Session 2468

CREATING A VISUALLY RICH, ACTIVE LEARNING ENVIRONMENT FOR TEACHING MECHANICS OF MATERIALS

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Abstract

For the last 4 years we have been working to develop a suite of tools to enhance our Introduction to Mechanics course here at the US Air Force Academy (USAFA). The course is taught to over 1000 students per year and covers standard Mechanics of Materials content at a basic level. The course is required of all cadets at USAFA, so most of the students who take the course are not engineering majors. The objectives associated with this research program are four-fold: 1) to reach a student population that has a great variety of learning styles, 2) to increase overall motivation in the topic area, 3) to create a more active learning environment and 4) to present problems which are open ended and therefore have no single "right" solution. We endeavored to do this beginning from a sound pedagogical foundation and guided by a formalized, multifaceted assessment program. We are attempting to achieve the 4 objectives through the use of a multimedia tool in development called Vis-MoM (for Visual Mechanics of Materials). This interactive multimedia courseware is designed to span the space of learning styles by providing extensive visualization and interactive content as well as thorough, step-by-step example problems. We have previously shown that these particular features of our courseware correspond well to a full span of learning styles as illuminated by the Myers Briggs Type Indicator. Vis-MoM is designed to increase motivation through extensive use of real-world examples and an interactive, thought-provoking learning environment. Finally, we show the open-ended nature of the subject by inclusion of open-ended design problems for each topic. Three separate assessment techniques have been used to evaluate the effectiveness of the interactive multimedia courseware. Our assessment indicates the students' perception of the learning tool is quite positive. However, there are some notable exceptions to this, which are detailed in the paper. In addition, our assessment shows that the visual modules did enhance understanding when compared to a traditional lecture format. This paper should provide others who are attempting to enhance mechanics courses with important information relevant to their development, implementation, and assessment processes.

1. Introduction

The Fundamentals of Mechanics course at the United States Air Force Academy (USAFA) was used as a testing ground for assessing the effectiveness of an interactive multimedia courseware tool called Vis-MoM (for Visual Mechanics of Materials). The course combines two basic topics in engineering mechanics (statics and strength of materials) at an introductory level and is mandatory for all students at USAFA **regardless of major**. Typically, the concepts of deflection, stress, and strain in objects caused by torsion, bending, combined loading, and to a lesser extent, axial loading, are difficult for students to grasp. For these topics, "visualization modules" were developed to bring an enhanced learning experience into the classroom in the hopes that improved comprehension of the basic principles would result. The objectives associated with this research program are four-fold: 1) to reach a student population that has a great variety of learning styles, 2) to increase overall motivation in the topic area, 3) to create a more active learning environment and 4) to present problems which are open ended and therefore have no single "right" solution. To date the study has encompassed 4 years with assessment results from each affording a directed evolution of the in-development courseware to its current state.

1.1. History

The initial study[1], completed in fall 1998, attempted to correlate the effects of the visualization modules with a student's learning preference or personality type. Learning preferences were determined from an assessment method known as VARK, while the personality type designation was obtained using the Myers-Briggs Type Indicator (MBTI).

The follow-on work[2], completed in fall 1999, focused solely on the effect of the multimedia visualization modules on the students' learning. The assessments produced during this study provided two noteworthy results: 1) students tend to quickly adopt a professor's perception of the utility of the modules and 2) students indicated that they disliked the use of these visualization tools in the classroom.

The fall 2000 study[3] was designed to address and eliminate the students' negative perception of the multimedia visualization modules and further isolate the modules' pedagogical effect. To do so, follow-on research was conducted using the same process, visually reinforcing the same engineering concepts but altering the visualization modules and assessment plan. It was hypothesized that the students' negative response to the multi-media presentations in 1999 was due to three main factors: 1) the students were not aware that concepts presented were testable, 2) the visualizations involved too much detail on the finite element method (FEM) and 3) the students mimicked the negative perception from one professor. Therefore, the fall 2000 work reflects data resulting from three changes to the fall 1999 experiment: 1) the professor who had a negative perception of the visualization modules chose not to participate in the fall 2000 study, 2) students were clearly informed that this material would be covered on the next exam and 3) the extraneous finite element analysis details were removed. Although these changes may appear minor, such subtleties are shown below to have a substantial effect on the effectiveness of the visualization modules as measured by student perceptions as well as increased learning.

The most recent study (fall 2001) demonstrated a significantly different result in student perception than recorded in previous years. Four classrooms of students, 104 cadets, were exposed to the software during class lecture during the semester and the software was available for individual use at the very end of the semester. In the classroom, the instructor utilized the multimedia aspects of the courseware to reinforce concepts of deflection, bending, and axial loading. Informal classroom feedback about the courseware was initially negative. Students found the software a waste of class time, citing that they were more interested in solving required homework examples. Another issue was that the instructor had difficulty integrating the courseware into the lecture because of differences in the order of information presented in the textbook and the courseware. After several lessons the instructor ceased presenting the courseware during lecture. With three weeks remaining in the semester the courseware was reintroduced to the class as a "good" review tool for the final exam. The courseware was made available for all of the students to use individually outside of class. Before the final exam, students were requested to evaluate the software using a feedback form discussed later. Students recorded very favorable marks and positive comments. The results are discussed in the following sections.

1.2. Courseware Development

The multimedia courseware used for this study is a module-based interactive learning program currently in development by MSC Software[4, 5]. The visualization modules are designed to provide extensive multimedia exposure for the three foundational application areas covered in a Mechanics of Materials (MoM) course: 1) Axial, 2) Bending and 3) Torsion. The primary focus of Vis-MoM is to provide extensive multimedia enhancement to the fundamental concepts in these 3 areas. This is done in the context of addressing the 4 objectives to provide an overall enhancement to the learning environment. The areas of axial, torsional and bending loading are chosen because these are the three application topics that *all* MoM courses include.

Developed incrementally over the last 4 years, the Vis-MoM courseware encompasses over 100 multimedia pages, hundreds of pictures and graphics, numerous animations and movies, extensive interactions, detailed example problems, and user directed design problems. The courseware is designed for use by professors to enhance their lectures as well as by students while studying, doing homework or preparing for class or exams. Additional primary features include ease of use, intuitive navigation, interesting real-world example problems, open-ended design problems and overall program reliability. Each iteration in the development of Vis-MoM has been guided both by course assessment results and by pedagogical issues. The pedagogical issues considered include Bloom's taxonomy, the Kolb's cycle, scaffolding theory and learning styles as portrayed by MBTI and VARK results[6, 7]. Assessment for the courseware has been in the form of quantitative data obtained from assessment instruments specifically designed for this project and summarized in this paper. Assessment has also been in the forms of insightful suggestions from the professors and students who have used the various versions of Vis-MoM. In particular, this latest version has received extremely high marks by professors and students alike and has been quantitatively shown to enhance learning[8]. Details concerning the assessment instruments and the corresponding results are discussed below.

