AC 2011-965: THE PURPOSEFUL USE OF ACTIVITIES TO AFFECT LEARNING

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The Purposeful Use of Activities to Affect Learning

Abstract

Demonstrations are often used by educators to engage students and increase their retention of material and ability to synthesize and apply concepts to new situations. However, the effectiveness of such demonstrations is hindered by students' tendency to compartmentalize concepts. We hypothesized that students who participated in purposeful activities designed to reinforce and build upon such demonstrations would demonstrate an increased ability synthesize the concepts and apply them to new situations.

To test our hypothesis, we worked with two different class sections of Mechanics of Materials, both taught by the same instructor, and both covering the same material at the same pace. Both sections participated in preliminary demonstrations and recorded their observations. Subsequently students in the test section participated in additional follow-up activities while students in the control section did not. Last, both the test section and the control section participated in a final materials test. Performance differences between the two pedagogical methods were assessed through a set of questions asking students in both sections to identify and explain the relationships of interest.

Assessment results did not uphold the hypothesis. While only a small number of students in either section correctly identified and explained the relationships of interest, the number of students in the test section to do so was half the number of students in the control section. In addition, most of students in both the test section and the control section had difficulty appropriately synthesizing the various concepts applicable to the final materials test.

Confounding factors that may have contributed to these results are discussed. In addition, suggestions are presented to guide further study of how activities can be better used to integrate understanding of concepts.

Introduction

Background

Compartmentalization often hinders students from seeing the interrelationship among various subjects they are studying.[1] In Mechanics of Materials, where many topics are presented during the course of the semester, such compartmentalization hinders students from being able to synthesize the material and apply it to new situations. Research has also shown that learning is increased when students actively participate in the material being presented.[2] Therefore, demonstrations are often used to help engage students. However, experience has shown that while students learn from demonstrations, the demonstrations alone do not help them synthesize the various concepts presented in the course.

Hypothesis

Students who participate in demonstrations followed by purposeful activities designed to reinforce and build upon the demonstrations will show an increased ability to synthesize the concepts and apply them to new situations.

Procedure

Experimental setup

Two sections of Mechanics of Materials provided a means for a controlled experiment to test the hypothesis. One section served as the test section and the other served as the control section. The two sections were offered in the same semester and both were taught by the same professor. In both sections, the professor used Hibbeler's latest Mechanics of Materials text,[3] following the progression of materials laid out in the text:

- concepts of stress and strain
- axial loading
- torsional loading
- normal stress in beams
- transverse shear stress in beams
- thin walled pressure vessels
- combined loading
- stress transformations
- strain transformations
- beam design
- beam deflection
- column buckling

In addition, the two sections were assigned the same homework and took common-hour exams.

Demonstrations and activities

Overview. The study focused on the concepts of axial loading, torsional loading, and stress transformations. Once axial loading and torsional loading had been covered, students in both the test section and the control section took part in initial demonstrations related to axial loading and torsional loading. Once the students had studied stress transformations in class, the students in the test section participated in in-class follow-up activities designed to reinforce the concepts presented in the demonstrations, and relate them to stress transformations. Finally, at the end of the semester, students in both sections performed a final torsional test, recorded their observations, and answered questions concerning their observations. The various demonstrations and activities employed in each section are listed in Table 1.

Table 1. Sections participating in each demonstration or activity.

Demonstration/Activity	Section Participating	
	Test Section	Control Section
Axial Load Demonstration	Yes	Yes
Torsion Demonstration	Yes	No
Activity 1: Axial Load Demonstration and State of Stress	Yes	No
Activity 2: Review of Torsion Demonstration	Yes	No
Activity 3: Torsion Demonstration, State of Stress and Mohr's Circle	Yes	No
Final Pretzel and Licorice Test	Yes	Yes

Axial load demonstration. Both sections participated in the Axial Load Demonstration. Students were given pieces of surgical glove material with squares and diamonds draw on them. Each student was then asked to work his/her way through the Axial Load Demonstration Form (Figure 1a). As they did so they were allowed to discuss their findings with their classmates. Once the forms were completed and had been collected, the professor worked through and explained the demonstration to the students.

