Statics in VLSM are discussed. This is then followed by the discussion of the procedure used for collecting data and the assessment of the role of these CIMS on student learning. These discussions are culminated with the concluding remarks and planned course of action for the future developments and enhancements.

II. CIMS for Statics Tier of VLSM

In this section, the key features of VLSM are introduced with the help of several examples. For a complete review of the CIMS for Statics, the reader can log into VLSM using guest and bmyguest as the user name and password, respectively.

Each module has a two-frame set layout. The left frame shows the table of contents as a list of hyperlinks. The right frame is used to display the content of each section. Navigation from one section to another or from one module to another is fairly straight forward.

The topics of interest are discussed in tutorial notes with no reference to any specific book as the course textbook is changed on the regular basis. However, the title chosen for each module makes it easy to find the corresponding chapter in any textbook on the subject. These tutorial notes highlight the important aspects of a particular subject, and are accompanied by pertinent mathematical equations and figures. In some cases, these notes are supplemented by Flash/Shockwave® animation. For example, in the discussion of vectors in the *Concurrent Force Systems* module, an animation applet is used to demonstrate the individual direction angles of a vector as the user changes the direction of the vector with the mouse pointer. The accompanying Cartesian vector equation shown at the bottom also changes dynamically. This tool helps students in visualizing the correct way a direction angle is measured, and in seeing the changes in direction reflected in the Cartesian vector equation. A single snapshot of the vector animation is shown in Fig. 1.

Besides the textbook type example problems with detailed description of the solution procedure, each module also contains a collection of interactive example problems. These examples are developed using the LiveMath® symbolic math software. What makes these examples

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interactive is the fact that the user can change the problem data and see the effects reflected in the solution notebook. Such alterations also affect the graphs that might accompany the solution procedure. By changing the problem data, the student can solve a number of different problems, all within the framework of a single example problem.

