Development and Assessment of Hands-on and Visualization Modules for Enhancement of Learning in Mechanics

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Abstract

Engineering mechanics education is currently undergoing a transformation from strictly lecture based education to a format where a variety of innovative learning techniques are used. Both new techniques for enhancing student learning as well as concrete data establishing the effectiveness of these techniques are needed. This paper builds on previous work using innovative teaching tools by developing and assessing our current use of two tools: computer based visualizations and hands-on demonstrations and experiments. These tools were used in our Fall 1998 Engineering Mechanics core course which is taken by all cadets at the U.S. Air Force Academy, regardless of their major. The hands-on tools are low-cost, interactive experiments designed to enhance understanding of specific abstract concepts. The visualization content consists of finite element based stress results displayed in color formats. Both the hands-on and the visualization tools are designed to emphasize aspects of stress analysis which our students have traditionally found difficult to grasp. Evaluation of the enhancement in student learning, brought about by use of these tools, has been accomplished by a variety of assessment techniques. Next, the assessment results are correlated with the student's Myers-Briggs Type Indicator (MBTI) as well as the type of "learner" they are, as measured by the VARK learning style inventory. Results indicate that the hands-on and visual content overall enhances the learning experience. Specifically, it is rated highly by the MBTI "N" type students, but not as highly by the MBTI "S" types. However, both S-types and N-types benefited from it in their ability to solve problems. VARK K-types gave the hands-on and visual content the highest rating of any student "type" we studied.

1. Introduction

The Fundamentals of Mechanics course (Fall semester 1998) at the United States Air Force Academy was used as a testing ground for introducing and assessing the effectiveness of visual and hands-on learning aids using photoelastic materials and the finite element method (FEM). The course combines statics and strength of materials at an introductory level for all students regardless of major. Typically, the concepts of stress caused in objects by torsion, bending, and combined loading are among the most difficult for students to grasp. For these topics, "enhanced learning modules" were developed to bring visualization and hands-on learning aids into the classroom experience. A complete description of these special modules is presented in the context of a learning styles environment.

Several means of assessment were used to learn whether the module-based lectures provided extra value to the learning experience in general and for specific types of students. Three of twenty-one sections of the class (61 of 429 students) were used to conduct this study. Student

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response to lessons was collected throughout the semester via one-minute surveys. Immediately before and after the enhanced learning modules were presented, "quick quizzes" were also administered to measure short-term conceptual learning. Student survey responses and quick quiz results were sorted and analyzed in various ways, based on students' Myers-Briggs Type Indicator (MBTI) and learning style preference determined from the VARK assessment. Special focus was placed on the "S" (sensing) or "N" (intuitive) descriptor in the MBTI type and on the "V" (visual) or "K" (kinesthetic) learning style preferences. Additionally, the results of selected midterm exam questions were used to evaluate the longer-term effectiveness of the enhanced learning modules. The findings of these assessment attempts are discussed in detail following an explanation of the MBTI and VARK types.

2. Enhanced Learning Modules

2.1. Background

There is an increasing emphasis being placed on quality instruction in engineering education. This is exemplified by the emphasis given to quality of teaching in promotion decisions [Boyer], by the expanding number of institutions focusing on curriculum development [Incorpera], by the significant number of publications in this area [Evans, Moriarty, Koen, Harris, Dutson, Armacost, Catalno, Brereton, Wankat, Jensen1-6], by the commitment of the engineering accreditation agency ABET in the assessment area [ABET], and by the continuing funding emphasis by the National Science Foundation and other agencies. Much of this effort to enhance engineering education is focused in the following areas: learning styles, multimedia visualization/simulation, hands-on experiences, use of real-world problems, and assessment techniques. These components form the foundation for the present work.

2.1.1. Learning Style Background Information

Learning-style techniques, as they relate to engineering education, have been discussed by [Felder1,2,3, Wankat, Solomon, Eder, Dunn] among others. Much of the focus has been on teaching "across the spectrum" [Felder1], meaning that teaching formats must be designed to span the spectrum of student learning orientations. A variety of techniques have been developed to categorize learning styles, including the Myers-Briggs Type Indicator (MBTI) [Jung, Keirsey, McCaulley1] and, more recently, the VARK (Visual, Auditory, Read/Write, Kinesthetic) tool [Flemming, Bonwell]. Work in the MBTI arena has included a massive study providing percentages of students with different MBTI types within specific engineering disciplines [McCaulley2]. Application of MBTI results has included efforts to improve creativity [Ramirez], to create more effective design teams [Wilde, Brickell], to aid students in their use of self-paced material [Smith] and, in general, to tailor the learning environment to meet students' differing preferences [McCaulley3, Lawrence, Jensen1, Rosati, Lumsdaime].

2.1.1.1. MBTI Types

The present work builds on what is known from MBTI types to implement hands-on and visualization content. A number of researchers have previously used knowledge of MBTI types to enhance engineering education [McCaulley, Jensen4, Otto1, Felder2,3]. The particular

method of incorporating MBTI types in the present study is very similar to that used previously by the second author [Jensen4, 6].

The MBTI type includes four categories of preference [Myers, Jung, Kersey, Lawrence]. The first category describes whether a person interacts with his or her environment, especially with people, in an initiating (extroverted) or more passive (introverted) role. Extroverts tend to gain energy from their surroundings while introverts usually gain energy by having space for themselves. The second category describes how a person processes information. Those who prefer to base their information processing on data or the input of their senses (sensors) are contrasted with those who view the intake of information in light of either its place in an overarching theory or its future use (intuitors). This sensor vs. intuitor category is seen by most researchers to be the most important of the four categories in terms of implications for education [Myers, Lawrence].

The third category for MBTI preference attempts to describe the manner in which a person evaluates information. Those who tend to use a logical "cause and effect" strategy (thinkers) are contrasted with those who use a hierarchy based on values or on the manner in which an idea is communicated (feelers). The final MBTI type category indicates how a person makes decisions or comes to conclusions. Those who tend to want to be sure that all data have been thoroughly considered (perceivers) are contrasted with those who summarize the situation as it presently stands and make decisions quickly (judgers). The four letter combination of these indicators ("E" vs. "I" for extrovert and introvert; "S" vs. "N" for sensor and intuitor; "T" vs. "F" for thinker and feeler; "J" vs. "P" for judger and perceiver) constitute a person's MBTI "type". Table 1, which is adapted from *Manual: A Guide to the Development and Use of the Myers-Briggs Type Indicator* [Myers, McCaully3], gives a brief overview of the four MBTI categories.