Torsion demonstration. Both sections also participated in the Torsion Demonstration. Students were given 12-inch lengths of 2½-inch diameter Styrofoam tubing. Each student was then asked to work his/her way through the Torsion Demonstration Form (Figure 1b). As they did so, students were again allowed to talk with their classmates. Once the forms were completed and had been collected, the professor worked through and explained the demonstration to the students.

Follow-up activities. The test section then participated in the three follow-up activities. In each case, the students and the professor worked through the activity and corresponding form together. (Figures 2a, b, and c) With Activity 1, students reviewed the Axial Load Demonstration and related the changes in the square and diamond to the stresses acting on them. With Activity 2, students reviewed the Torsion Demonstration and related the changes in the square and the diamond to the stresses acting on them. With Activity 3, students reviewed Activity 2. They identified the stresses acting on the square as σ_{ave} and $\tau_{max\text{-}in\text{-}plane}$ and the stresses acting on the diamond as the principal stresses. In addition, the students drew Mohr's Circle for the state of stress on the surface of the Styrofoam tube.

Final pretzel and licorice test. At the end of the semester, thirty-eight students from each section participated in the final torsional test of pretzels and licorice. Students were given 12-inch pieces of red licorice and 8-inch pretzel sticks. Each student was then asked to work his/her way through the Pretzel and Licorice Test Form (Figure 3). This form consisted of three portions. The first portion dealt with brittle versus ductile materials. The second portion dealt with observations of the torsion failure of the licorice and the pretzel. The third portion dealt with stress transformations. The questions asked in this portion were as follows:

- Brittle versus ductile material
  - Draw a typical stress-strain diagram for a ductile material
  - Draw a typical stress-strain diagram for a brittle material
  - Classify the pretzels and licorice as brittle or ductile material.
- Torsion tests of the licorice and pretzel
  - Apply torsion to the pretzel and to the pretzel
  - Sketch the resulting failure for each material
  - Identify the angle of the failure plane for each material
- Application of stress transformations to pretzel failure
  - From the list provided, select the stress that was exceeded when the pretzel failed

compressive stress	axial force	bending moment
torsion	shear stress	tensile stress

  - Explain your reasoning behind your choice of failure stress

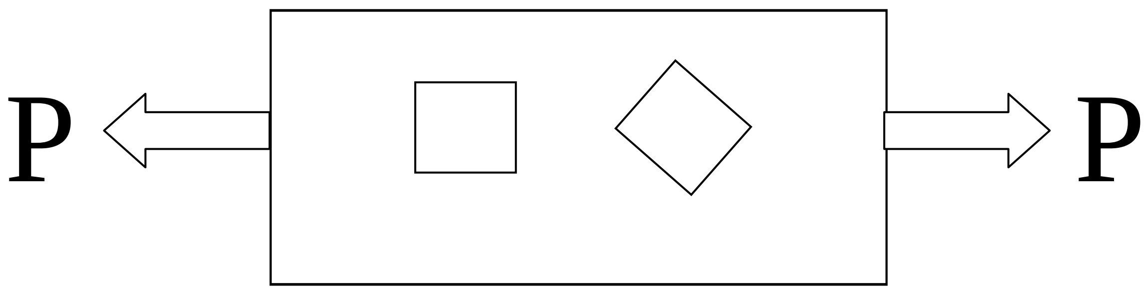
The students were allowed to talk with their classmates as they worked through the form. Once the forms were completed, the professor had the students pass them in row by row before discussing the test with them. The forms from each section were then numbered in the order they were turned in, and the data was tabulated.

Figure 1a: Axial Load Demonstration

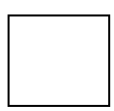
Define shear strain.

Define normal strain.

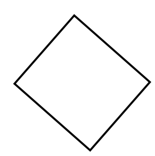
The pictures below show a portion of a surgical glove. Pull on the glove as shown. As you do, carefully observe what happens to the square and the diamond.