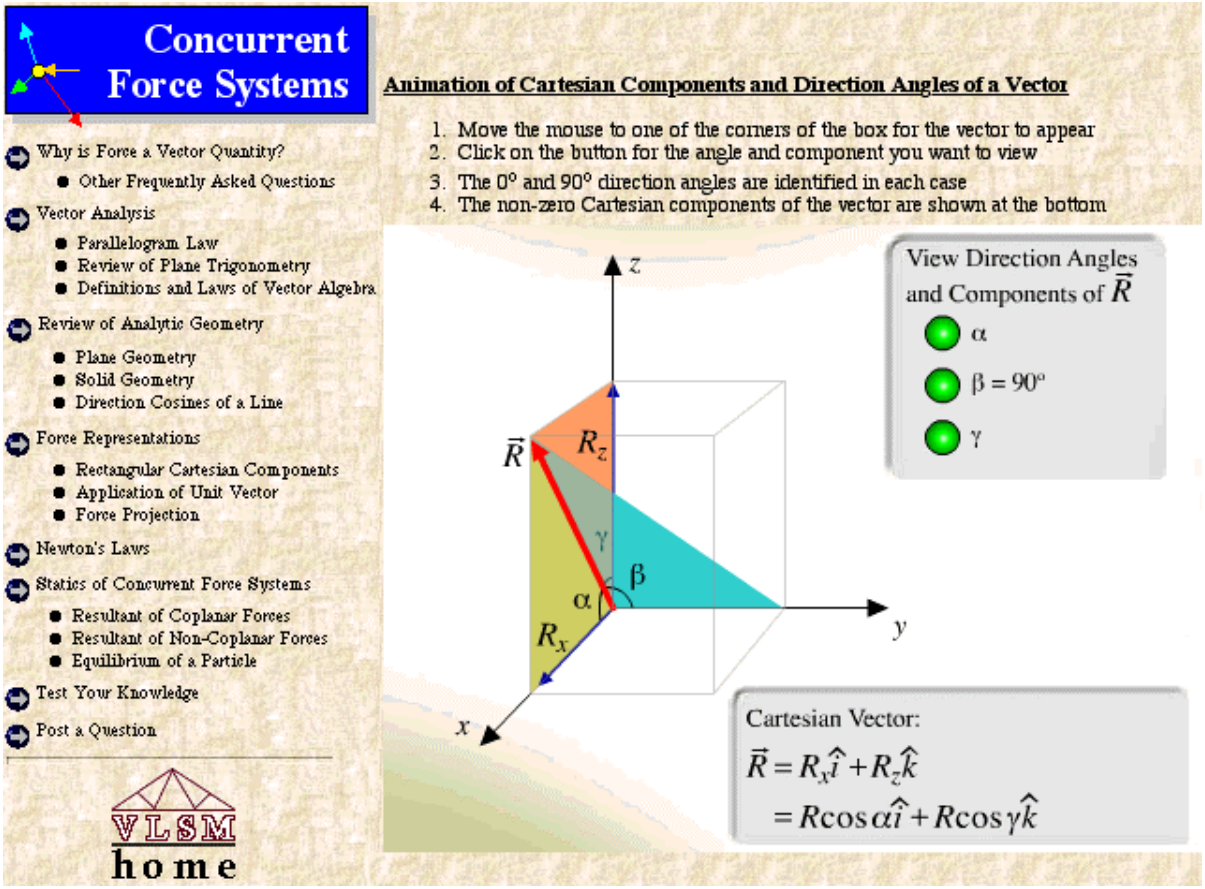

Fig. 1 Vector animation applet in the *Concurrent Force Systems* module

The educational value of these interactive example problems is in the way the changes to the problem data are captured in the solution sequence enabling the student to see the effect of each parameter on the final answer. These examples also help students in developing their intuition. The ability to view the graph from different angles and at different magnification factors brings the beneficial element of visualization to the description of the solution. Figure 2 shows a LiveMath® example problem on equilibrium of a particle under a non-coplanar concurrent force system.

Another key feature of the CIMS for Statics in VLSM is the Java based Shape Design and Analysis Tool (S-DAT) in the *Geometric Properties of Shapes* module. The modeling tool in S-DAT can be used to draw two-dimensional composite shapes of varying degrees of complexity.

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The built-in software then calculates all the geometric properties of the model including its centroid location, moments of inertia, radii of gyration, etc.