TABLE 1. OVERVIEW OF THE MBTI CATEGORIES

MANNER IN WHICH A PERSON INTERACTS WITH OTHERS			
E	Focuses outwardly on others. Gains energy from others.	Focuses inwardly. Gains energy from ideas and concepts.	I
EXTROVERSION		INTROVERSION	
MANNER IN WHICH A PERSON PROCESSES INFORMATION			
S	Focus is on the five senses and experience.	Focus is on possibilities, future use, big picture.	N
SENSING		INTUITION	
MANNER IN WHICH A PERSON EVALUATES INFORMATION			
T	Focuses on objective facts and causes & effect.	Focuses on subjective meaning and values.	F
THINKING		FEELING	
MANNER IN WHICH A PERSON COMES TO CONCLUSIONS			
J	Focus is on timely, planned conclusions and decisions.	Focus is on adaptive process of decision making.	P
JUDGEMENT		PERCEPTION	

2.1.1.2. VARK Learning Style Preferences

The present work also builds on student learning style preferences, as obtained from an instrument called the VARK Catalyst. Rather than being a diagnostic tool for determining a student's learning preference, the VARK test serves as a catalyst for reflection by the student [Bonwell]. A student's VARK descriptor is based on a simple 13-question test that is aimed at discovering how the student prefers to receive and process information, but not necessarily how the student learns best.

A student's VARK descriptor is formed from one or a combination of the letters "V", "A", "R", and "K" which represent four different modes of taking in information. As [Bonwell] describes, visually (V) oriented students prefer to receive information from depictions "of information in charts, graphs, flow charts, and all the symbolic arrows, circles, hierarchies, and other devices that instructors use to represent what could have been presented in words" . An aural (A) orientation indicates preference for hearing information; i.e. the student learns best from a lecture, tutorial, or talking with other students. Students with a read/write (R) orientation prefer information displayed as words, which is perhaps the most common instructional method used in Western education. A preference for "learning by doing" is described as kinesthetic (K) learning. By definition, this refers to a student's "perceptual preference related to the use of experience and practice (simulated or real)."

Using a scoring rubric, a student's VARK descriptor is determined according to the strength of preference for the different modes of learning. In this study, "strong" preferences were determined. If a student's VARK descriptor is composed of just one letter, this indicates a strong preference for that single mode of learning. If multiple letters are used, the student has an affinity for a wider range of learning modes. For comparison purposes in this study, students that strongly preferred visual (V) and kinesthetic (K) modes were of particular interest. These categories were allowed to include bimodal preferences (a V or K preference combined with one other letter). Interestingly, several students had a VK bimodal preference, so they were included in both the V category and the K category. In fact, most of the students in the V category had a VK type, which could distort any conclusions for V-type students.

2.1.2 Visualization Background Information

A wide variety of efforts to use computer-based visualization to enhance education have been reported in the literature. There are a large number of web sites maintained by universities that contain multimedia features, from simple electronic syllabi to interactive simulation [URL/CD refs 1-7]. Many book companies have formed multimedia divisions, and a number of smaller multimedia production companies are producing CD-ROMs intended to provide visualization enhancement to technical learning [URL/CDrefs 8-11]. In addition, many examples of stand-alone software for specific courses have been reported in the literature [Tan, Kriz, Martin, Abbanat, Oloufp, Crismond, Meyer, Jensen1,3].

Results reported from the use of these tools have been mixed. Of the cases inspected for the current study (approximately fifty cases), about half of the researchers reported that the tools did *not* significantly increase student performance on tests [Sheppard, Reamon2], while half did report enhancement of students performance [Meyer, Cooper, Wallace1]. In the cases where student performance did increase, some common components were found in the multimedia tools; they include: 1) the use of specific learning objectives to guide development of the software; 2) the use of student feedback to create updated software version;, 3) the use of open ended problems; 4) the fact that software needed to be interactive and of high quality; and 5) that hands-on exercises often supplemented the material [Wallace1, Cooper, Regan]. In addition, [Wallace 2] gives some suggestions on how to restructure the course content if World Wide Web-based tools are used.

Despite the numerous publications in this area, there appear to be no studies derived from a large, statistically significant data set on which to base an evaluation of the effectiveness of the presently available tools. The reports cited above refer to assessment strategies which are almost entirely qualitative or have very small sample sizes, lacking different control groups to isolate the effect on learning derived from the introduction of multimedia.

Over the last few years, new visualization material in the area of solid mechanics [Cooper, Jensen1-3,5,Gramoll, Behr,URL/CD12,13,15,16,17, White,Mason], as well as many other areas (notably dynamics and statics), has become available [URL/CD13]. However, particularly in the areas of solid mechanics, there continue to be some significant gaps in the availability of quality, computer-based visualization programs that help undergraduate students in these fundamental engineering courses.

2.1.3. Hands-on Background Information

Significant work has been done in the development of hands-on content, with the goal of enhancing learning [Otto, Carlson, Kresta, Aglan, Catalano]. Much of the literature indicates that the combination of visualization and hands-on content creates a positive effect on learning [Cooper, Regan, Behr, Sheppard]. Other studies indicate that the effectiveness of the hands-on material depends on the type of content the student is attempting to master. In cases where the material is abstract, the addition of hands-on experience seems to provide an increase in learning potential. In the case of learning more rudimentary material, such as the simple retention of facts, the supplementary hands-on material does not appear to provide significant enhancement [Laurillard, Flori]. Also, the hands-on content appears to be received differently by students with different MBTI types [Jensen4]. As with the visualization content, there again appears to be a lack of statistically significant assessments in this area.

In the particular area of solid mechanics, current hands-on content appears to be limited to some photoelasticity-based experiments (which sometimes are really class demonstrations, hands-on content for the student) and simple uniaxial tensile tests. In fact, most solid mechanics courses appear to be taught without any significant hands-on or experimental content. Yet, there is a variety of hands-on content that could be incorporated. Potential shortfalls of the hands-on tools currently used in courses in solid mechanics include: 1) the high cost of the experimental apparatus; 2) the large time commitment for setup, take down, and performance of the experiment; 3) the lack of actual hands-on experience for ALL students performing the lab; 4) the lack of clear correlation between the lab and the course content; and 5) the large storage space required for some of the equipment.

2.2. Module Descriptions

The three enhanced learning modules used in the present study were designed to highlight conceptual material in the following three areas: 1) torsion; 2) bending; and 3) combined loading. All three modules contained both visualization and hands-on components in the context of a real-world application; although, in certain cases, either the hands-on or the visualization content was deleted for assessment purposes. Table 2 provides an overview of module content.