Sketch what happens to the square.



Sketch what happens to the diamond.



State the figure – the square or the diamond – that experiences solely length change as the axial load is applied.

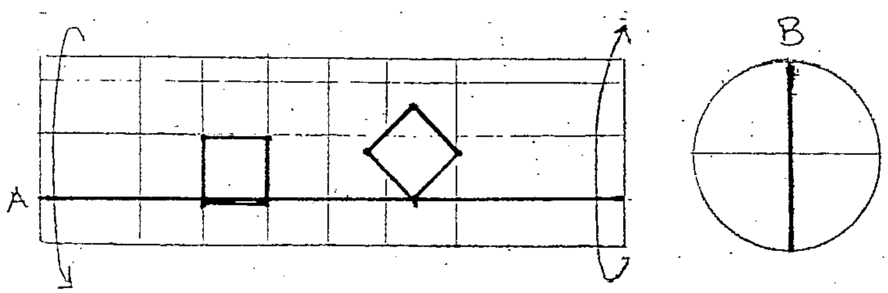
State the figure – the square or the diamond – that experiences angle change as the axial load is applied.

Figure 1b. Torsion Demonstration

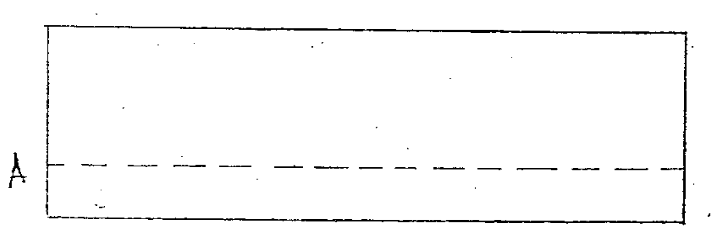
Define shear strain.

Define normal strain.

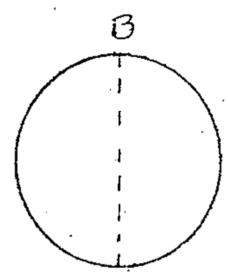
The pictures below show the front and end view of a Styrofoam tube. Twist the tube as shown. As you do, carefully observe what happens to each of the items shown in bold – line A, line B, the square, and the diamond.



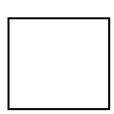
Sketch what happens to line A.



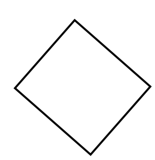
Sketch what happens to line B.



Sketch what happens to the square.



Sketch what happens to the diamond.



In one of the figures above, identify the average shear strain, γ, over the length of the tube.

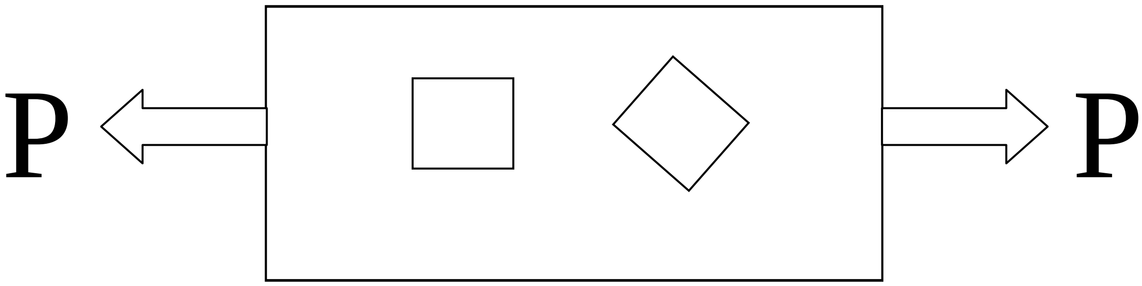
In one of the figures above, identify the angle of twist, θ, of the right end relative to the left end of the tube.

