Is There A Better Way To Present An Example Problem?

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Abstract

Statics, Dynamics, and Mechanics of Materials are introductory engineering courses that employ principles of mechanics and mathematics to solve a wide array of engineering problems. Accordingly, these courses are taught largely through the use of example problems, traditionally delivered to students either by the professor in a classroom setting or by a textbook. The computer offers new possible ways for delivering instructional content such as example problems; however, there has been little data gathered to indicate whether computer-based instructional materials are as effective in communicating example problems to students as the more traditional lecture and textbook formats. During the 2002 fall semester at the University of Missouri – Rolla, a learning experiment was conducted in four sections of the Mechanics of Materials course based on the topic of shear flow. The goal was to assess the relative effectiveness of delivery mode on student comprehension of example problems. All participating students viewed a common video introductory lecture on shear flow. Then, students were randomly assigned into three groups that viewed two example problems either by: (a) video lecture presentation; (b) static HTML webpage delivery; or (3) interactive animated modules featuring high quality, three dimensional graphics created with Macromedia Flash software. This paper reports the details of this experiment and the results.

I. Introduction

Considerable time, money, and effort have gone into the development of learning technologies for engineering education in recent years due to the wide availability of capable computers, the world wide web, and powerful authoring environments. Unfortunately, a substantial number of these technology-based learning innovations have been developed with little thought given to design issues or to their systematic evaluation (Tergan, 1997). This is unfortunate because without meaningful feedback, the most effective new practices are not sufficiently identified, and ineffective practices are allowed to persist. The situation is changing, though. The current funding and accrediting agency mantra is “assess, assess, assess.” For example, the 2000 ABET criteria for engineering education (www.abet.org) strongly emphasizes the importance of a recursive method of course and curriculum evaluation. This process will surely lead to more effective practices.

This same criticism has been aimed at all types of educational hypermedia—not just those in engineering. There have been surprisingly few examinations of the efficacy of hypermedia learning systems. In particular, few studies have systematically examined factors that affect the usefulness of these tools (Landauer, 1995; Dillon & Gabbard, 1998). Research that has been conducted has mostly failed to find that hypermedia instructional systems are significantly more effective than traditional instruction. In a now classic review of thirty studies published in the *Review of Educational Research*, Dillon and Gabbard (1998) conclude, "The majority of experimental findings to date indicate no significant comprehension difference using hypermedia or paper" (p. 326). They also note that, given the popularity of this technique, it's quite surprising that they could only find thirty controlled experiments of hypermedia that made use of objective outcomes. Further, they suggest that the lack of supporting evidence for the efficacy of hypermedia is most likely partly due to flaws in experimental design. In a similarly comprehensive assessment of the existing literature, Tergan echoed their sentiment, writing that "…because of inherent shortcomings in design and research the potential of hypertext/hypermedia for enhancing learning may have been underestimated." (Tergan, 1997) Four years after the publication of the Dillon and Gabbard review, the picture appears to have changed little (Dillon, 2002).

One of the first issues that needs to be addressed is the degree to which enriched multimedia should be added to facilitate instruction. This is particularly important, given practical issues with web based instruction, since such enrichments often require a good deal of development time and can also be problematic in terms of download time required. On the other hand, such enrichments have the potential to significantly facilitate learning by providing the learner with information via multiple modalities (e.g., auditory and visual) (Mayer, 1997). This fundamental balance between the use of basic vs. resource-rich presentations, is an important balancing act in web design for learning (Hall, 2001; Hall, Watkins & Eller, in press).

Richard Mayer and colleagues developed a theory of multimedia learning which poses two basic principles: the modality and contiguity principle (Mayer, 1997). The modality principle contends that multimedia materials should utilize different perceptual modalities. For example, pictorial information should be presented via auditory speech rather than written text, since the pictures and text both utilize the visual channel. The contiguity principle declares that multimedia presented simultaneously in time or space are more effective than when presented in sequence. A series of controlled laboratory experiments with children supported these principles (Mayer, 1997; Moreno & Mayer, 1999; Mayer, Heiser & Lonn, 2001). In recent years, however, research with so called “pedagogical agents”, which are computerized characters that appear on a student’s screen to help guide the learning process, has posed some challenges for the modality principle. Though these agents appear to create redundancy for the visual channel when they appear on a screen with visual information, they still have been found to facilitate learning (Atkinson, 2002).