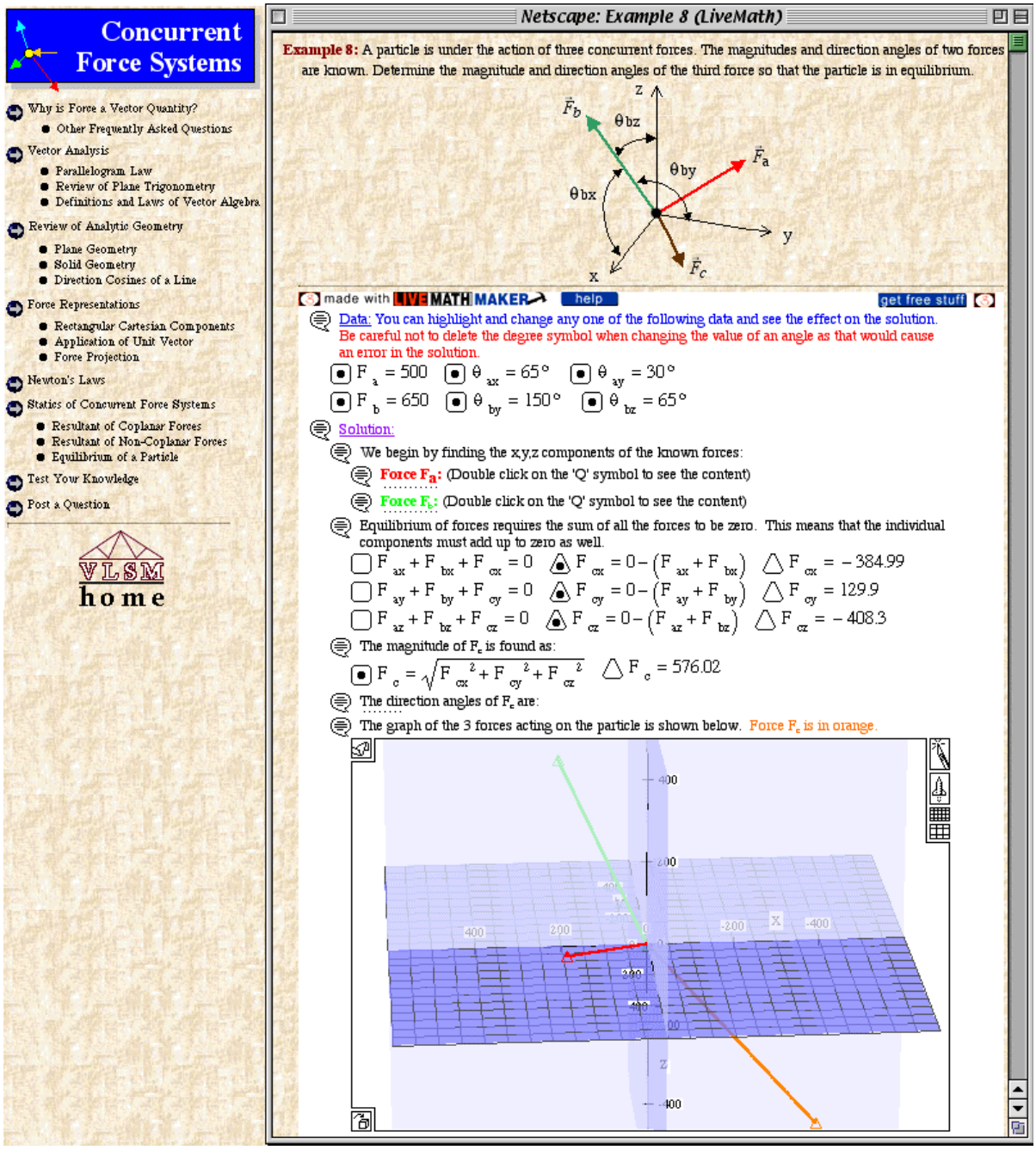

Fig. 2 A LiveMath® example problem in the *Concurrent Force Systems* module

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Testing has a significant role in education, and in the case of CIMS, such an assessment tool can help to determine how well the student has understood the concepts in solid mechanics and how well he or she can apply the methods of analysis to the solution of a given problem.

The test-your-knowledge exercises in each module represent a collection of problems to which the student must supply the answers. In some exercises the correct answers must be selected from a set of multiple choices while in others some hand calculations are needed before submitting the answer. The built-in response system praises the student for finding the right answer, and—more importantly—provides hints when the answer to a question is wrong.

A more detailed discussion of design and analysis tools and test-your-knowledge exercises can be found in Ref. 4.

III. Assessment

A study was conducted in Fall 2000 semester to assess, for the first time, the effectiveness of VLSM on students' learning of Statics. The author taught two out of five sections of EM2413. At the beginning of the semester, with the help of a survey and a search of university database of registered students, a comparison was made between the students in the two sections to identify significant differences in the population samples. The demographic information collected included some key indicators such as grades in the two prerequisite courses (i.e., Physics I and Calculus II), ACT/SAT scores, accessibility to computers and the Internet, and the level of interest in using CIMS containing a specified set of features.

The collected data indicated that the two population samples have similar characteristics with no significant difference in any of the key indicators. Hence, Section 1—with the larger number of students (31)—was chosen as the experimental group and Section 2 with 25 students as the control group. Table 1 shows the degree programs sought by students in the two sections of EM2413.