TABLE 2. OVERVIEW OF ENHANCED LEARNING MODULES

Module	Specific Concepts	Real-World Example	Multimedia Visualization	Hands-On
Torsion	- Relationship to torque - Stress distribution through the cross-section - Effect of hollow cross sections	Shaft of a jet engine is used as a motivational example	Interactive, FEM-based[1] color fringe plots highlight torsion stress concepts	Photoelasticity[2] demo using USAFA-developed micro torsion tester[4] shows torsion stress concepts
Bending	- Relationship to moments - Stress distribution through cross-section - Location of neutral axis - Cross-section orientation - Concentrated and distributed loading	F-16 wing bending is used as motivational example	Interactive, FEM-based[1] color fringe plots highlight bending stress concepts	Photoelasticity[2] demo using "student opticon"[3] shows bending stress concepts
Combined Loading	- Effects of combined axial and bending loads - Loading direction and placement -Superposition of stresses and displacements -Shifting of neutral surface	Human knee joint status, pre-operative and post-operative, is used as a motivational example	Interactive, FEM-based[1] color fringe plots highlight stress concepts.	Photoelasticity[2] demo using "student opticon"[3] shows combined bending & axial stress concepts

Note[1]: FEM (Finite Element Modeling) is a numerical technique that uses discrete approximations to solve boundary value problems.
Note[2]: Photoelasticity is based on the birefringent properties of certain materials which, when seen through filters, show color changes corresponding to changes in maximum shear stress.
Note[3]: Student opticon is shown in Figure 1.
Note [4]: Micro torsion tester is shown in Figure 2.

2.2.1 Hands-on Content

The hands-on content for the study involved use of the "student opticon" and the "micro torsion tester" shown below (Figures 1 and 2). The student opticon device is composed of two polarizing filters and a birefringent photoelastic material beam or load cell mounted in a wooden box. Student push on the beam or load cell with their fingers to produce color patterns corresponding to changes in the magnitude of maximum shear stress in the specimen. The device also enables visualization of stress distribution. Materials for the device cost about $30.

The hand-held micro torsion tester, in combination with two small polarizing filters, allows the student to apply torque to a circular cross section and see the resulting stress distribution. It is

constructed of a circular wafer of birefringent photoelastic material centrally sandwiched with clear adhesive between two pieces of clear 1/8 inch thick Plexiglas. The Plexiglas pieces are cut with a circular central section and two lever arms extending in opposite directions. When the components are bonded, the upper and lower Plexiglas lever arms are offset from each other about 20° so that the student may squeeze on the two sets of opposing arms to produce pure torque in the photoelastic wafer. When students applied torque to the device, the color patterns indicating changes in maximum shear stress were slightly distorted due to bonding imperfections. However, the concentric distribution of shear stress over the cross section was still apparent.

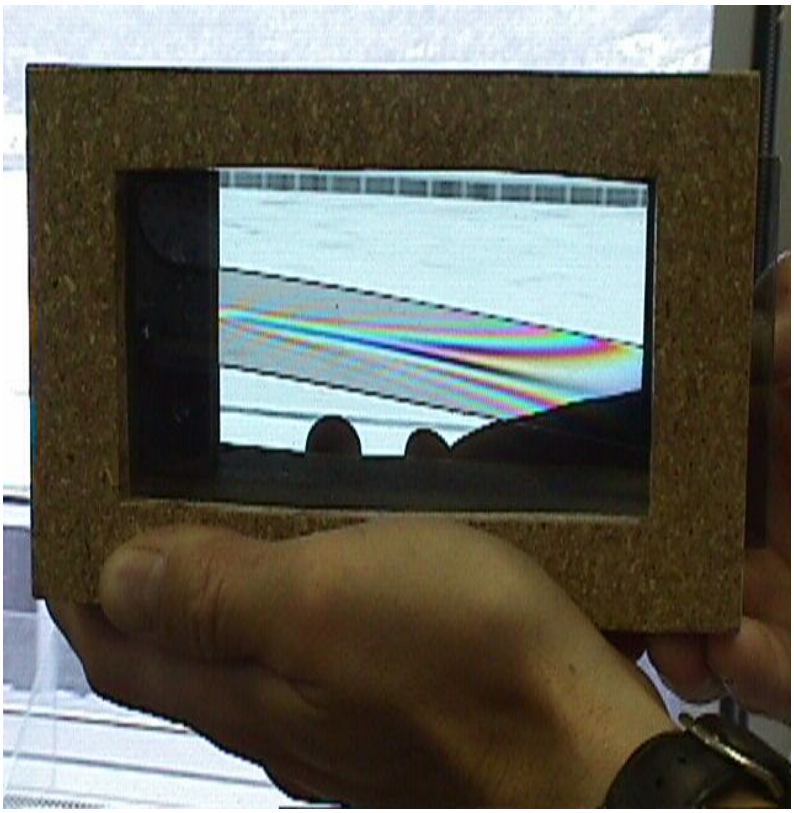


FIGURE 1. STUDENT OPTICON

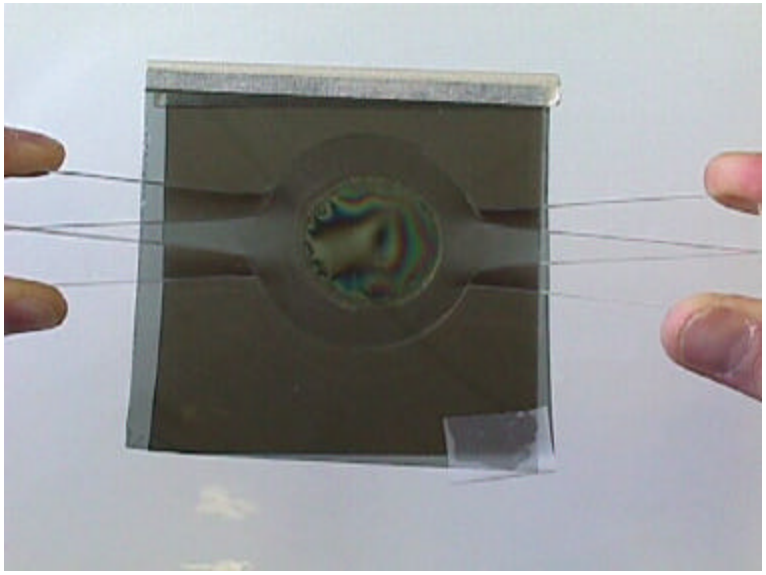
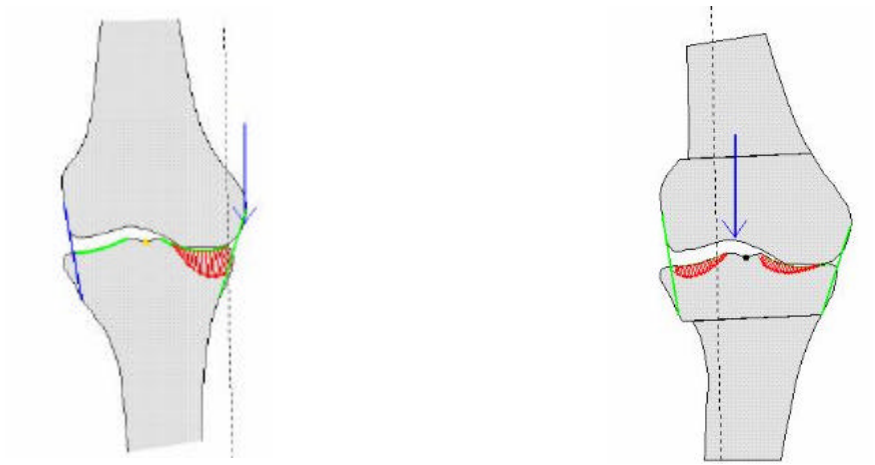