1.3. Assessing Results

The Vis-MoM courseware has been through a number of assessment/redesign/rebuild cycles as introduced in the program's history above. In this process, we have developed a number of assessment instruments specifically for this project. Assessment results indicate that the present form of the Vis-MoM courseware is well received by both professors and students. In addition, quantitative results indicate a significant increase in both short term and longer-term conceptual understanding when using the Vis-MoM courseware over standard lecture alone. The assessment instruments developed specifically for this program are as follows:

- 1) 30-second surveys: As a first assessment technique, student responses to each lesson were collected throughout the semester using this method.
- 2) Quick Quizzes: Immediately before and after the enhanced learning modules were presented, these "quick quizzes" were administered to measure short-term conceptual learning.
- 3) Exam Questions: As a third technique, the results of selected midterm exam questions were used to evaluate the longer-term effectiveness of the enhanced learning modules.

The details on our assessment program and the results are provided in this paper.

2. Visual Mechanics for Active Learning

2.1. Educational Objectives

From the outset, one of our primary considerations in the creation of Vis-MoM has been educational theory and learning styles. These pedagogical foundations have been used to guide the development and use of the courseware from the beginning. Of primary use have been the Kolb cycle, Bloom's taxonomy and the concept of scaffolding. In addition, we have attempted to engage the full breadth of learning styles as illuminated by both the students' MBTI and VARK scores. In concert with this foundation has been achievement of basic educational objectives, which would ensure the success of the desired goals of the project. The educational objectives as previously stated are: 1) to reach a student population that has a great variety of learning styles, 2) to increase overall motivation in the topic area, 3) to create a more active learning environment and 4) to present problems which are open ended and therefore have no single "correct" solution. We have endeavored to do this beginning from a sound pedagogical foundation and guided by a formalized, multifaceted assessment program. This interactive multimedia courseware is designed to span the space of learning styles by providing extensive visualization and interactive content as well as thorough, step-by-step example problems. We have previously shown that these particular features of our courseware correspond well to a full span of student learning styles. Vis-MoM is designed to increase motivation through extensive use of real-world examples and an interactive, thought-provoking learning environment. Finally, we show the open-ended nature of the subject by inclusion of open-ended design problems for each topic.

2.2. Visual Mechanics of Materials

The overall goal of Vis-MoM is to enhance learning of MoM through the creative use of multimedia. In order to meet this goal, numerous specific features have been designed into Vis-MoM. The following describes features designed into Vis-MoM and how they are related to our educational objectives and to pedagogical issues.

There is a built-in interrelationship between the text explanations, non-interactive visualization and opportunity for interactivity. Each fundamental MoM concept is presented using these 3 styles. The text usually provides details, the non-interactive visualizations promote the jump toward application and the interactivity promotes integration of knowledge and helps correct misunderstandings. This 3-fold style of communicating a concept attempts to span the range of learning styles and to reinforce conceptual understanding. Although there is not a 1 to 1 relationship, the flow from text to non-interactive visualization to interaction and feedback is intended to facilitate the transition to the higher levels in Bloom's taxonomy. With respect to the Kolb cycles, it also moves from "Abstract Hypothesis and Conceptualization" (text material) to "Concrete Experience" (non-interactive visualization) to both the "Reflective Observation" and especially the "Active Experimentation" (interactive open-ended problem) parts of the cycle[9].

The courseware's outline for each module follows the same four-part outline of :

- Why study that particular module's topic (e.g. "Bending")
- Visual Overview of topic
- Example Problem and
- Design Problem

This structure organizes the content in a simple way to increase efficiency and learning. Content is framed in terms of real world problems increasing motivation for learning. This is especially true for MBTI "S" types[7]. Assumptions used to develop the equations specific to each module are explained visually. Assumptions are critical to understanding applicability of the theory. Understanding that applicability is not universal is a move toward a higher level in the Bloom's taxonomy and is a "Reflective Observation" task in the Kolb cycle[9, 10]. Content which is logically subordinate to a previous topic branches off in the courseware from this parent topic. To avoid excessive layers of navigation, content that is not subordinate is organized with tabs on a single page to facilitate inclusion of additional information. This format, where page organization mirrors logical content organization, facilitates correct mental models of content. This is consistent with the concept of "scaffolding" as it applies to learning theory[9].

Each module in the program has been specifically designed with extensive use of colorful visualization by way of pictures, graphs, plots, animations, and movies. There are many interactive sections of Vis-MoM structured specifically to visually portray relationships between related content. A typical example of how learning is visually aided by the use of media in Vis-MoM is the page in the Axial/Visual Overview/Background section where the relationships between the 'material, loads and geometry' graphic and the 'stress, strain and deformation' graphic are interactively displayed as the user moves the cursor over the different pieces of the content as shown in Figure 1. This kind of interaction is designed specifically to use multimedia to develop connections (scaffolds) between the different pieces of the MoM structure. This is thought to produce longer-term retention of the material as well as to aid in applying the material beyond the context in which it is framed[9].

Vis-MoM uses a consistent, pleasing color scheme to ensure that text is visible, links are easy to locate and interaction is clearly identified. This visually pleasant environment reduces frustration and facilitates efficient learning. Additional examples of the visualization can be seen in Figure 2 - Figure 4.