Figure 2a. Activity #1: Axial Load Demonstration and State of Stress

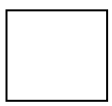
State the type of stress that produces shear strain.____

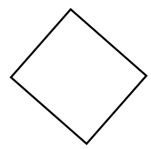
State the type of stress that produces normal strain.____

Recall what happens when a piece of surgical glove material is axially loaded as shown.



Sketch what happens to the square. Sketch what happens to the diamond.



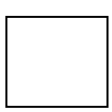


OBSERVE THE SQUARE:
The square changes lengths in two directions.
State the type of stress that axial load causes on the square________________________________
Circle the direction – horizontal or vertical – that this stress would be acting on the square.
State the cause of the change of length in the **other** direction.______________________________

Below, sketch the state of stress on the square. Because there is no shear stress on this figure, the stresses shown must be ____

OBSERVE THE DIAMOND:
The diamond changes angle as well as length.
State the type of stress that causes angle change.____
State the type of stress that causes length change.____

Below, sketch the state of stress on the diamond. Because this figure is rotated 45° from the square, the stresses shown must be ____



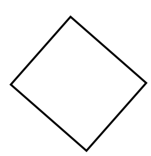
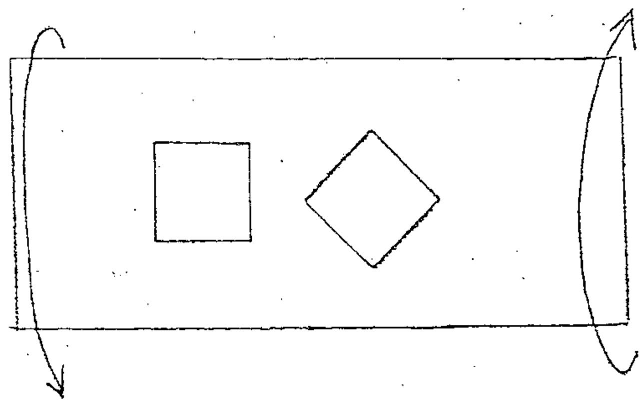
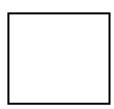


Figure 2b. Activity #2: Review of Torsion Demonstration and State of Stress

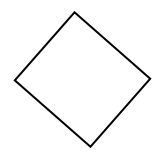
Recall what happens when a Styrofoam tube is twisted as shown.



Sketch what happens to the square.



Sketch what happens to the diamond.



State the figure – the square or the diamond - that experiences solely length change as the torsional load is applied.____

State the figure – the square or the diamond - that experiences angle change as the torsional load is applied.____

State the type of stress that produces length change.______________________________

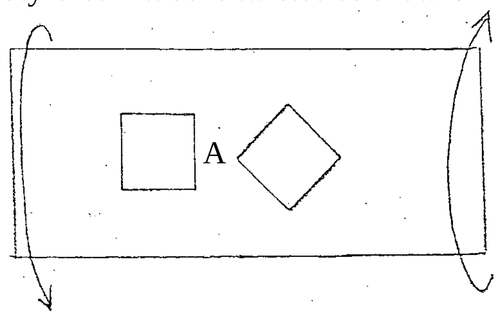
State the type of stress that produces angle change.______________________________

Figure 2c. Activity #3: Torsion Demonstration, State of Stress and Mohr’s Circle

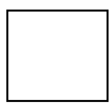
State the type of stress that produces shear strain.____

State the type of stress that produces normal strain.____

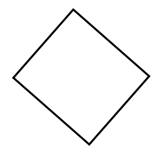
Recall what happens when a Styrofoam tube is twisted as shown.



Sketch what happens to the square.

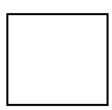


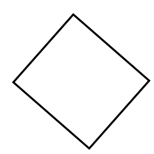
Sketch what happens to the diamond.