Table 1 Engineering degrees sought by students in the two population samples

Section	ASE	CE	CHE	EE	IE	ME
1	4	13	3	0	0	11
2	5	6	3	2	3	6

The university policy on the use of human subjects in research required the full consent of students prior to engagement in this study. This policy also required that students be given total freedom to stop participating in this study at any time during the semester, and that someone other than the instructor be in charge of collecting the data. These requirements were meant to assure students that their participation or lack thereof will by no means affect their grades in the course. By signing the consent form, a student would agree to have his or her VLSM sessions monitored by an automated system with no knowledge of the instructor until after the end of the semester. Students also pledged not to share their access codes with those in Section 2 (i.e., the

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control group). The examination of these consent forms, after the end of the semester, indicated that all 31 students had agreed to participate in this study.

The student participants were issued individual access codes to VLSM by the system administrator, and a system was set up to keep track of their login activities to determine the pages each visited and the frequency of such visits. This information would help to establish a possible correlation between the use of VLSM and performance in the course. In addition to giving students in Section 1 full access to VLSM, the author used VLSM in about 20% of his lectures to make use of features such as Flash/Shockwave® animation applets or LiveMath® example problems to enhance the discussion of particular topics in the course.

To avoid any bias in the study, both sections received identical homework assignments, tests and final exam. The assignment and test problems were selected by the author whereas the problems on the final exam (common for all sections of Statics) were selected by the team of instructors teaching the five sections of Statics during the Fall semester. The problems in all assignments were chosen from the exercise sets in the textbook. All assignments were graded by a teaching assistant, all tests were graded by the author, and the final exams were graded by all three instructors with each grading a specific number of problems for all students.

Students in the two population samples were evaluated based on their performance on nine assignments, three in-class tests, and a final exam. A summary of student grades is presented in Table 2. The scores in the second column are the mean and standard deviation (inside parenthesis) values for all nine assignments together. In Section 1, the class average grades on the nine assignment sets ranged from 72.1 to 91.7 and in Section 2 from 70.6 to 94.1. The class average grade and standard deviation on each test as well as the final exam are shown in the remaining columns of Table 2. While the performance on homework assignments and test 3 were nearly identical, students in Section 1 (experimental group) did noticeably better than those in Section 2 (control group) on tests 1 and 2 and the final exam.

Table 2 Grade means and standard deviations in the two population samples

Section	Assignments	Test 1	Test 2	Test 3	Final Exam
1	85.0(7.2)	67.9(15.7)	77.7(19.0)	69.7(17.6)	72.7(19.6)
2	84.0(8.2)	57.6(18.6)	68.1(14.2)	69.1(18.0)	68.9(13.3)

The course grade distributions in the two sections are presented in Table 3. It is evident that as a group, students in Section 1 did better than those in Section 2, but is this because of VLSM or other factors?

Table 3 Course score distributions in the two population samples

Section	A	B	C	D	F
1	5	10	7	6	3
2	1	6	11	2	5

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To answer this question, students in the experimental group were asked to fill out a survey and answer a number of questions near the end of the semester. This anonymous survey contained 27 questions, and it was designed to gauge students' assessment of VLSM including the features they liked or disliked and areas on which future enhancements should be focused. Also, the server login file containing data on student access during the semester was examined to identify the students who used VLSM. A summary of the survey results and VLSM login data is described next.

Of 31 students, 27 (87%) responded to the survey. The survey questions and responses are as follows:

- *How helpful to you was the instructor's use of VLSM in class?*
  not helpful (2) somewhat helpful (9) fairly helpful (10) very helpful (5)

- *How frequently should the instructor make use of VLSM in class?*
  not at all (3) less frequently (1) same frequency (17) more frequently (5)

- *Did you ever use VLSM outside of class during the semester?* yes (16) no (11)
  If no, skip to last question.

The response to the question on the use of VLSM outside of class was rather disappointing. However, the examination of the server login file indicated that of 31 registered students, 20 had successfully logged into VLSM during the semester. It also showed 3 other students as having tried to access VLSM, but were unsuccessful because of entering wrong access codes. Some of the reasons as to why a large portion of students did not use VLSM can be found in their comments, which will be discussed later in this section.

The students who indicated they had used VLSM outside of class were asked to answer several more questions.