FIGURE 2. MICRO TORSION TESTER

2.2.2. Visualization Content

Visualization content for each module involved several slides showing FEM-based color stress plots illustrating various concepts from stress analysis. Real world examples were used as the context for the visualization. These examples entailed brief overviews of how torsion, bending, and combined loading applied to the cases of turbine shafts, aircraft wings, and human knee joints respectively. For example, Figure 3 was one of the slides used to illustrate a knee operation which was proposed to change combined axial and bending loading of a knee joint to pure axial loading aligned with the mechanical axis of the bone [URL/CD 19]. This real world example was followed by a series of FEM based stress plots showing various concepts intrinsic to combined loading. nother example utilized the illustration shown in Figure 4 where the distribution of bending stress through an F-16 wing cross-section was roughly approximated with a beam model.



Pre-operative Loading **Post-operative Loading**

FIGURE 3. PRE- AND POST-OPERATIVE LOADING OF A KNEE JOINT

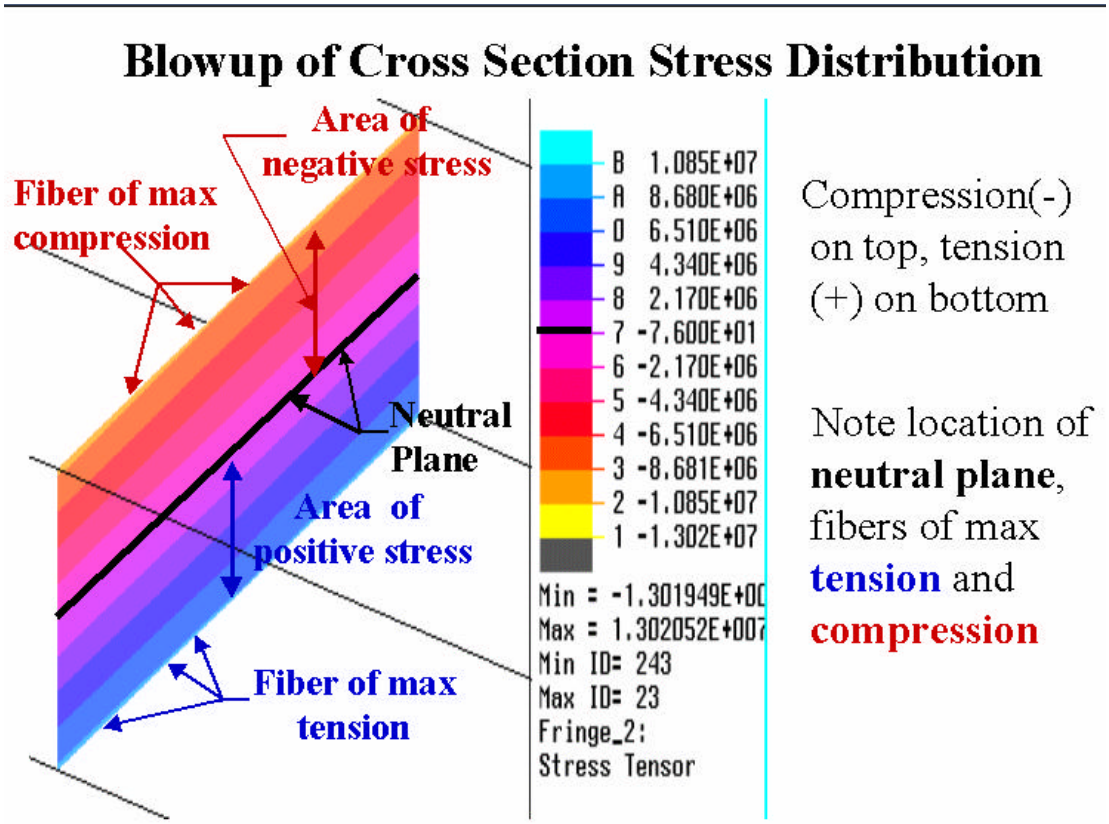


FIGURE 4. VISUALIZATION OF NORMAL STRESSES DUE TO BENDING

2.3. Student Treatment

The three sections of students that experienced the enhanced learning modules all received different combinations of the visualization and hands-on content for a given topic. For each topic (torsion, bending, and combined loading), one section experienced just the visualization content, one section experienced just the hands-on content, and one section experienced a combination of both the visualization and hands-on content. Each section experienced different module content for each topic so that all sections experienced the visualization only, hands-on only, and combined visualization/hands-on exposure one time.

3. Assessment

3.1. Assessment Strategy Introduction

Three different assessment techniques will be used to determine the effectiveness of the modules: 1) one minute surveys (OMS) taken after each lecture; 2) quick quizzes taken before and after the modules; and 3) specific exam questions designed to measure students' understanding of the concepts covered in the modules. The use of three different 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 will allow us to measure different components of effectiveness. Table 3 shows the different aspects measured by the different assessment tools.

TABLE 3. USES OF THE ASSESSMENT TOOLS

ASSESSMENT TOOL	**WHAT THE TOOL MEASURES**
One Minute Surveys (OMS)	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? 5. Which did students find most helpful - the hands-on content alone, the visualization content alone, or the combination of the two?
Quick Quizzes	Which type of content helped the students answer a conceptual question the most (hands-on alone, visualization alone, or the combination of the two)?
Exam Questions	Did the modules help the students answer exam questions in the same content area as the module?

In addition to providing insight into the questions in Table 3, our assessment program measured effectiveness of the modules as correlated with the students' Myers-Briggs (MBTI) and VARK type. Recall that an overview of these two student categories was given previously.

3.2. Results Based on the OMS

Two separate sets of results were obtained from the OMS data. First, we were able to determine the effect of the use of hands-on and/or visualization by comparing the students' rating of the module-based lectures to those with no module. This study is summarized in section 3.2.2. The second way that the OMS data can help us determine the effectiveness of the modules is to use it to compare the use of "visual only" vs. "hands-on only" vs. "both". This study is detailed in section 3.2.3. In both cases, the data can be correlated with students' MBTI or VARK types or it can be tabulated without regard to type. Before proceeding to the OMS based results, an overview of the OMS itself is given in section 3.2.1.