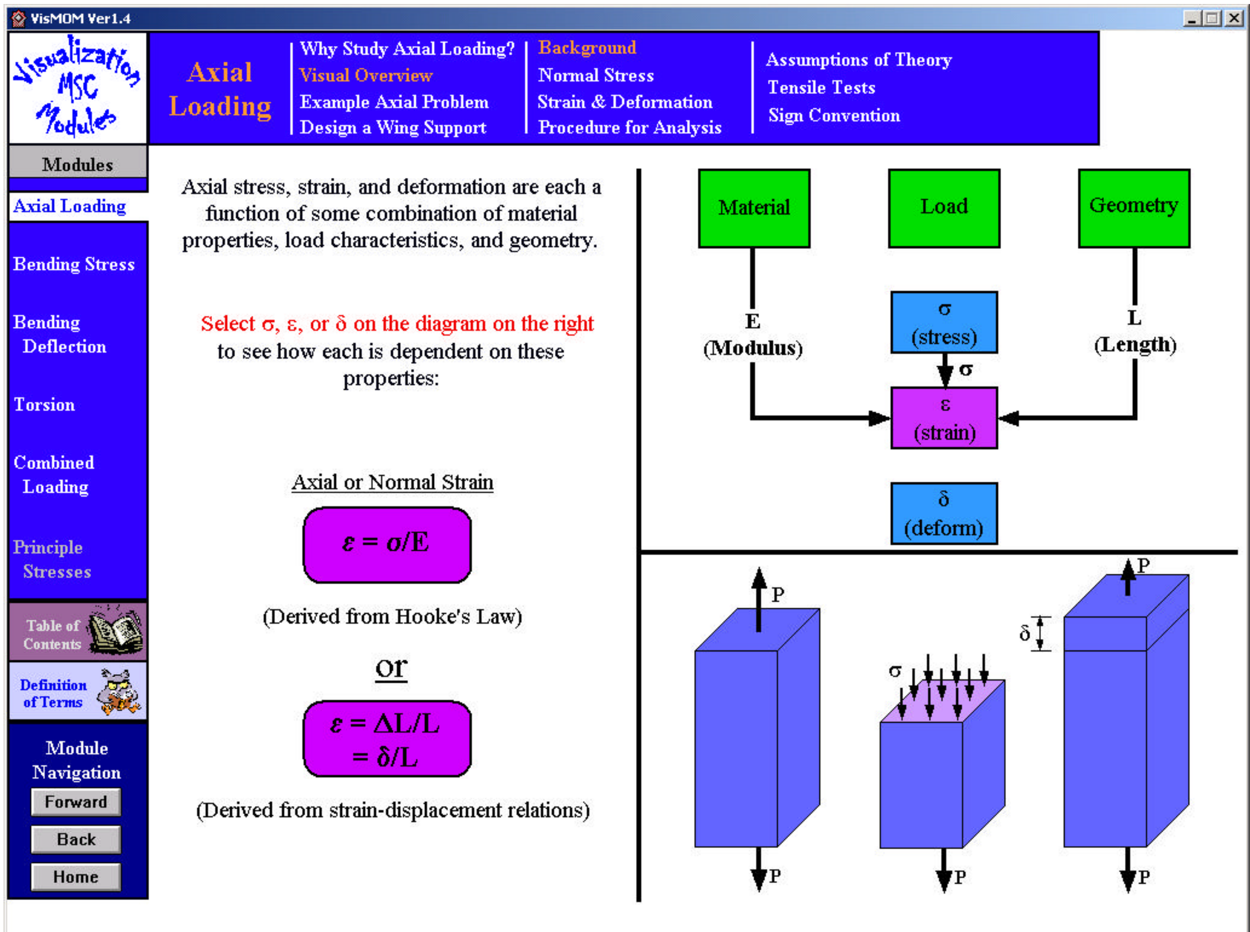

Figure 1. Example Visualization Content of Axial Module

Interactivity has been and continues to be a major focus in the development of Vis-MoM and its importance is continually reinforced by the assessment data received every semester. Interactivity and its integration to visualization are pervasive throughout the modules. Interactivity is focused on meeting specific learning objectives. For each topic, a select set of concepts are visually portrayed (e.g. the cross-sectional distribution of bending stress) and then interactively reinforced in the example problem and again in the design problem. This promotes increased conceptual understanding by repetition of fundamental principles while incrementally increasing the level of detail. This represents another implementation of the scaffolding learning theory. Interactive navigation through the modules is identical. A visual mapping of your location in the courseware is always visible on the top of each section. This feature also allows interactive navigation within Vis-MoM. This not only aids in quick navigation, but also continually keeps a conceptual map of the content before the user. We have found this type of "content map" to be especially valuable to MBTI type "T"s who like content organized in outline form[6, 7].

Sections of each module contain specific consideration of concepts, which are either fundamental to further understanding of basic concepts or are traditionally difficult to comprehend with out extensive study. Figure 2 below provides an example of this feature. This interactive demonstration allows students to experiment with virtual tensile tests of different classes of materials. Visualization of a virtual hardware test, which is often repeated in the lab, while observing development of the stress-strain curve provides a valuable link between theory and experiment and enforces the learning of this and similar foundational principles.