- *How was the accessibility of VLSM for you?*
  easy (8) neither easy nor difficult (5) difficult (3)

- *Did you find VLSM a useful supplement to your lecture notes?*
  not useful (1) somewhat useful (9) fairly useful (2) very useful (4)

- *Did you find VLSM a helpful supplement to the textbook?*
  not helpful (1) somewhat helpful (7) fairly helpful (5) very helpful (3)

The subsequent 20 questions were on specific modules of VLSM. A summary look at the questions and responses is presented next. An average of 10.5 (66%) students indicated that they had looked at all four available modules while an average of 5.25 (33%) students said that they had not looked at one or more modules. Asked if they found the contents helpful to their understanding of related concepts, an average of 4.25 (27%) students said somewhat helpful, 4.25 (27%) students said fairly helpful while 1.5 (9%) students said very helpful. Asked if the

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contents were helpful in doing their assignments, an average of 1.5 (9%) students said not helpful, 3.25 (20%) said somewhat helpful, 4.25 (27%) said fairly helpful, and 1.75 (11%) said very helpful.

As to what changes they would recommend, students asked for more textbook type and LiveMath® example problems as well as more test-your-knowledge exercises, especially in the *Concurrent and Non-Concurrent Force Systems* modules. A few also asked for the expansion of the list of frequently asked questions in each module.

Other questions and responses are as follows:

- *Did you feel less inclined to attend class as a result of having access to VLSM?* yes (1) no (15)

- *What did you like the most about VLSM?*
  - *Using LiveMath and being able to change variables to check my calculated predictions.*
  - *The way, on some problems, you could work a homework problem to see if it was correct.*
  - *It was available after hours.*
  - *VLSM was a good overview of the basic topics studied in class. The examples were clear and easy to follow.*
  - *The examples helped a lot.*
  - *Listening to the lecture without taking notes.*
  - *It was helpful when the instructor used VLSM in class.*
  - *If I didn't understand a concept from the lecture, I would go to it to help me understand the concept. Also I used it to check some of my answers to homework.*

- *What did you like the least about VLSM?*
  - *I don't feel I learned anything more because of it.*
  - *Not much different from book, as far as, stating theoretical info. I think it would be a little easier to digest and understand if the information was given in a practical sense.*
  - *Needed more examples that are more like homework and tests.*
  - *I did not care for the LiveMath examples.*
  - *Difficulty downloading programs to run example problems off campus.*
  - *Was very difficult to access b/c pages were so large, took some time to load.*

- *What is your overall impression of VLSM?*
  poor (0) fair (5) good (9) excellent (2)

In the last question, all students were asked to *write their general comments*. Those who had used VLSM outside of class wrote:

- *I don't think it's necessarily a bad idea, but I would rather go over everything in class. That's just my preference, I suppose.*
- *Really enjoyed using VLSM. It's a good addition to class time and homework assignments. Wish I had more time to experiment with VLSM throughout the semester.*
- *Overall I found VLSM fairly helpful. VLSM was not my first source in understanding the topics presented in class, but was a good resource when a topic was not totally clear.*

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- *VLSM helped me a lot during the first part of the course because I wasn't used to the information or problems. Once I started thinking in a statics frame of mind, I found I used VLSM less and less. I believe it helped me to get an A instead of a B out of this course.*
- *I was unable to download the program to run the LiveMath examples, which I thought would be very helpful.*

As mentioned previously, 11 out of 27 respondents said they did not use VLSM outside of class at any time during the semester. The following comments shed some light as to what some of the reasons were:

- *It's a neat use of computers but I would rather learn by using a textbook and working problems by hand.*
- *I use Linux on my machine, and the lack of necessary plugins for Linux prevented me from using VLSM.*

Other comments by students who did not use VLSM were:

- *VLSM seemed to be a well made site that appeared to be something that potentially could be very helpful for many students.*
- *Using VLSM made examples quicker and easier to see.*
- *I think this program should be used as an extra studying tool outside the classroom but not as a method of teaching the material. Watching the computer explain the steps with little input from the instructor is much less helpful than using example problems or some other method with the instructor doing most of the work so we can see step by step.*
- *I found VLSM helpful in learning about 2D trusses because it quickly illustrated the member forces internal, and external in the trusses. I was only exposed to minimal use of VLSM, but it seemed to be more useful for graphical explanations of problems than algebraic, because of visibility on the classroom monitor.*
- *VLSM was a good tool to use to demonstrate what is being taught in class. I believe that it could best be used by the student outside of class instead of as a main teaching tool during* class.