The shear flow study reported here is an attempt to add a data point to the above investigations on the efficacy of hypermedia in learning. This study consists of a controlled examination of different types of learning factors in computerized instruction. Different types of multimedia modalities are examined: (a) video lecture, which utilizes both audio and visual channels; (b) HTML text and graphics, which utilize two types of visual information in a static format; and (c) interactive Flash animations, which include animated three dimensional graphics and text.

This research reaches beyond the above studies in a number of ways, though. First, the shear flow topic is a relatively complex one, and we of course are dealing with learners who are engineering students at a technologically oriented university. Second, the dynamic animations are used to present core visually oriented concepts in three dimensions, rather than relatively simple illustrations, or an animated character. There is evidence that one of the primary areas in which educational hypermedia can be effective is for displaying complex spatial concepts

(Dillon & Gabbard, 1998). A third difference between this and previous research is that student ability was considered. There is evidence that the single most important factor in determining performance with instructional multimedia is ability (Lanza & Roselli, 1991; Dillon & Gabbard, 1998; Dillon, 2002).

II. Shear Flow Experiment Background

The topic of shear flow in a Mechanics of Materials class was chosen for the experiment because it is a difficult topic requiring three-dimensional images to adequately present, describe, and understand the concept. Four sections of the Mechanics of Materials course, a total of around 100 students, participated in the experiment. The students had studied beam bending stresses, but because their text, Beer and Johnston's Mechanics of Materials, introduces beam shear stresses with shear flow, this lesson on shear flow was their very first exposure to the entire idea of transverse and longitudinal shear, and to shear flow.

Experimental Details

Approximately 100 University of Missouri-Rolla (UMR) students participated in the experiment, in four sections of approximately 25 students each. For each section, the following steps/activities were all completed in a single 50-minute class period during October, 2002.

(1) Computer Lab: On the day of the experiment, the students reported to a computer learning center instead of their regular lecture-style classroom.

(2) Human Subjects Form: All students completed a human subjects form giving permission to use the data collected in the experiment.

(3) Ten Minute Lecture: On their individual computer screens, each student viewed a 10-minute lecture presented by Dr. Ralph Flori that introduced the concepts of shear flow and transverse and longitudinal shear stress. Dr. Flori was chosen to present the video lecture because he was not the Mechanics of Materials instructor for any of these students; therefore, a possible source of experimental bias was eliminated. In addition to the presentation of the pertinent theory, Dr. Flori also worked a simple example illustrating how to calculate the first moment of area Q.

(4) Example Problems: After the 10-minute lecture, two additional example problems were presented to each student, in one of three possible formats:

- **(a)** One-third of the students viewed a video lecture showing a professor (again, Dr. Ralph Flori) working and explaining the two example problems.
- **(b)** One-third of the students navigated through an HTML-based presentation (text and graphics, analogous to a textbook) of the two problems. Students were free to view the HTML presentation in any sequence or at any pace that they desired.
- **(c)** One-third of the students navigated through animated Flash modules of the two problems. The animated media consisted of high quality three-dimensional graphics, textual explanation, and equations. Students were free to view the animated modules in any sequence or at any pace that they desired.

(5) Assessment: After completing viewing of the example problems, all students were given a quiz and were asked to complete a survey.

(a) Quiz: The quiz, shown in Appendix A, contained nine multiple choice questions to assess student understanding of various key concepts of shear flow.

(b) Survey/Comments: The students completed a questionnaire in which they were asked to rate their agreement-disagreement with eight statements on a nine point scale. The questionnaire is reproduced in Appendix B.