State the figure – the square or the diamond – that experiences solely length change as the torsional load is applied.____
Below, draw the state of stress on this figure. Because there is no shear stress on this figure, the stresses shown must be ____

State the figure – the square or the diamond – that experiences angle change as the torsional load is applied.____
Below, draw the state of stress on this figure. Because this figure is rotated 45° from the square, the stresses shown must be ____





Draw Mohr’s Circle for the state of stress at point A on the surface of the Styrofoam tube. Label the points that correspond to the states of stress on the diamond and the square.

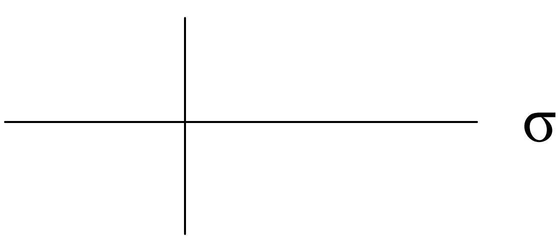


Figure 3: Final Pretzel and Licorice Test

Sketch a typical stress-strain diagram for a ductile material and for a brittle material.

Examine the pretzel stick and the licorice stick. Classify each and as to whether it is ductile or brittle.

Pretzel Stick _______________

Licorice Stick ______________

LICORICE:

Apply a torsional load, as shown above, to the licorice stick, and continue to do so until the licorice stick fails. Sketch the appearance of the licorice stick when it fails.

Angle of failure plane, measured from horizontal = __________

PRETZEL:

In the same way, apply a torsional load to the pretzel. Sketch the appearance of the pretzel stick when it fails.

Angle of failure plane, measured from horizontal = __________

From the list below, circle the type of stress that was exceeded as the failure occurred. Explain your reasoning.

Compressive Stress	Axial Force	Bending Moment
Torsion	Shear Stress	Tensile Stress

REASONING:

____

____

____

____

Results

Brittle versus ductile material

The responses to the questions dealing with brittle and ductile materials were similar in the two sections. In the test section, 34 of the 38 students (89%) correctly sketched a stress-strain diagram for ductile material, and 17 of the 38 students (45%) correctly sketched a stress-strain diagram for brittle material. In the control section, 36 of the 38 students (94%) correctly sketched a stress-strain diagram for ductile material and 25 of the 38 students (66%) correctly sketched a stress- strain diagram for brittle material.

In both sections, 37 of the 38 students correctly classified pretzels as brittle material and licorice as ductile material. Typical student sketches for ductile and brittle stress-strain diagrams are shown in Figure 4. Student responses to the questions over brittle versus ductile material for both sections are tabulated in Table 2.

Figure 4: Stress-Strain Diagrams Typical of Those Provided by Students.

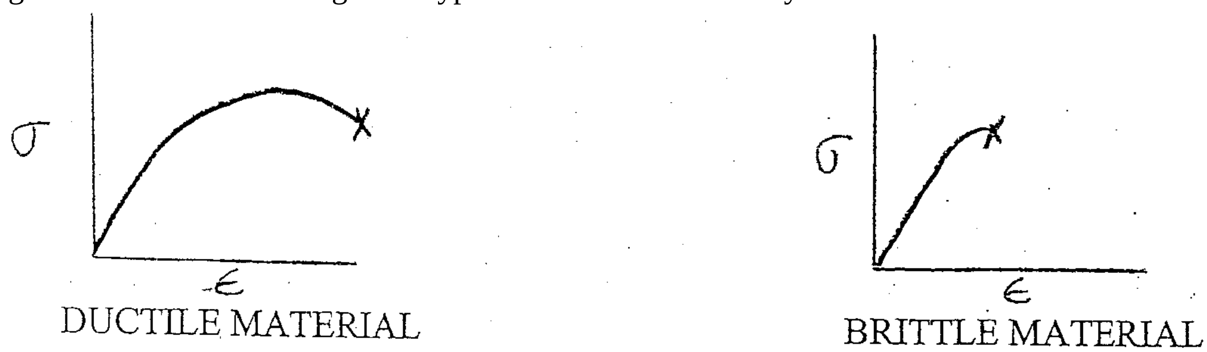


Table 2. Student responses to questions over brittle versus ductile materials.