3.2.1. The One Minute Survey (OMS)

The one minute survey (OMS) being used in the current course has been iteratively developed over the last three semesters. The original OMS used for a previous study [Jensen4] asked only for MBTI type and overall lecture rating. In order to gain additional insight into the effectiveness of the modules, a refined OMS was developed and used for the present study. The refined version requests information about the students' perception of interest, learning, applicability and motivation for future exploration (see Fig 5). In addition, both the MBTI and VARK types are recorded. This OMS was given after each lecture and took about a minute for students to complete. Figure 5 shows the content and form.

1 MINUTE SURVEY EM120 - FALL 1998
Lesson #: _____
MBTI Type: _____ VARK 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. ONE MINUTE SURVEY FORM

3.2.2. OMS-based Results for the Overall Effectiveness of the Module-based Content

In order to measure the effect of the module-based content in a generic manner, a four step process for analyzing the data has been developed. This method for processing the data has been successfully used in previous studies [Jensen4,6] and entails a four step process as shown below.

Step 1: Obtain Averaged Values for Each Lecture for S-type, N-type, K-type and V-type Students for Each of the 4 OMS Questions

Students rated each of the lectures on a 1-10 scale for each of the 4 questions on the OMS. The lecture ratings from students having MBTI S-type were separated from those students who were N-type, while those who had VARK K-type were separated from those who had V-type. The S-type, N-type, K-type and V-type students' rating were averaged for each lecture. In the calculations below, these averaged lecture ratings are denoted $\overline{X^{Q}_{S_i}}$, $\overline{X^{Q}_{N_i}}$ $\overline{X^{Q}_{K_i}}$ and $\overline{X^{Q}_{V_i}}$ for i =1,2,…number of lectures and Q = 1,2,3,4 where the first subscript indicates the MBTI or VARK type and the sub-subscript indicates the lecture number and the superscript indicates the question number from the OMS.

Step 2: Obtain Overall Averaged Lecture Ratings and Standard Deviations for S-type, N-type, K-type and V-type Students for Each of the 4 OMS Questions

For each of the four questions on the OMS, a mean and standard deviation was calculated for the S-types', N-types', K-types' and V-types' ratings across all of the lectures. The mean and the standard deviations for the four different types are labeled $\overline{X}_S^{Q=1-4}$, $\overline{X}_N^{Q=1-4}$, $\overline{X}_K^{Q=1-4}$, $\overline{X}_V^{Q=1-4}$ and $s_S^{Q=1-4}$, $s_N^{Q=1-4}$, $s_K^{Q=1-4}$, $s_V^{Q=1-4}$ for the 4 questions for S-types, N-types, K-types, and V-types respectively. Table 4 summarizes these calculations.

TABLE 4. MEANS AND STANDARD DEVIATIONS
FOR S-TYPE, N-TYPE, K-TYPE & V-TYPE

TYPE	$\overline{X^{Q=1}}$	$s^{Q=1}$	$\overline{X^{Q=2}}$	$s^{Q=2}$	$\overline{X^{Q=3}}$	$s^{Q=3}$	$\overline{X^{Q=4}}$	$s^{Q=4}$
S	7.01	0.37	7.75	0.49	7.72	0.48	6.36	0.51
N	7.99	0.59	8.09	0.61	7.90	0.46	7.10	0.48
K	7.84	0.52	7.91	0.56	7.80	0.51	6.17	0.55
V	7.40	0.67	7.53	0.65	7.33	0.69	5.75	0.76
All-types	7.84	0.40	7.86	0.47	7.77	0.40	6.70	0.37

Step 3: Obtain Means for Module-Based Lectures

The OMS ratings for N-types, S-types, K-types and V-types from the three module-based lectures were each averaged producing a mean. These module-based mean are labeled $MB\overline{X}_N^{Q=1-4}$, $MB\overline{X}_S^{Q=1-4}$, $MB\overline{X}_K^{Q=1-4}$, $MB\overline{X}_V^{Q=1-4}$ where the $MB\overline{X}$ stands for module-based mean, the subscript indicates the student type and the superscript indicates the question number from the OMS.

Step 4: Obtain the Percentile as Rated by S-types, N-types, K-types and V-types

In order to determine an S-type, N-type, K-type and V-type percentile rating for the module-based content, the average number of standard deviations away from the mean for each question on the OMS first computed for each of the four questions from the OMS. The computation for the first question from the OMS for S-type takes the following form:

$$No.\ Std.\ Dev.\ off\ \ Mean = \frac{MB\overline{X}_S^{Q=1} - \overline{X}_S^{Q=1}}{s_S^{Q=1}} \quad \text{(Eq. 1)}$$

Calculations for the other three questions and for the N-types, K-types and V-types, as well as for all types combined, proceed similarly. Using results from (Eq. 1) in the probability distribution function for normal, Gaussian data, a percentile rating for each of the content areas can be found for the four different types studied for each OMS question. The results are summarized in Table 5 where the number of standard deviations off from the mean is given with the associated percentile in parenthesis.

TABLE 5. NUMBER OF STD. DEV. OFF MEAN (PERCENTILE)
FOR QUESTION NUMBER AND TYPE

1 min. Survey Question	**S-TYPE**	**N-TYPE**	**K-TYPE**	**V-TYPE**	**ALL-TYPES**
Q1: Lecture was interesting?	-0.29 (39)	0.12 (55)	0.41 (66)	0.56 (71)	-0.1 (43)
Q2: Lecture helped me learn?	-0.22 (41)	0.49 (69)	0.41 (66)	-0.08 (47)	0.11 (54)
Q3: Lecture helped me to apply material?	0.00 (50)	0.16 (56)	0.30 (62)	-0.04 (48)	0.04 (52)
Q4: Lecture motivated me to explore subject further?	-0.88 (19)	-0.22 (41)	-0.06 (48)	-0.66 (25)	-0.74 (23)

As can be seen in Table 5, N-types rate the module-based lectures higher than do the S-types for each of the four questions from the OMS. This is not an expected result. In previous studies with hands-on content [Jensen4,6], the S-types have responded more favorably than N-types to the modules. In this case, however, we believe that the response from the S and N-types is reversed because the module-based content required the students to abstractly apply the content contained in the modules. This is due to the fact that the modules were used to help introduce ***new*** material, which the students knew they would need to be able to use to solve problems. The abstract process of using sensory information to formulate problem solving strategies, is a process which the N-types would view more favorably than would the S-types. Note that the students, without reference to type (i.e. the "All-Types"), did rate the module-based material more highly than the lectures without modules when asked if the content helped them learn and

apply material (questions 2 and 3). Note as well that, when asked if the material motivated them to pursue the subject further, the module-based lectures were rated below average by each type category (N,S,K,V). We believe that this is due to the fact that this course has more non-technical majors than technical majors and also the fact that these lectures were introducing new sections of material, which has a tendency to make the students feel overwhelmed.