III. Discussion of the Experiment

For any topic but particularly for a topic as difficult as shear flow, it is wildly optimistic to expect students to learn the topic well enough in a 50-minute period so that they can score reasonably well on a quiz. Nevertheless, we chose to adopt this approach to maintain some level of control on the learning experiment. If the shear flow topic had been introduced to students by their regular instructor (or by a common instructor, either live in the classroom or by video) during a previous class period, a wide range of potential variation would have been introduced into the experiment. Factors such as the degree to which students worked homework problems or studied their texts between class periods would have seriously confused and confounded interpretation of the experimental results. Consequently, all tasks were clustered into one 50-minute class period. Students had time to complete all assigned tasks, but their average score on the multiple choice quiz was only 3.7 out of 9. Not stellar, but given the topic and the conditions, believable.

IV. Questionnaire Results – Grouped by Class Meeting Times

Results from the questionnaire (see Appendix B) grouped according to class meeting times are presented in Table 1. Note that for each class meeting time, the average result combines the responses of students who viewed example problems from all three types of media. The results show that the students were mildly favorable toward most of the activity and would be willing to use similar materials again. They admit that they didn't learn a great deal from the examples, and they remained somewhat fuzzy about how to calculate Q, but these results are perfectly understandable given the brevity of the presentation. And as most Mechanics of Materials instructors know, more students than we care to admit never seem to figure out Q.

On the next page is given a table comparing the survey results according to the kind of media the students used to view the example problems. Keep in mind that all students started out with a video introductory lecture. Those students who continued with the video lecture were slightly more satisfied overall with the experience, probably because they didn't have to change learning modalities. Furthermore, the students who viewed the video lecture example problems scored highest (4.12/9) on the multiple choice quiz. Two further reasons that the lecture videos competed well could be that they combined both visual and auditory elements (whereas the other two media did not), and simply because lectures in general are familiar and comfortable for students. It certainly helped that the video lecturer in this study is well regarded as an effective teacher. For those who argue that the lecture is dead, these results suggest that there is still some value in the lecture method.

Table 1: Survey and Quiz Results for Fall 2002 Shear Flow Experiment					
Shear Flow Survey Statements	**Class Meeting Times**				**Average Rating**
	8:30	**9:30**	**10:30**	**11:30**	
Overall evaluation of video lecture	6.32	6.08	5.93	6.26	**6.15**
Learned great deal from examples	5.86	5.24	5.33	5.41	**5.46**
Examples helped me visualize shear	6.59	6.12	5.78	5.88	**6.09**
Examples helped me calculate Q	5.95	5.72	5.85	5.44	**5.74**
Helped me know what I don't know	6.64	7.04	6.92	7.3	**6.98**
Shear flow presentation motivational	4.55	5.44	4.37	5.04	**4.85**
Technical problems with my computer ruined my experience	1.62	1.52	2.04	4.37	**2.39**
I would like to use these matls again	6.32	6.44	4.7	6.78	**6.06**
Overall	6.33	6.36	5.78	6.11	**6.15**
Multiple choice quiz score (out of 9)	3.18	3.64	3.63	4.22	**3.67**

V. Questionnaire Results – Grouped by Media

Results from the questionnaire (see Appendix B) grouped according to media type are presented in Table 2. Students who used the HTML-based materials, much like self-study of example problems from a text, were the least satisfied, least interested in using them again, and scored the poorest on the quiz.

Students who viewed the Flash-based example problems noted that these helped them with visualization of the problem and with discovering what they didn't know (probably the 'wow' factor of seeing the graphics caused them to say, 'I never knew that; I can see that now.') Also, the Flash students were the most likely to admit that the materials were motivational. Unfortunately, they scored lower on the multiple choice quiz. Possible explanations could include:

- Some of these students may not have finished navigating through their Flash example problems.
- Because of the 'wow' factor of the Flash problems, the students' attention was drawn to the visualization aspects of the problems and they focused less on other elements.
- One additional explanation could be the lack of a 'voice' or 'teacher' to guide them and explain the problem to them. Students like to navigate themselves, but they can overlook important information if someone doesn't point it out to them.