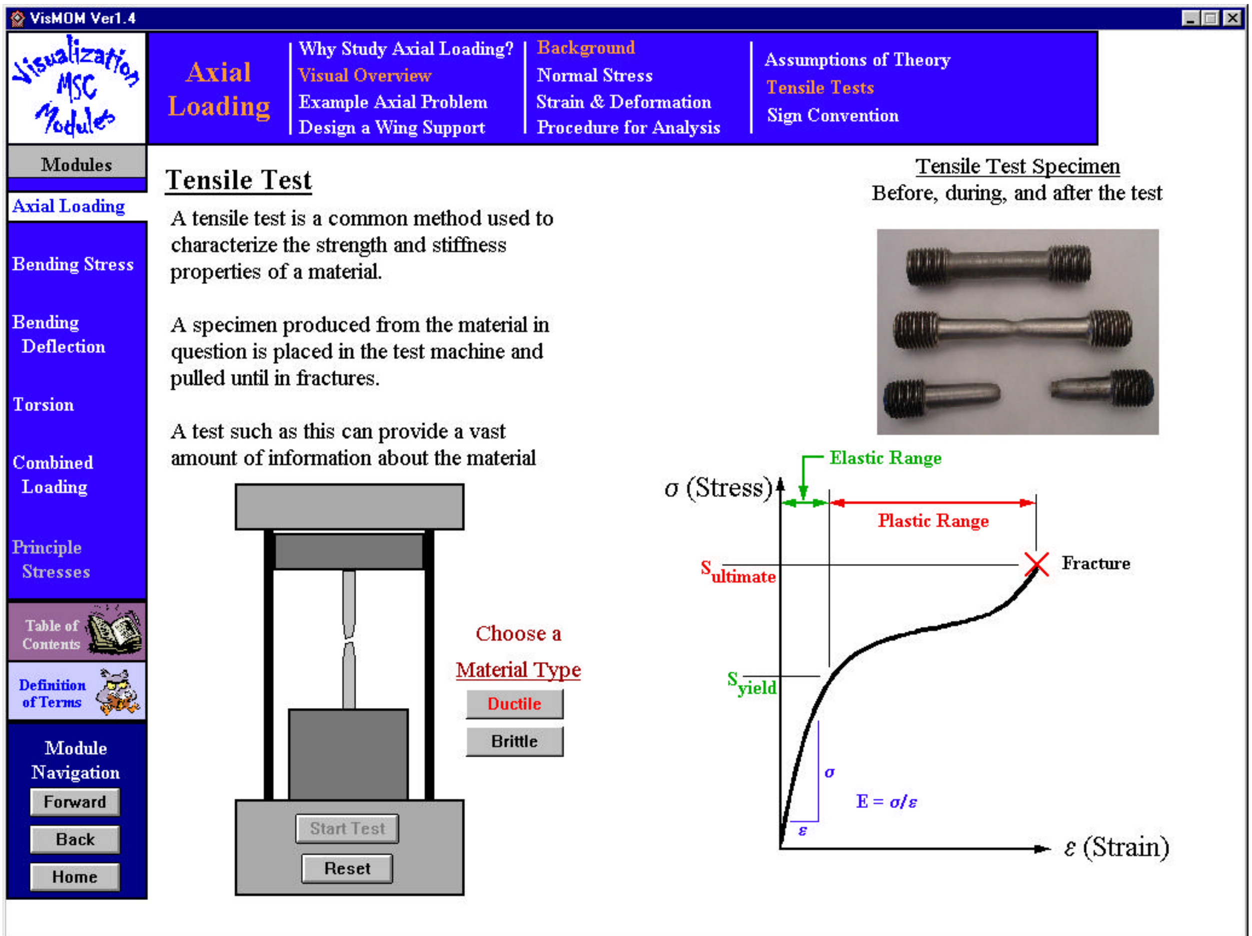

Figure 2. Interactive Tensile Test and Resulting Stress-Strain Diagram

A broad range of examples have been chosen encompassing areas such as mechanical, civil, aerospace and biomedical engineering. The effort to incorporate the interests of a broad range of students is intended to maximize the overall increase in motivation for learning. The text-based example problems provide feedback through extensive text solutions and visual (finite element based) representations of the solution in the form of stresses, strains, and deflections, depending on the nature of the problem.

Each example problem consists of a Problem Description followed by a series of step-by-step solution procedures complimented by extensive interactive graphics and navigation capabilities. This format allows to the student to proceed through the example at a pace and method best suited for their particular learning style. Figure 3 shows an example from the axial module.

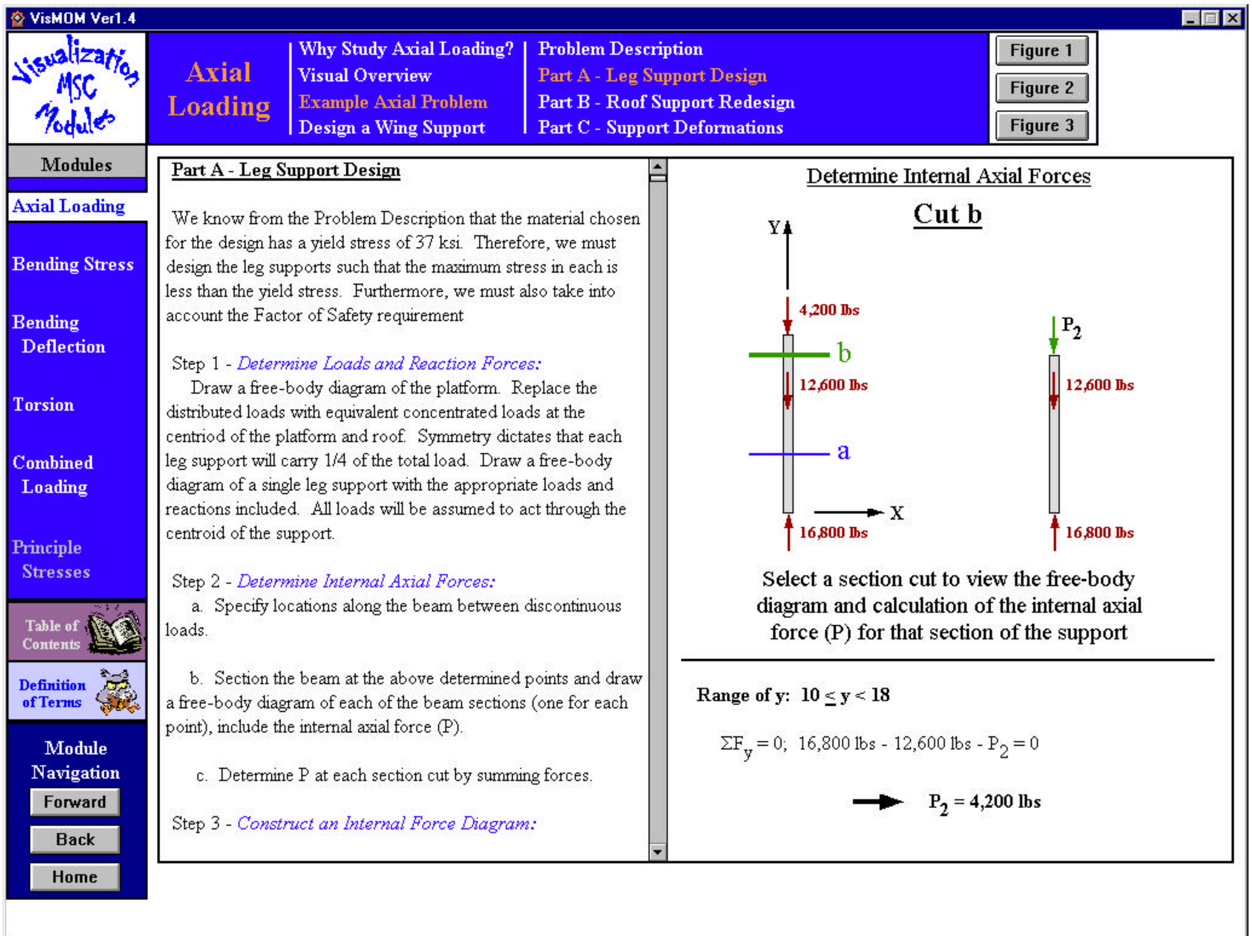

Figure 3. Example Problem Featuring Interaction and Step-by-Step Solution

The open-ended design problems with their immediate numerical and visual feedback are intended to more fully engage the student. This again moves toward higher levels in the Bloom's taxonomy and engages the visual learner (VARK type "V" and MBTI type "S"). It also corrects misunderstandings and reinforces both the "Reflective Observation" and especially the "Active Experimentation" parts of the Kolb cycle[9]. Immediate feedback is critical for increasing both understanding and motivation.

The open-ended design problem can be used as either an in-class exercise, a demonstration by the instructor, or an assignment to the students. These problems pose design criteria and then provide an interactive worksheet that allows students to select critical design values (like material properties, size and shape). The results of the students' selections can be seen in performance values (most often including stresses, deflections, factor of safety, and cost) shown both numerically and visually. Figure 4 shows an example of a design worksheet in which a specific design has been chosen by selection of a structural material and specification of the structures' cross-sectional geometry. The results are shown in the form of a visual plot of the axial deflection of a strut and the numerical values of specific design parameters.