Table 5 also shows that K-type students responded more positively to the material than any other type group, most likely because of the inclusion of the hands-on material. V-types found the module-based material interesting (question #1 from the OMS) but lowered their responses when asked if they felt those lectures helped them learn or apply the material.

3.2.3. OMS-based Results for Different Types of Module-based Content

As described previously, the module-based content could be presented in three different manners: 1) the hands-on content could be presented alone; 2) the visualization content could be presented alone; or 3) both could be presented to the students. Table 6 shows the distribution of the content as used in this study.

TABLE 6. HOW THE MODULES WERE PRESENTED

MATERIAL	SECTION 1	SECTION 2	SECTION 3
TORSION	Visual only	Both Visual & Hands-on	Hands-on only
BENDING	Both Visual & Hands-on	Hands-on only	Visual only
COMBINED LOADING	Hands-on only	Visual only	Both Visual & Hands-on

Using the OMS and the data in Table 6, the ratings for the “hands-on only”, “visual only”, and “both” can be correlated with the four different types (N,S,K,V). The procedure for the data analysis follows a process similar to that for general OMS based analysis described in section 3.2.2. The results are contained in Table 7 where the responses for the four questions from the OMS are averaged.

TABLE 7. RATINGS FOR DIFFERENT PARTS OF MODULE CONTENT: NUMBER OF STD. DEV. OFF MEAN (PERCENTILE)

	N-TYPE	S-TYPE	K-TYPE	V-TYPE
VISUAL ONLY	0.12 (55)	-0.13 (45)	-0.02 (49)	-0.06 (48)
HANDS-ON ONLY	0.04 (48)	-0.21 (42)	0.01 (50)	-0.68 (25)
BOTH VISUAL & HANDS-ON	0.48 (68)	-0.09 (46)	0.32 (63)	-0.41 (34)

As can be seen in Table 7, three out of the four types (N,S,K) prefer the combination of the hands-on and the visual content. The V-types, however, prefer to have the material presented in visual form alone, without the hands-on content. This supports the accuracy of the VARK instrument in its statement that those who have "V" types will prefer visual learning environments. In addition, it is interesting to note that the V-types indicate a strong dislike for the hands-on only content.

3.3. Results from Quick Quizzes

Immediately before and after the enhanced learning modules were presented, a conceptual quick quiz was administered to measure short-term increase in understanding as a result of the module. Appendix A shows the quick quizzes that were used. The results of the quick quizzes were compiled for S-type, N-type, V-type and K-type learning style preferences, and for all students without regard for differences. Results for the visualization only, hands-on only, and combined visualization/hands-on content were lumped together based on the topic presented. Table 8 shows the improvement in the percentage of correct answers on the quiz questions as a result of the material presented in class.

TABLE 8. MEASURED QUICK QUIZ IMPROVEMENT

Quick Quiz Question		**S**	**N**	**V**	**K**	**ALL**
TORSION	#1	20.0%	7.7%	0.0%	8.4%	14.3%
	#2	20.9%	3.5%	11.4%	17.2%	13.4%
BENDING	#1	20.0%	15.0%	33.3%	22.2%	23.1%
	#2	32.0%	30.0%	33.3%	44.5%	32.7%
COMBINED LOADING	#1	24.1%	25.0%	16.7%	39.1%	32.8%
	#2	41.4%	25.0%	50.0%	34.8%	32.8%
AVERAGE		26.4%	17.7%	24.1%	27.7%	24.9%

Although a rigorous statistical analysis would have to be conducted to ensure statistical significance, it does seem apparent that the enhanced learning modules do provide additional benefit to the S-type and K-type students compared to the general population when looking at the average results. One might expect the hands-on content to help these students the most. For the S-type students, the greatest benefit, when compared with the "all" category, was found in the torsion and combined loading modules. The N-type students almost always showed lower rates of improvement. The V-type students did exhibit significant improvement on one of the bending questions and one of the combined loading questions, however the small sample size of V-types makes it difficult to arrive at any firm conclusions. Not surprisingly, the K-type student appeared to derive significant benefit from all three modules.

3.4. Results of Exam Questions

Two multiple choice questions, shown in Appendix B, were included on a midterm exam and used to evaluate the longer term understanding of torsion and bending concepts by the students

that experienced the enhanced learning modules. Results from the test were first analyzed according to the content received from the modules (i.e. visualization only, hands-on only, or combined visualization/hands-on). These results, in percentage of correct answers, are shown in Table 9. One might conclude that hands-on only content produced the best results – even better than the combined visualization/hands-on content. It is possible that presenting both could somehow lead to confusion. However, the section (Section 1) with recognizably lower aptitude and motivation did not receive the hands-on only content for torsion or bending; so consequently the results are quite likely skewed.

TABLE 9. EXAM RESULTS ACCORDING TO CONTENT

Content	**Torsion Results**	**Bending Results**	**Combined Results**
Visualization Only	17.6% (Section 1)	55.6% (Section 3)	31.4%
Hands-On Only	41.2% (Section 3)	43.5 % (Section 2)	42.5%
Visualization/ Hands-On	26.1% (Section 2)	26.3% (Section 1)	26.2%
Combined Content	28.1%	41.7%	35.0%

Results of the exam were also compared between the three sections receiving the content of the enhanced learning modules and the rest of the course who had not received the content. Table 10 summarizes the comparison. Interestingly, the sections having received the module content did significantly worse with torsion and significantly better with bending than the rest of the course. With the two questions combined, the sections with module exposure scored almost 5% higher. This seemingly significant result becomes hollow knowing that the three specially treated sections had a 4.7% higher grade at mid-semester than the whole course (including the three sections). Ultimately, little can be concluded from this part of the analysis except that something in the bending module appeared to be very helpful and that something in the torsion module appeared to be possibly detrimental. As indicated in other studies, even subtle details in module content, or in test question content, can have significant impact on effectiveness. We hope that future studies will provide additional insight in this area.

TABLE 10. EXAM RESULTS COMPARING MODULE EXPOSURE TO NON-EXPOSURE

Module Exposure	**Torsion Results**	**Bending Results**	**Combined Results**
Exposure	28.1%	41.7%	35.0%
Non-Exposure	40.5%	20.1%	30.14%

4. Conclusion

The present work has focused on developing and assessing two learning enhancement tools: computer based visualizations and hands on demonstrations and experiments. These tools were used in our Fall 1998 Engineering Mechanics core course which is taken by all cadets regardless of their major. Assessment has been accomplished by use of three techniques: 1) scores on quick quizzes taken before and after the enhancement tool; 2) specifically designed exam problems; and 3) daily detailed student feedback. The daily student feedback used a survey which took the students approximately a minute to complete after each lecture. The survey asked for feedback in four specific areas for each lecture: 1) student's interest in that lecture's subject matter; 2) that day's learning experience; 3) student's ability to apply material covered that day; and 4) student's interest in exploring that lecture's material further. The quick quizzes and exams questions were designed to measure conceptual understanding of certain abstract stress oriented concepts. Three control groups were used in the assessment process: 1) a group using the hands-on content only; 2) a group using the visualization content only; and 3) a group using both the hands-on and the visualization content. The hands-on devices are low-cost, interactive experiments designed to enhance understanding of specific abstract concepts. The visualization content consists of finite element-based stress results displayed in color formats.