	Test Section	Control Section
Correct Ductile Stress Strain Diagram	34 of 38 students (89%)	36 of 38 students (94%)
Correct Brittle Stress-Strain Diagram	17 of 38 students (45%)	25 of 38 students (66%)
Correctly Classified Pretzel as Brittle and Licorice as Ductile	37 of 38 students (97%)	37 of 38 students (97%)

Torsion tests of licorice and pretzels

Licorice. Student observations of the angle of the failure plane in the licorice were varied. A typical student sketch of licorice failure is shown in Figure 5. In the test section, student observations of the licorice failure plane ranged from 0^0 to 140^0, with 29 of the 38 recorded observations (76%) falling in the range of 85^0 to 95^0 from horizontal. In the control section, student observations of the licorice failure plane ranged from 0^0 to 360^0, with 28 of the 38 recorded observations (74%) falling in the range of 85^0 to 95^0 from horizontal. In addition, in this section three students mistakenly recorded the number of degrees the licorice was twisted through before failing. This data is tabulated in Table 3. In both sections a failure plane of approximately 90^0 was the most common observation.

Figure 5: Licorice Failure Sketch Typical of Those Provided by Students

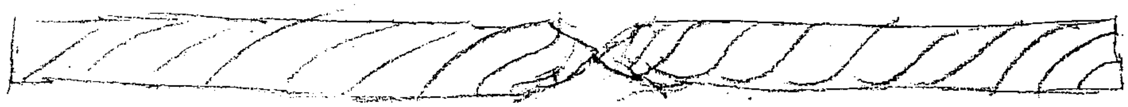


Table 3.   Student observations of failure planes in licorice.

Observed Failure Plane Angle, degrees	Number of Responses	
	Test Section	Control Section
0^0	2	2
$35^0 – 70^0$	5	4
$85^0 – 90^0$	**29**	**28**
$140^0 – 360^0$	1	2
>2300^0 (angle of twist)	0	2
Did not fail	1	0
TOTAL	38	38

Pretzels. Student observations of the angle of the failure plane in the pretzel were also varied. A typical student sketch of pretzel failure is shown in Figure 6. In the test section, observations ranged from 10^0 to 45^0, with 24 of the 38 observations (63%) in the range of 40^0 to 45^0 from horizontal. In the control section, observations ranged from 0^0 to 180^0, with 27 of the 38 students observing a failure plane in the range of 40^0 to 45^0 from horizontal. This data is also tabulated in Table 4. In both sections a failure plane of approximately 45^0 was the most common observation.

Figure 6: Pretzel Failure Sketch Typical of Those Provided by Students

Table 4. Student observations of failure planes in pretzels.

Observed Failure Plane Angle, degrees	Number of Responses	
	Test Section	Control Section
$0^0 – 20^0$	4	3
$30^0 – 36^0$	10	5
$40^0 – 45^0$	24	27
90^0	0	3
TOTAL	38	38

Application of stress transformations to pretzel failure

Choice of failure stress. When asked to select the type of stress that was exceeded when the pretzel failed, students provided mixed responses. In the test section, 20 students chose shear stress, while 6 students chose tensile stress as the stress that was exceeded when the pretzel failed. The other 12 students did not select a stress. Rather, 8 students chose torsion, 1 chose bending moment, and 3 circled more than one response. In the control section, 18 students selected shear stress, while 13 students selected tensile stress as the stress that was exceeded when the pretzel failed. The remaining 7 students did not choose a stress. Rather, 4 students chose torsion, 1 chose axial force, and 2 circled more than one response. These responses are tabulated in Table 5. In addition, these responses are recorded with the corresponding explanations of failure in Table 6. In both sections most students chose shear as the stress that had been exceeded when failure occurred. Of the smaller number of students in each section choosing tensile stress as the stress exceeded at failure, twice as many students in the control section made this selection than students in the test section.

Table 5. Student responses for the stress exceeded when the pretzel failed.