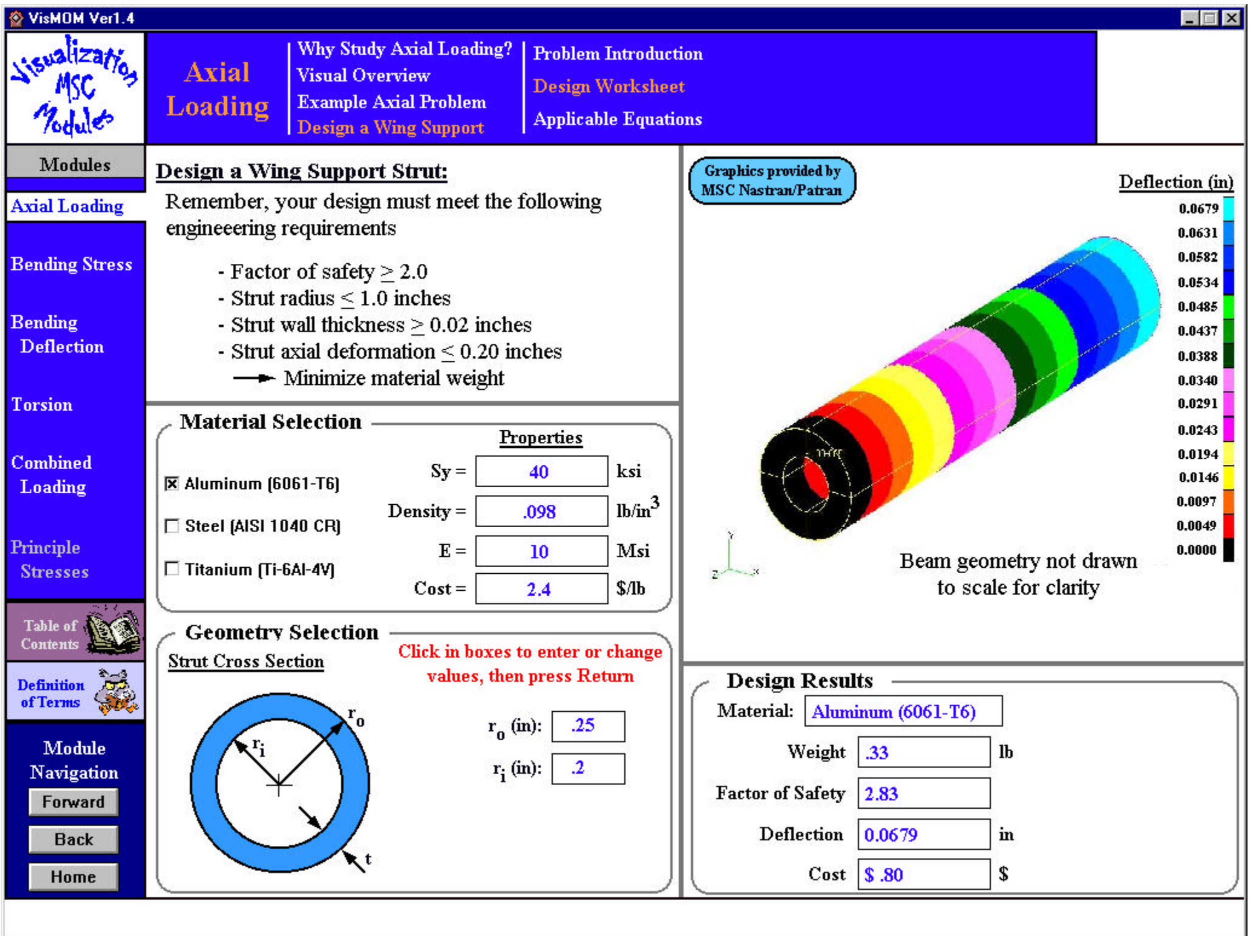

Figure 4. Axial Module Design Problem Featuring One of Many Solutions

2.3. A Measure of Success

2.3.1. Assessment Strategy Introduction

Throughout the study (i.e. from fall 1998 through present), three different assessment techniques have been used to determine the effectiveness of the modules as used to augment lectures: 1) 30-second surveys taken after each lecture; 2) quick quizzes taken before and after lectures presented using the modules; and 3) specific exam questions designed to measure students' understanding of the concepts covered in the modules. The use of three different assessment tools accomplishes two things. First, the use of a variety of tools reduces the "noise" in the results simply by creating redundant measures. Second, the different tools allowed measurement of different components of effectiveness. Table 1 shows the different aspects measured by the different assessment tools.

Table 1. Uses of the Assessment Tools

ASSESSMENT TOOL	WHAT THE TOOL MEASURES
30-Second Surveys	1. Did students find the lectures which had modules more interesting than the lectures with no modules? 2. Did students indicate that the lectures with modules were better learning experiences than the lectures without modules? 3. Did students find the content explained by modules easier to apply than content with no module? 4. Were the students more motivated to explore topics further if the topic was presented with a module?
Quick Quizzes	1. Which type of content helped the students answer a conceptual question the most—a visualization module or a classic lecture style with traditional example problems? 2. Does having different professors potentially affect the results?
Exam Questions	Did the modules help the students perform better on the exam?

Obviously neither the use of multiple assessment instruments nor the specific instruments shown above are unique contributions to the assessment literature. The reason for documenting the specifics of the assessment strategy is to provide a context for the various attempts to gain understanding into the true potential of the visualization modules.

2.3.2. The 30-Second Surveys

2.3.2.1. The 30-Second Survey Instrument

The 30-Second Survey currently being used has been iteratively developed over the last seven semesters. The original survey, used for a previous study[6], asked only for MBTI type and overall lecture rating (recall previous studies had been done to correlate effectiveness with a student's personality type designated by MBTI). In order to gain additional insight into the effectiveness of the modules, the surveys have been refined to obtain information about the students' perception of interest, learning, applicability, and motivation for future exploration. In addition, MBTI types have still been recorded for possible future study. This survey was given after each lecture and took about 30 seconds for students to complete. Figure 5 shows the content and form.

30-Second Survey **EM120 - FALL 1999**
Lesson #: _____
MBTI Type: _______
Please rate the following statements on a scale from
1 to 10 (1 - very untrue; 10 - very true):
___ 1. Today's class kept me interested.
___ 2. Today's class was a good learning experience.
___ 3. This class prepared me well to apply today's
concepts to problems.
___ 4. This class motivated me to further explore today's concepts.

Figure 5. 30-Second Survey Form

2.3.2.2. 30-Second Survey Assessment Results

In order to measure the effect of the module-based content in a generic manner, the data was reduced as follows. Average values (and standard deviations) were obtained for each question on the survey for every lecture. The results for the four questions were averaged for each lecture to produce an "over-all student perception" for each lecture. The data is plotted for the fall 1999 and the fall 2000 studies in Figure 6 and Figure 7, respectively. It is clear from a visual inspection of Figure 6 and Figure 7 that the perception of the multimedia lectures was much closer to the mean in 2000 than in 1999.