It is important to note, when interpreting these means and our proposed explanations, that the difference among the experimental condition means (i.e., video vs. HTML vs. Flash) did not reach statistical significance for any of these questionnaire items (see analysis section below). Though the means demonstrate interesting trends and it is useful to speculate about these differences, it's important to remember to consider them within the constraint that we have not ruled out the probability that they can be attributed to error variance.

Table 2: Survey and Quiz Results (by media used for example problems)

Shear Flow Survey Questions	Media / Avg Rating		
	Video	HTML	Flash
Overall evaluation of video lecture	6.55	6.00	5.88
Learned great deal from examples	5.94	5.14	5.28
Examples helped me visualize shear	6.12	5.72	**6.42**
Examples helped me calculate Q	5.97	5.69	5.53
Helped me know what I don't know	6.61	6.94	**7.44**
Shear flow presentation motivational	4.79	4.81	**4.97**
Technical problems with my computer ruined my experience	2.36	2.11	2.94
I would like to use these matls again	6.12	5.50	6.56
Overall	6.64	5.66	6.13
Multiple choice quiz score (out of 9)	**4.12**	3.44	3.53
Overall evaluation of video lecture	4.05	3.42	3.68

VI. Statistical Analysis of the Survey and Quiz Results

A series of nine, 2-way, between-subjects analyses of variance (ANOVA's) were computed with experimental condition (video vs. text vs. animation) and GPA (high vs. low, based on a median split) serving as the independent variables. In the first ANOVA, the multiple choice quiz score served as the dependent variable. In the other eight ANOVA's, the other eight survey questions results served as a dependent variable.

In the ANOVA in which the multiple choice quiz was the dependent variable, a main effect for GPA was found $F(1,94) = 4.73$, $p < .05$, with high GPAs ($M = 4.18$) scoring higher than low GPAs ($M = 3.24$). In the ANOVA in which students rated their level of motivation, a marginally significant main effect of GPA was also found $F(1,94) = 3.90$, $p = .051$ with high GPAs ($M = 4.46$) rating the material as less motivating than low GPAs ($M = 5.32$). No other effects in any of the ANOVAs were significant.

VII. Conclusions

The results indicated, not surprisingly, that higher ability students scored higher on the post test covering the experimental materials than their peers. In addition, these same high ability students rated their levels of motivation substantially lower than their peers. However, this effect did not interact with experimental condition and, in fact, there was no significant effect for experiment condition across all dependent measures. It did not appear to make an appreciable difference whether a student viewed example problems in the form of a video lecture or static text/graphics or a 3-D animation.

These results are inconsistent with what one might expect since there would appear to be some important advantages to the video lecture and/or the animation. The former was the only method to provide information via two perceptual modalities (which should be advantageous according to the theory of multimedia discussed in the introduction) and the animation would seem to have an advantage in that it was the only method that allowed for the visual representation of 3-D concepts that were an important part of understanding these materials.

There are at least three possible explanations for these somewhat counterintuitive findings. First, the relatively short twenty-minute presentation of the materials may not have been very representative of the way in which these materials would be used in a traditional class. This is the common dilemma researchers face, in that the strength of the study, in terms of internal validity and control, may have negatively impacted the external validity and generalization to applied situations. Second, students' motivation level may not have been as high as would have been the case had the outcomes test counted toward their grade, which was reflected at least in the low motivation levels for those in the high GPA group. Third, the lower-level knowledge assessed via the multiple choice test may not have accurately reflected the additional spatial and applied knowledge that could have been gained by those who were exposed to the 3-D multimedia presentation.

It should be noted that the instructor presenting the video lectures in the experiment is an exceptional teacher who has received 12 Outstanding Teaching Awards in his 13 years at UMR. The fact that students viewing the animated Flash modules had ratings and scores that were not statistically different from those of students viewing the lecture suggests that multimedia presentations can compete favorably with traditional lectures.