Possible Choice for Stress Exceeded at Failure	Number of Students Choosing	
	Test Section	Control Section
Compressive Stress	0	0
Tensile Stress	6	13
Shear Stress	20	18
Torsion (Tor)	8	4
Axial Force (AF)	0	1
Bending Moment (BM)	1	0
Shear Stress, Torsion	1	
Shear Stress, Torsion, Bending Moment		1
Torsion, Bending Moment		1
Torsion, Bending Moment, Axial Force	1	
Circled all 6 possible choices	1	
TOTAL	38	38

Explanation of failure. Students demonstrated varied depth of understanding as they explained their reasoning behind their choice of the stress that was exceeded at failure. In the test section, of the 6 students who stated that tensile stress had been exceeded, 4 correctly related the failure to stress transformations by stating that torque produced normal stress at 45^0, and 2 either provided no explanation or restated that the tensile stress was exceeded. Of the 20 students who stated that shear stress had been exceeded, 9 said that torsion produces shear stress, and 11 either provided no explanation or restated that shear stress was exceeded. In the control section, of the 13 students who stated that tensile stress had been exceeded, 8 correctly related the failure to stress transformations by stating that torque produced normal stress at 45^0, 2 stated that the tensile stress was at sigma-max, 2 stated that brittle materials fail in tension, and 1 student stated that torsion produced tensile failure. Of the 18 students who stated that shear stress had been exceeded, 10 said that torsion produces shear stress, 5 said that brittle materials fail in shear, and 3 either provided no explanation or restated that shear stress was exceeded. The actual explanations can be seen in Table 6, sorted by choice of failure stress. Only a small number of students in either section correctly related the pretzel failure to stress transformations. However, twice as many students in the control section did so than in the test section.

Table 6. Students' explanations of failure.

A. TEST SECTION (Tor = Torsion, AF = Axial Force, BM = Bending Moment)

Sheet #	Failure Stress Selected	TEST SECTION Students' Explanations of Failure
3	tensile stress	Pretzel is in tension fail.
4	tensile stress	
9	tensile stress	Pretzel fails at an angle of around 30 degrees. Needs something.
10	tensile stress	Because it breaks at 45 degrees where there is no shear stress and max tensile and that why it breaks.
11	tensile stress	Fails in tension applied 35 to 40 degrees from horizontal.
12	tensile stress	Pretzel appears to fail in tensile stress but at a different angle. When you compare to a Mohr's circle it might look the same.
1	shear stress	The pretzel breaks because of the torsion being applied causing shear stress.
5	shear stress	The pretzel was subjected to shear force at an angle.
6	shear stress	Because the torque creates shear stress
7	shear stress	Torque loads create shear stress.
8	shear stress	Shear stress is created by torsion loads.
13	shear stress	shear across the outside of the object
18	shear stress	
19	shear stress	
20	shear stress	Shear torque causes shear stress.
21	shear stress	Torsion causes shear stress which when exceeded causes failure.
22	shear stress	Shear torque causes shear stress causes shear strain.
23	shear stress	Change in orientation. Applying the torsional moment causes shear stress.
24	shear stress	Shear stress is a change in orientation, we applied a moment.
25	shear stress	The shear stress causes the failure of the pretzel.
26	shear stress	The shear stress is what causes the failure in the pretzel.
27	shear stress	
28	shear stress	
35	shear stress	
37	shear stress	
38	shear stress	Pretzel exceeded shear stress max.
2	Tor	because we apply torsion
16	Tor	because of its failure points
17	Tor	because of its failure appearance
29	Tor	Pretzel fails almost immediately.
30	Tor	That was the load applied.
31	Tor	It's not compressive or tensile because the force applied is a torque.
33	Tor	Pretzel snapped when torque was applied. At a 45 degree angle with no twist must have failed due to torsion.
36	Tor	Force applied is a torque about the x-axis which then causes the break.
34	Shear Stress, Tor	
15	AF, BM, Tor	
14	BM, Tor	
32	circled all	because this class is awesome

Control Section data is on the next page.