The results from the surveys, quick quizzes and specific exam questions were correlated with the student's Myers Briggs Type Indicator (MBTI) as well as the type of "learner" they are as measured by the VARK learning style inventory. A variety of results were obtained using the three assessment instruments. From the surveys, students indicated that the hands-on and visual content overall was interesting, enhanced the learning experience and helped them to solve problems. However, the majority of students did not find that the module-based lectures motivated them to explore the day's content further. Surveys further indicated that the module-based content was rated highly by the MBTI "N" type students, but not so highly by the MBTI "S" types. Although this runs contrary to what was expected, our conjecture is that the N-types prefer this content (and S-types do not) because the manner in which it was presented necessitated that the conceptual content be abstractly applied to solve problems. Similarly, VARK K-types rated the content more highly than did the VARK V-types. Finally, survey results indicate that, in most cases, the combination of hands-on and visualization content was preferred over either hands-on or visualization alone. The exception to this was the VARK V-types, who did not respond as positively to the hands-on content.

From the midterm exam problems, we learned that all four types (S,N,V,K) benefited from the module-based content in their ability to solve problems. However, the type of content and the form of the exam questions appeared to play a significant role in the amount of benefit achieved. We believe this is a measure of the "longer term" effectiveness of modules. The quick quiz gives indication of the short term gain in problem solving skills. Results from the quick quizzes indicate that the S-types and K-types achieve more benefit than the average student from the module-based content. However, larger data sets would be needed in order to ensure accuracy of this particular result.

Overall, we believe that the project provided a solid foundation in terms of development of content and assessment strategies. Significantly more work needs to be done in order to obtain modules and assessment results which have been definitively shown to enhance students learning. Continuation of this work is planned. Others are welcome to use our modules or

assessment results in any way they feel is appropriate. To obtain these resources, simply contact one of the authors.

This work has been partly sponsored by the Air Force Office of Scientific Research and by NSF under contract DUE-9751315.

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Samples of URLs and CDs for University and other Multimedia Projects

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2. RPI (Rensselaer Polytechnic Institute), The Rensselaer Studio Courses, URL= http://ciue.rpi.edu/studio/studio.htm
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TORSION QUICK QUIZ

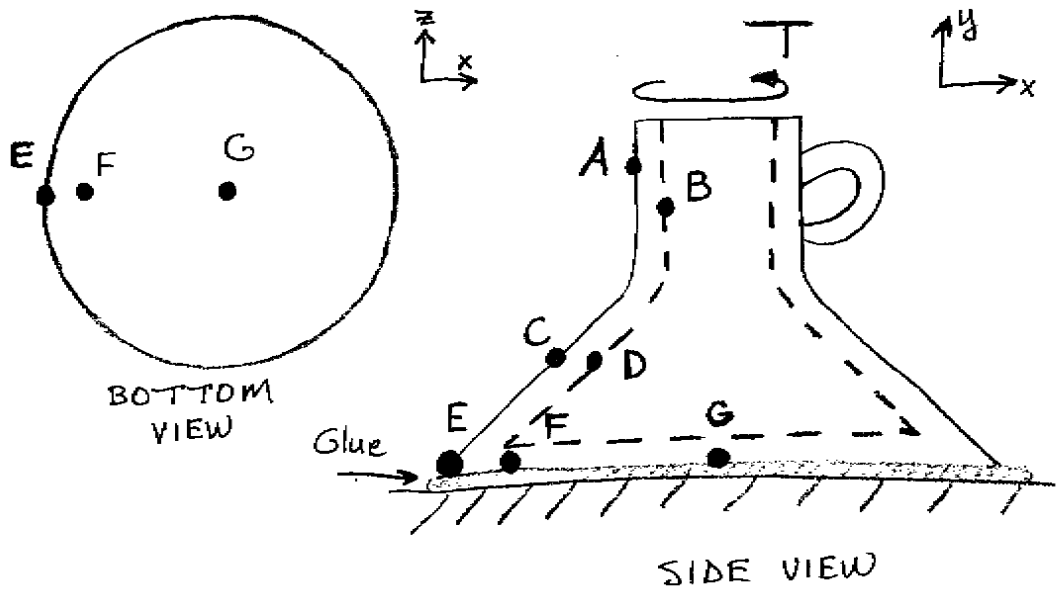


FIGURE A-1. TORSION QUICK QUIZ GRAPHIC

With a pure applied torque (referring to Figure A-1) ….

1. If the glue is not strong enough to hold, at which point on the bottom of the mug is the glue most likely to break away first?

a) Point E
b) Point F
c) Point G
d) All points have an equal possibility

2. If the glue is strong enough to hold, which point on the mug is most likely to fail first?

BENDING QUICK QUIZ

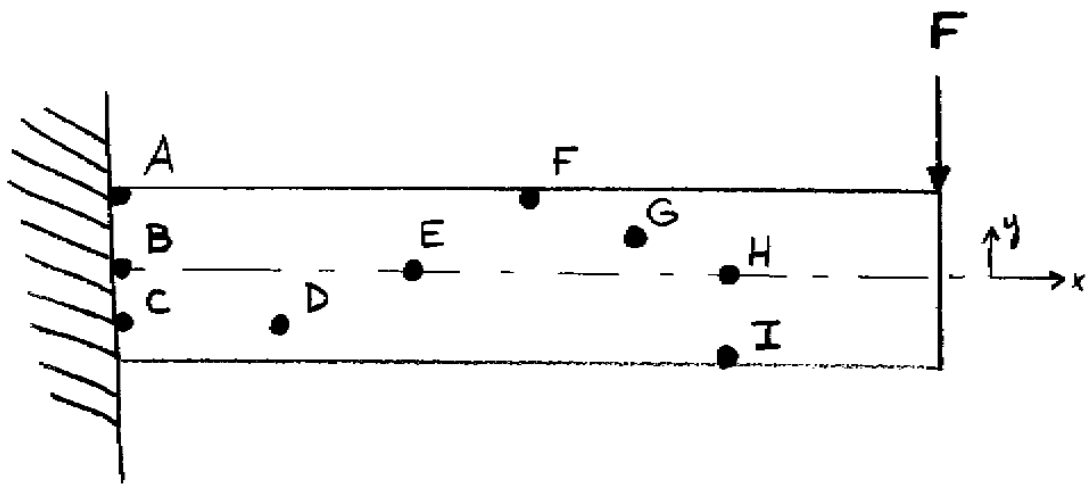


FIGURE A-2. BENDING QUICK QUIZ GRAPHIC

For the beam with loading as shown in Figure A-2:

1. Of the points indicated, which is most likely to fail first?

2. If a hole (with a diameter 10% of the height of the beam) must be drilled through the beam, which of the points shown is the best location for the hole to minimize the affect on the beam's ability to support loading?