The examination of the server login file showed a significant variation in students access ranging from 18 to 1359 requests with a mean of 374 and standard deviation of 414. These server access requests represent the number of pages viewed by a given student during the whole semester.

Table 4 Comparison of students who did and did not use VLSM outside of class in the experimental group (Section 1)

Student Group	Assignments	Test 1	Test 2	Test 3	Final Exam
Used VLSM	87.1(8.3)	67.5(15.7)	79.5(15.7)	73.2(15.4)	77.1(13.7)
Did Not Use VLSM	83.7(7.3)	73.8(11.2)	74.7(24.1)	70.7(14.7)	75.8(12.2)
Whole Class	85.0(7.2)	67.9(15.7)	77.7(19.0)	69.7(17.6)	72.7(19.6)

Table 4 compares the grade means and standard deviations of students who did and did not use VLSM outside of class. It is important to note that all students in the experimental group were

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exposed to VLSM during in-class demonstrations. With the exception of test 1, students who used VLSM outside of class did better.

The comparison of course grades in Table 5 seem to indicate a clear advantage of those who did use VLSM over those who did not. However, since the experiment was not conducted in total isolation from other factors, it is difficult to make a direct correlation. Those students who failed the course, had 6 to 18 class absences, had very poor assignment submission record, and obviously did not do well on the tests and the final exam. Although these students did refer to VLSM, that alone could not make up for other serious deficiencies.

Table 5 Course score distributions of students who did and did not use VLSM outside of class in the experimental group (Section 1)

Student Group	A	B	C	D	F
Used VLSM	4	6	5	2	3
Did Not Use VLSM	1	4	2	4	0

IV. Summary

This paper described the use and effectiveness assessment of the computer based instructional materials for the first course in engineering mechanics (Statics) taught at Mississippi State University. Four modules were developed and placed online in the Virtual Laboratory for the Study of Mechanics for students to access as a tutorial outside of class.

To assess the effectiveness of the tutorial, a study was conducted by comparing the students' performance in two different sections of the Statics course taught by the author with only one section having access to VLSM. Although it is difficult to make a direct correlation, the results of this study support the notion that the effective use of computer technology can be beneficial to students. The data on students' login activities along with the anecdotal information collected in a survey indicate that for most students VLSM had a positive impact and that future developments and enhancements should make it a more valuable resource for students taking Statics.

Currently, effort is underway to complete the *Friction* module and to expand the number of LiveMath® examples and test-your-knowledge exercises in all modules. The comments made by students who were exposed to VLSM during Fall 2000 semester as well as those of several faculty members with experience in teaching Statics will be used to direct the future development and enhancement efforts.

Acknowledgment

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Bibliography
1. Jack, H., "A Paperless (almost) Statics Course," Proceedings of the 1998 ASEE Annual Conference, Seattle, WA, June 21-24, 1998.
2. Li, J. and Lee, M.Y., "Teaching Mechanics with Multimedia Tools," Proceedings of the 1999 ASEE Annual Conference, Charlotte, NC, June 20-23, 1999.
3. Gramoll, K., "Teaching Statics Online with only Electronic Media on Laptop Computers," Proceedings of the 1999 ASEE Annual Conference, Charlotte, NC, June 20-23, 1999.
4. Rais-Rohani, M., "VLSM: An Online Tutorial for Solid Mechanics," *Computers in Education Journal*, Vol. XI, No. 1, January-March 2001.

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