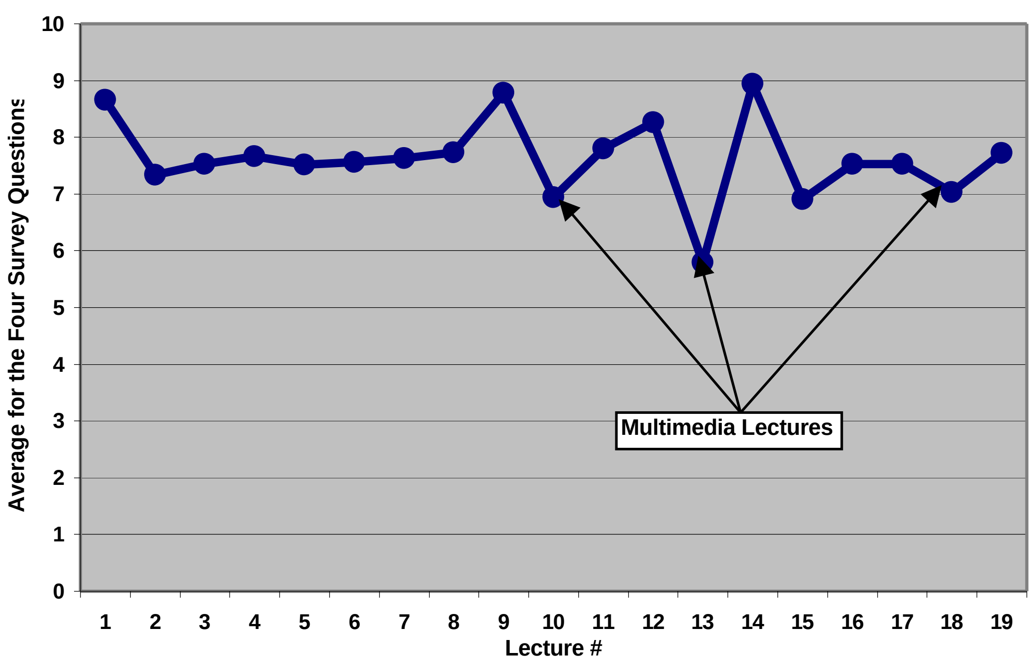

Figure 6. Fall 1999 30-Second Survey Results for Each Lecture

Based on these fall 1999 results (Figure 6), the students were asked for more feedback on the modules to pinpoint the source of the more negative responses. That source seemed to center around three major problem areas with the multi-media presentation: 1) the students were not as attentive to the material presented because it was not clear that the concepts were going to be tested, 2) some of the advanced analysis and theory (based on FEM) proved to confuse the students and 3) one of the three professor's negative perception of the modules affected student perception. As a result of these findings, these problems were addressed in the fall 2000 study.

Specifically, in the fall 2000 study students were clearly told before the visualization modules were presented, that the concepts taught were definitely relevant to the up-coming exam. The testing would be in the form of multiple-choice questions designed to evaluate students' conceptual understanding. As mentioned above, such an emphasis can have a drastic impact on student response and involvement, especially in a USAFA core course. Second, the mathematical and mechanical background to FEM (the advanced analysis technique) was removed from the visualization modules to place more emphasis on the fundamental mechanics concepts. FEM-developed stress plots were still used to illustrate the mechanics concepts, but without the background and theory which had been labeled by the cadets as counterproductive. Finally, the professor who had a negative perception of the visualization modules chose not to participate in the fall 2000 study. Results of the fall 2000 study, which reflect the changes just noted, are shown below in Figure 7.

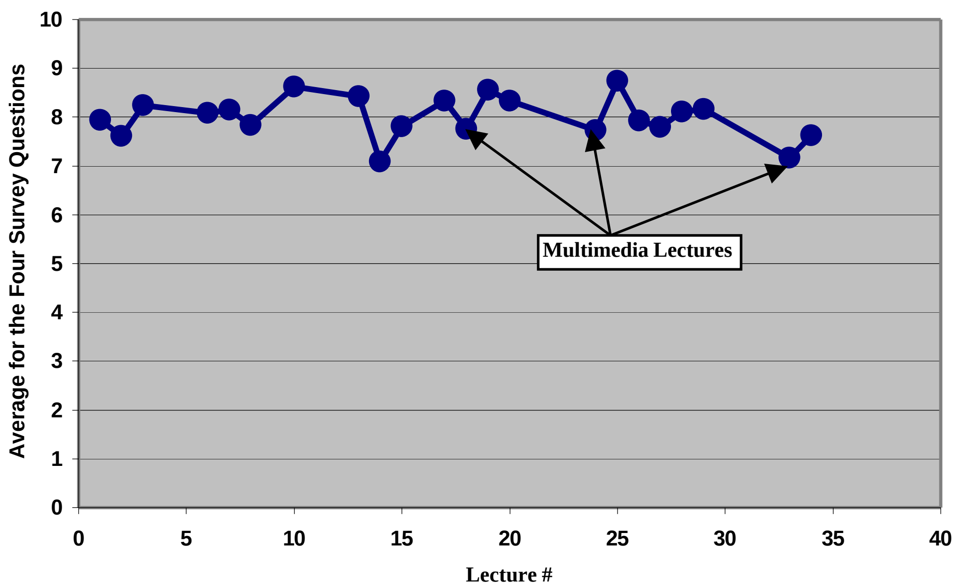

Figure 7. Fall 2000 30-Second Survey Results for Each Lecture

Means and standard deviations were then isolated for the lectures containing the multimedia based enhancement modules. Next, overall averages were found for the lecture-only lessons and for the multimedia lessons. Table 2 and Table 3 show (for fall 1999 and 2000 semesters, respectively) the overall averages for a normal lecture style lesson compared to those of the multimedia lessons, as well as the number of data points used in the tabulation. Table 2 shows the average drop in "satisfaction" for the multi-media lessons is between .50 and .69 standard deviations for the fall 1999 study as compared to a drop of only between .19 and .39 standard deviations for the fall 2000 results (Table 3).

Table 2. Fall 1999 Means for 30-Second Survey Results

Survey Question	**Normal Lecture (1446 Data Points Used)**	**Multimedia Lecture (173 Data Points Used)**	**% Change**	**# of Standard Deviations Change**
Q1: Lecture was interesting?	7.91	6.67	-15.6%	-0.64
Q2: Lecture helped me learn?	8.04	6.78	-15.6%	-0.69
Q3: Lecture helped me to apply material?	7.8	6.62	-15.2%	-0.62
Q4: Lecture motivated me to explore subject further?	6.97	5.68	-18.5%	-0.50

Table 3. Fall 2000 Means for 30-Second Survey Results

Survey Question	**Normal Lecture (564 Data Points Used)**	**Multimedia Lecture (93 Data Points Used)**	**% Change**	**# of Standard Deviations Change**
Q1: Lecture was interesting?	8.11	7.38	-8.9%	-0.39
Q2: Lecture helped me learn?	8.12	7.68	-5.5%	-0.25
Q3: Lecture helped me to apply material?	8.15	7.68	-5.8%	-0.27
Q4: Lecture motivated me to explore subject further?	7.57	7.18	-5.1%	-0.19

As evidenced in the tables above, although students' perceptions of the modules rose significantly between 1999 and 2000, it still remained slightly below the mean even in the 2000 study. A qualitative student assessment was conducted to pinpoint the elements of the multi-media that the students still did not like. It appears that the primary reason for the remaining negative impression of the modules was that the FEM-based stress plots took significant time and effort to comprehend. With virtually none of the students ever having been exposed to FEM, the multi-colored stress distribution needed significant instructor explanation before the concept was understood. While the FEM theory and methodology portions had been removed, the students still looked at each module negatively when they saw colors distributed along an object. So while the students did not *despise* the modules, they definitely did not prefer it over standard instruction. Possibly, if the potential that the modules appear to provide to increase exam performance (as shown in Table 6) was made known, the difficulty in understanding the stress distributions would seem insignificant.