COMBINED LOADING QUICK QUIZ

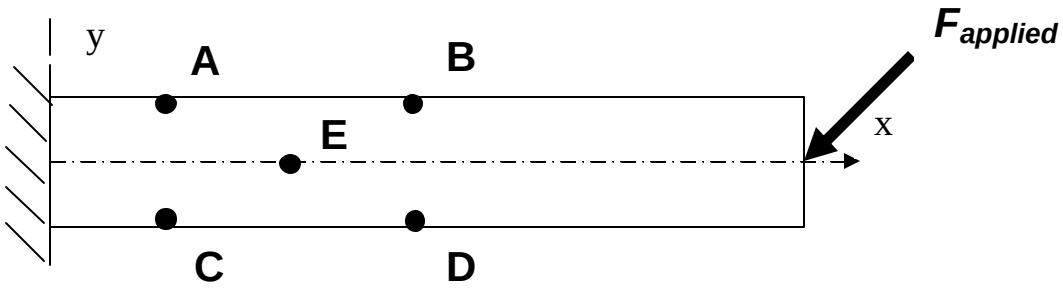


FIGURE A-3. COMBINED LOADING QUICK QUIZ GRAPHIC

Referring to Figure A-3 …

1. Which of the 5 points shown has the greatest absolute value of normal stress?

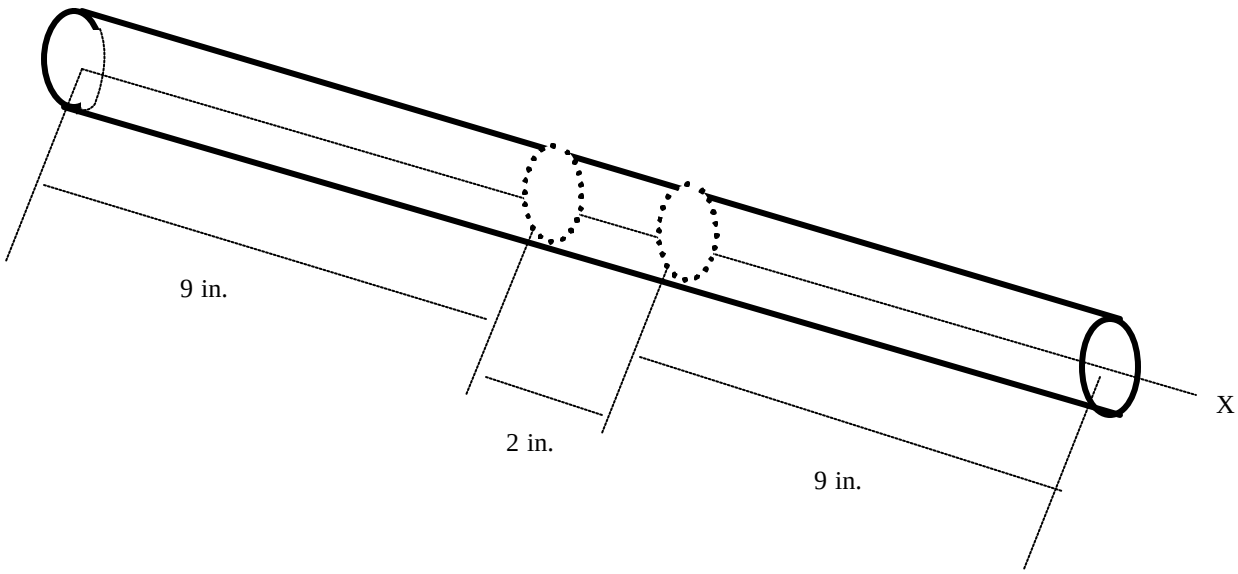
2. Normal stress at Point E will be

   (a) Tensile
   (b) Compressive
   (c) Zero

Appendix C. Exam Questions

TORSION

The middle 2 inch section of the shaft below experiences a maximum shear stress of 25 ksi. The shaft has a solid cross section and a 1 inch radius

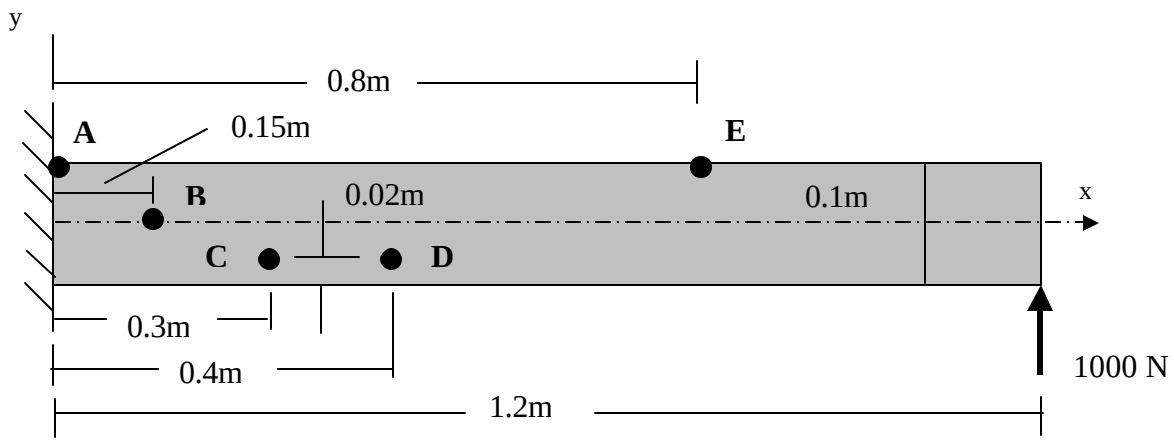


If "r" is the radial distance from the X axis, where in the center 2 inch long section does the shear stress equal 15 ksi?

a) r = 0.6 inches and X=10 inches only
b) r = 0.4 inches and X=10 inches only
c) r = 0.6 inches and 9 < X < 11 inches
d) r = 0.4 inches and 9 < X < 11 inches
e) nowhere

BENDING

Of the five points shown on the constant cross-section cantilever beam below, which will have the greatest normal stress in tension due to loading shown? Note: Drawing is not exactly to scale.



a) Point A
b) Point B
c) Point C
d) Point D
e) Point E

The views expressed are those of the author and do not reflect the official policy or position of the US Air Force, Department of Defense or the US Government.