VIII. References

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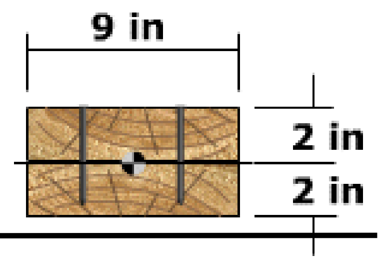
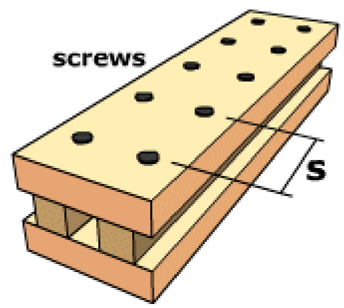
Appendix A: Quantitative Assessment, Shear Flow (q = VQ/I)

___ 1. To calculate the shear flow associated with the two nails shown in the figure, which area or areas should be included in the calculation of Q?
- a. Area (1)
- b. Areas (4) and (7)
- c. Areas (3), (4), (6) and (7)
- d. Areas (2), (3), (5), and (6)

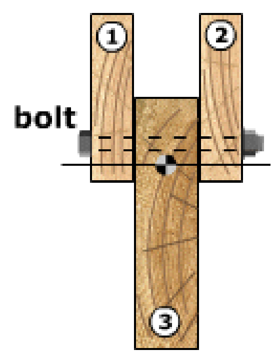
___ 2. The value of Q needed for the shear flow calculation for the shape shown is:
- a. 36 in^3
- b. 9 in^3
- c. 18 in^3
- d. none of the above



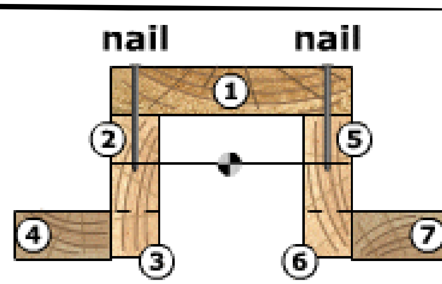
___ 3. Screws are used to fabricate the wood beam. Each screw has an allowable shear force of 1,000 N. If s = 200 mm, what shear flow can be resisted by the beam?
- a. 2.5 N/mm
- b. 5.0 N/mm
- c. 10.0 N/mm
- d. 20.0 N/mm



___ 4. To calculate the shear flow associated with the bolt shown in the figure, which area or areas should be included in the calculation of Q?
- a. Area (1)
- b. Areas (1) and (3)
- c. Areas (1) and (2)
- d. Areas (1), (2), and (3)

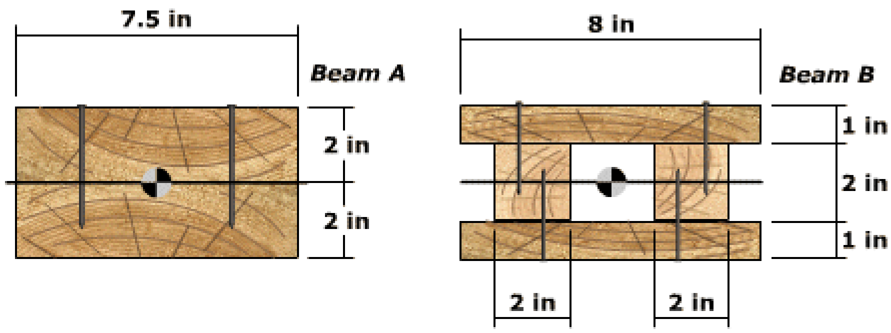


___ 5. In calculating the shear flow associated with the two nails shown in the figure, which area or areas should be included in the calculation of Q?
- a. Area (1)
- b. Areas (4) and (7)
- c. Areas (3), (4), (6) and (7)
- d. Areas (2), (3), (5), and (6)