During the fall 2001 semester we continued both our assessment and development of the Vis-MoM program by further investigating the specific areas of the courseware that were viewed as both positive and negative from the students perspective. The form shown in Figure 8 was developed in an attempt to gain information on how the students perceived the potential benefits of the courseware in the framework of their individual study methods.

Feedback on Multimedia Courseware

The multimedia courseware you have used is being considered for use with various textbooks and/or as a standalone study aid. Please answer the following 6 questions to help us refine this courseware.

SCALE: 0 = Statement is very inaccurate
1 = Statement is mostly inaccurate
2 = Statement is 50% accurate
3 = Statement is mostly accurate
4 = Statement is very accurate

STATEMENT	**0 – 4 RATING**
Q1: The courseware helped me understand the content.	
Q2: The courseware motivated me to study this topic by showing me applications.	
Q3: I believe the courseware would help me study for the exam.	
Q4: The courseware made the lecture more interesting.	
Q5: The courseware helped me visualize the basic mechanics.	
Q6: I believe the courseware would be a good way to familiarize myself with the material BEFORE the lecture.	
Q7: The interactive design problem was interesting and helpful.	

What would you change about the courseware?

What are the best features of the courseware?

Figure 8. Fall 2001 Feedback Request Form

The study was designed to help the courseware development team obtain a cross-section of the student population representing the full spectrum of student learning styles. The intent of the survey was for the students to complete the form following a brief 30-minute review of the modules. The results of the survey are shown in Figure 9 below.

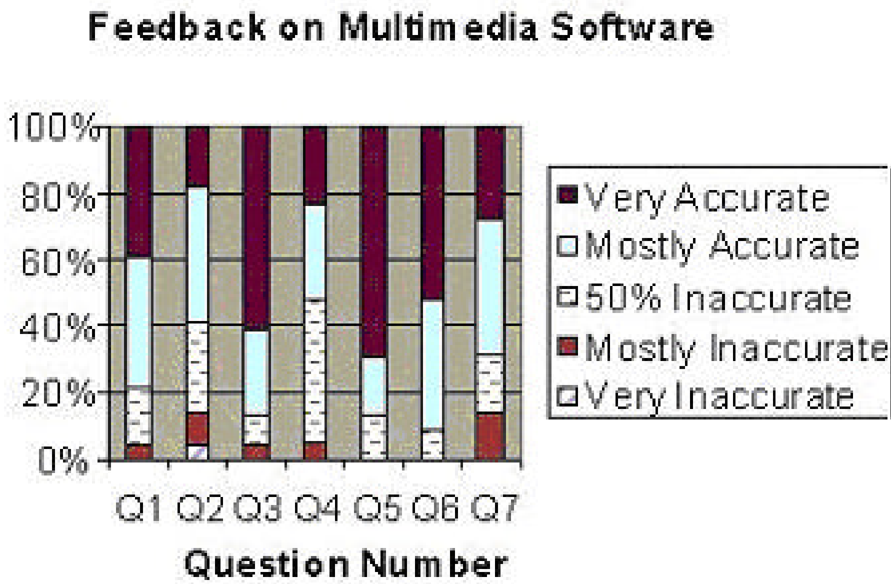

Figure 9. Fall 2001 Feedback on Multimedia Courseware Results

Of the 104 students, 23 responded to the feedback form. The individuals using the software were a diverse mix of academic performers. The figure above shows that the students found the courseware to be an extremely helpful tool for individual study. Students commented on the various features that were especially helpful, noting specifically the easy navigation and helpful visualization. They also recommended some possible improvements to the software, for example “provide more interaction”.

One possible reason for a change in the students’ response was the fact that the software was used as a reinforcement tool rather than as a presentation tool. The students found the content and examples in the course much more stimulating after they were already somewhat familiar with that content. Many of the students commented how the interactive features of the software made reviewing the vast amount of information more efficient than reading and reviewing the textbook. Some even wanted hard copies of the visual content stating that they would prefer using the hard copy from the multimedia over using the text as a way to study for the exam.

2.3.3. The Quick Quizzes

2.3.3.1. The Quick Quiz Instrument

Immediately before and after the enhanced learning modules were presented, a quick quiz was administered to measure short-term increase in understanding as a result of the module. The quizzes focused on conceptual understanding of the material and did not require any significant calculations. The quick quizzes were also administered during the same lesson before and after a classic lecture style class (during which the enhancement module was NOT used). This obviously forms the control group. A student could receive a 0, 1, or 2 for a grade on the quiz (2 being the best). The results were normalized to indicate the average score (percentage) achieved with and without the multimedia. The results are tabulated below in

Table 4 and Table 5 summarizing the quick quiz assessment for fall 1999 and 2000. The tables' data includes the number of data points for inferring statistical significance.

2.3.3.2. Quick Quiz Assessment Results

Figure 10 gives insight into the issue of the professor in the 1999 study who had a negative perception of the modules. The difference in professors' attitudes appears to have greatly affected the "success" of the multimedia presentation. The figure shows the quiz score averages during the fall semester of 1999. The hollow symbols represent average scores with multimedia, the solid symbols without multimedia. Each type of symbol represents a different instructor – a circle for Instructor A, triangle for Instructor B, and a square for Instructor C. Note that Instructor B did not conduct the Bending Quick Quiz, while Instructors A and C did not do the Combined Loading control group (i.e. all their groups were given the multimedia presentation). The horizontal axis delineates between the three different quick quizzes while the vertical axis quantifies the difference between the students' scores after and before their "treatment". The two different "treatments" are the multimedia (MM) or a standard lecture (No-MM).

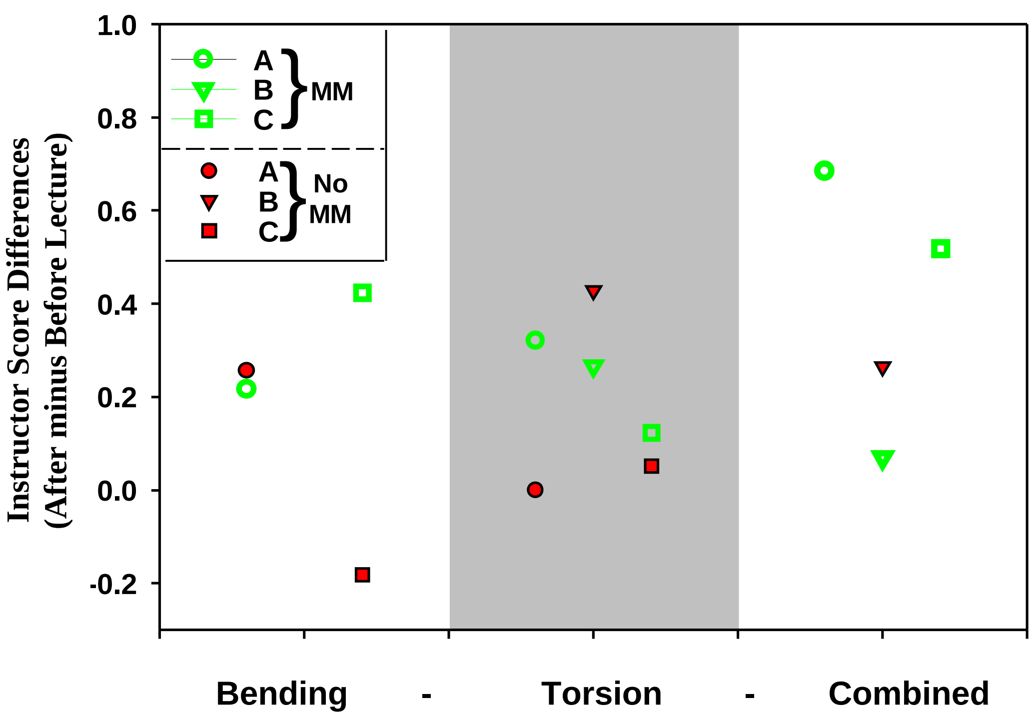

Figure 10. Fall 1999 Comparison of Results from Instructors A, B, & C

In examining these results, it is interesting to note that Instructors A and C both saw better quiz score improvement when using the multimedia presentations. Both of these instructors supported the visual presentations and thought they would add to the interest level of the students. In fact, they thought the Combined Loading example involving biomechanics of a knee joint was so motivating that they did not want to run the control group without multimedia. This enthusiasm for the visual material appears to have positively affected the student's learning.

This can be contrasted to the quiz scores for Instructor B. Note that the score improvements for the Torsion and Combined Loading modules when using the multimedia were actually lower than when using the traditional lecture for Instructor B. It was well known that this instructor was not a strong proponent of the modules, and often complained about "death by PowerPoint". While there may have been some positive bias towards the modules for Instructors A and C, there was definitely a negative bias for Instructor B.

Clearly, this type of information must be considered when evaluating any new teaching tool. Even well constructed, interesting learning modules will fail if they do not fit in well with the teaching methods of the instructor. If the professor has a negative perception of the learning enhancement tool, the students will likely perceive this. Similarly, if an instructor shows great enthusiasm for a new tool, this may positively bias the learning of the students. Therefore, these visualization modules should be tested with as great a number of professors as possible to determine their effectiveness (a strategy which we are in the process of implementing), and quick quiz scores must be analyzed along with subjective surveys and correlated exam results to fully evaluate new teaching tools.

Table 4. Fall 1999 Quick Quiz Results

	Number of Data Points	**Average Quiz Score Before**	**Avg. Quiz Score After**	**% Improvement**
Students who saw the module	152	0.89	1.16	31%
Students who did NOT see the module	118	0.85	1.10	30%

Table 5. Fall 2000 Quick Quiz Results

Module Subject		Number of Data Points	Average Quiz Score Before	Average Quiz Score After	% Improvement
Torsion	Students who saw the module	15	80%	100%	20%
	Students who did NOT see the module	21	62%	71%	9%
Bending	Students who saw the module	24	27%	69%	42%
	Students who did NOT see the module	15	43%	76%	33%
Combined Loading	Students who saw the module	14	35%	93%	58%
	Students who did NOT see the module	14	21%	75%	54%

The data for 1999 (as shown in Table 4) is obviously inconclusive in terms of showing any positive affect from the visualization modules. Note that this data contains results from all three professors using the visual modules. The fall 2000 data shows with reasonable significance that the multimedia did increase conceptual understanding over instruction without multimedia.

2.3.4. Results of Exam Questions

In the fall 2000 semester, an exam question was used to further evaluate the effectiveness of the modules. This was done in an attempt to get a longer-term assessment of the visual modules. As can be seen in Table 6, the percentage of students who correctly answered the exam question was significantly greater (45%) for those who viewed the module than for those who did not (28%).

Table 6. Fall 2000 Final Exam Results According to Content

	Number of Data Points (Students)	% of Students Correctly Answering the Exam Prob.
Students Receiving the Module	40	45%
Students NOT Receiving the Module	635	28%
% Difference		23%

3. Discussions and Conclusions

Two categories of conclusions can be drawn from this work. First, conclusions regarding the assessment plan and its implementation can be made. Second, specific conclusions regarding the effectiveness of the visual modules can be stated.

Regarding the assessment plan and implementation, it is clear in retrospect that some critical details were overlooked in the 1998 and 1999 phases of assessment. Although extensive background work was done to investigate what other engineering educators had learned regarding the assessment of multimedia, implementation of their "lessons learned" was not sufficient to avoid significant problems. Specifically, the 1998 study attempted to encompass too many variables with too small a sample size. Two critical errors encountered in the 1999 study were failure to consider the attitude of the professors involved and failure to go beyond the professor's course objectives and consider the student's course objectives as well. This realization would have provided the insight to make a firm connection between the content and the exam (a lesson only learned in retrospect).

In terms of the conclusions related to the visual multimedia itself, three primary conclusions can be drawn. First, the results of this study indicate that students' perception of the post 1999 versions of the visual, multimedia driven lectures has been significantly enhanced over previous versions by: 1) emphasizing that the concepts will be tested on exams, 2) minimizing extraneous FEM theory included in the modules and 3) insuring that the professors believe that the visual modules will be helpful. Second, the 2000 study showed an improvement in students' conceptual understanding was gained through the use of the visual modules as opposed to use of a traditional lecture format. This result was validated through the use of quick quizzes given before and after the visual modules were presented or before and after the traditional lecture. Third, longer-term retention of the conceptual material was also enhanced through the use of the modules as compared to traditional lectures. This was substantiated with performance results on a specific exam question. The 2001 study demonstrated that the courseware can be an effective reinforcement tool for the students. In the classroom environment, students and faculty had reservations regarding the multimedia's usefulness. But survey results revealed that the students where excited to use the tool as an extracurricular study aid to review for major exams.

This project continues to evolve at USAFA and has expanded to a number of other universities. We are in the process of developing more interactive versions of the visualization modules. These will eventually become commercially available for use in mechanics of materials courses.

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