___ 6. The sketch shows two cross-sectional configurations: Beam A and Beam B. Both Beam A and Beam B have the same shear force V, the same moment of inertia I, and the same nails. The nails in Beam A are spaced at 5-inch intervals along the beam span. For Beam B, the nail spacing will be:

a. greater than 5 inches
b. 5 inches
c. less than 5 inches
d. not enough information given

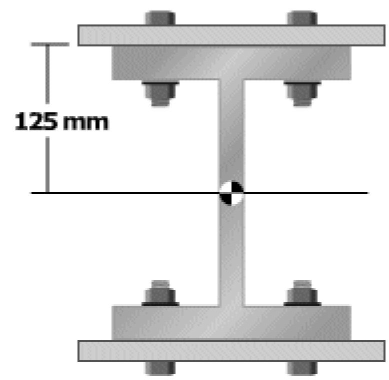


___ 7. The steel W-beam shown has been reinforced by two 12 x 150-mm cover plates. What value of Q will be needed to compute the shear flow for the upper flange bolts?

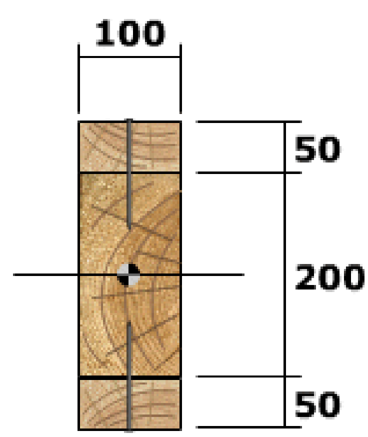
a. 225,000 mm³
b. 235,800 mm³
c. 246,600 mm³
d. not enough information given

___ 8. If the cross-sectional area of each bolt is 200 mm² and the allowable shear stress is 60 MPa for the bolts, how much shear flow q can the beam withstand?

a. 12 kN
b. 24 kN
c. 48 kN
d. not enough information given



___ 9. What is the value of Q needed to calculate the shear flow for the lower nail in the cross section shown.



Appendix B: Student Assessment of the Learning Experience

BE 110: Assessment, Shear Flow in Beams

Enter the number on
your computer monitor: _______

Please use the scale below to respond to the statements.

Strongly Disagree 1 … 2 … 3 … 4 … 5 … 6 … 7 … 8 … 9 **Strongly Agree**

A. Evaluation of the 10 minute video lecture on shear flow:

_____ 1. Give your overall evaluation of today's video lecture on shear flow, using the 1…..9 scale, with 1 = very poor and 9 = outstanding.
Comments:

B. Evaluation of the presentation you viewed of the two example problems:

_____ 2. I learned a great deal of information from the example problems on shear flow.
Comments:

_____ 3. I found that the example problems helped me to better visualize how to apply the shear flow equation.
Comments:

_____ 4. I found the example problems helped me to better understand how to calculate Q.
Comments:

_____ 5. Today's presentation on shear flow helped me to recognize how much I know and don't know about shear flow.
Comments:

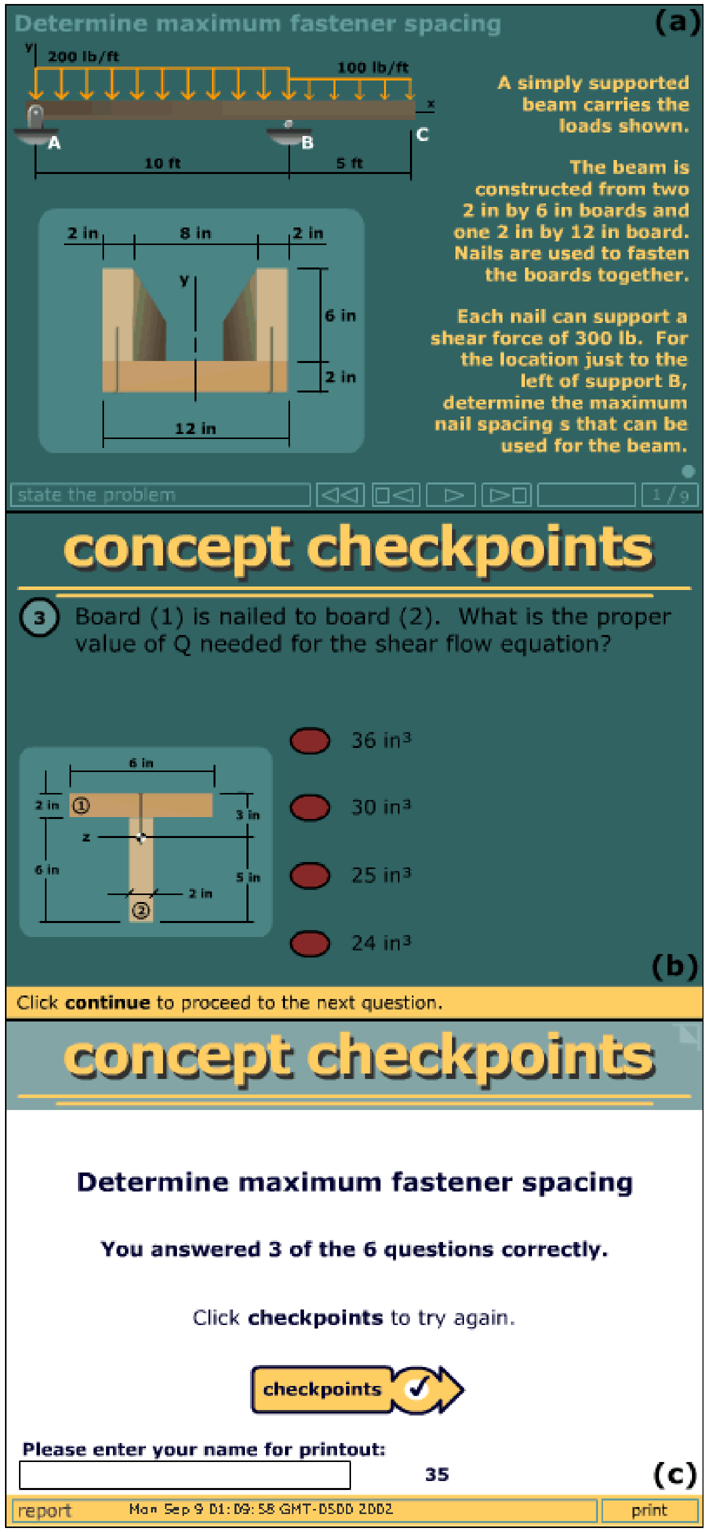
_____ 6. I found today's presentation of the shear flow problems to be motivational.
Comments:

_____ 7. Technical problems with my computer hardware or with the software caused me to dislike the computer-based instructional materials that I viewed.
Comments:

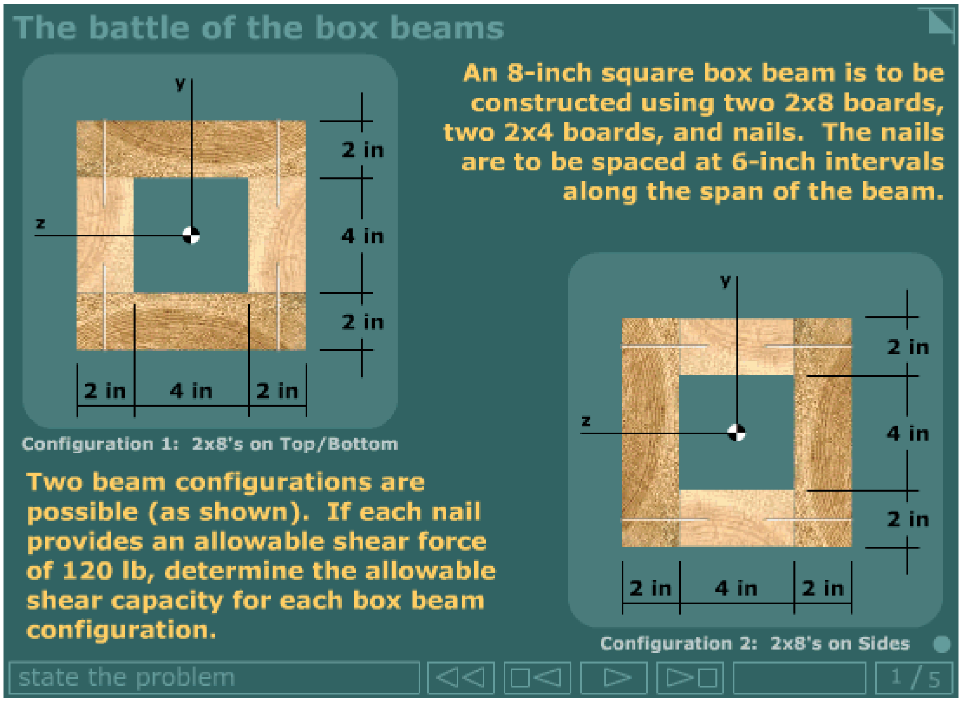
_____ 8. I would like to use materials like these again, either in class like today or out of class.
Comments:

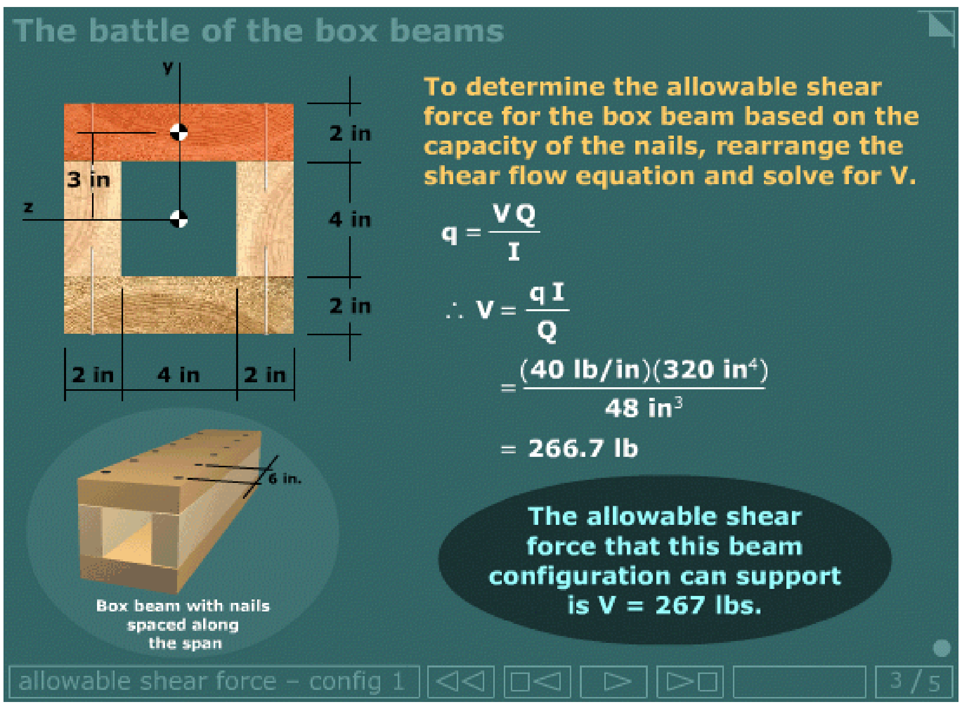
_____ 9. Give your overall evaluation of the presentation of the two shear flow example problems, using the 1…..9 scale, with 1 = very poor and 9 = outstanding.
Comments:

Appendix C: Selected Scenes from Flash Example Problems



Appendix C (continued): Selected Scenes from Flash Example Problems





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