B. CONTROL SECTION (Tor = Torsion, BM = Bending Moment, AF = Axial Force)

Sheet #	Failure Stress Selected	CONTROL SECTION Students' Explanations of Failure
1	tensile stress	Torque caused tensile stress at 45 degrees for pretzel failure.
3	tensile stress	Brittle materials fail due to tensile stress.
5	tensile stress	Brittle materials fail in tension.
9	tensile stress	Torsion created a tensile stress in the pretzel.
14	tensile stress	If you picture an infinitesimal element and rotate it about 45 degrees you can think of the compressive/tensile stresses at that angle.
19	tensile stress	Maximum normal stresses are reached on a 45 degree and the pretzel failed at 45 degrees.
22	tensile stress	Torque creates stresses within the material. When we look at a differential element the maximum stress occurs approximately along the fracture line for the pretzel
27	tensile stress	The tensile for pretzel since sigma is at max.
28	tensile stress	Tensile stress fails for the pretzel because the sigmas are at the max.
29	tensile stress	Pretzel failure was away from the 90 degree plane where torsion also causes tensile stress.
30	tensile stress	Failed along a 45 degree angle. The orientation at that angle would indicate that there were larger tensile stresses at that angle.
31	tensile stress	The pretzel pulled apart and failed on about a 45 degree plane which means the tension was what made it fail.
33	tensile stress	The pretzel broke at a 45 degree angle but if you look at it in the direction that it broke the tension on it caused the break.
2	shear stress	A torsional force is applied.
10	shear stress	Torque causes an internal shear stress in both, however the orientation of the plane for max shear stress is different for each because one is ductile and one is brittle.
12	shear stress	
15	shear stress	From the formula for shear stress, torsion causes the internal torque which in tern results in the shear stress.
16	shear stress	When a brittle breaks at 45 degrees from horizontal it is because of shear stress.
17	shear stress	In brittle materials they fail in shear like concrete.
18	shear stress	When a brittle breaks at 45 degrees from horizontal it is because of shear stress.
20	shear stress	The failure was at 45 degrees.
21	shear stress	The reason I think this is the 45 degrees angle the material broke at.
23	shear stress	When torque is applied is causes shear stress failure.
24	shear stress	Torque is applied which causes a shear stress to form. As more torque is applied the shear stress increases until failure occurs.
25	shear stress	We use torsion to find the shear stress.
26	shear stress	Pretzel failed due to shear caused by the torque on the surface at the angle of failure.
32	shear stress	Torsional loads create shear stress.
34	shear stress	
35	shear stress	Torsion causes shear stress.
36	shear stress	Shear stress is exceeded for the pretzel.
37	shear stress	Applied torsion which resulted in a torsion load creating shear stress. When failed it was due to the exceeding of max-in-plane shear stress.
6	Tor	Torsion was only one applied.
7	Tor	The only applied load was torsion.
11	Tor	because of the way we applied the load
13	Tor	because of the way the force was applied
8	AF	The pretzel broke quickly. It kinda pointed.
4	shear, BM, Tor	applying a torque
38	BM, Tor	

Discussion

The results of this experiment did not support the hypothesis, and raised questions about issues that may have confounded the data. Of course since only 38 students in the test section and 38 students in the control section participated in the final test, the sample size was small. In addition, the experiment did not control for several factors that may have influenced the results. (see below). Beyond that, the fact that students were allowed to talk among themselves as they completed the Final Pretzel and Licorice Test Form, seems to have affected the results. Finally, the course sequence itself may have inhibited the students' ability to synthesize the material.

Factors not controlled for

The experiment did not control for several factors which may have affected the outcome. First, the actual performance of the students in the course itself was not considered. However, the professor teaching the two sections of Mechanics of Materials noted that the control section had a larger group of high performing students than the test section. In fact, students in the control section averaged approximately 4 percentage points higher on tests all semester than students in the test section. Second, the individual students who participated in each demonstration or follow-up activity were not tracked. Both the test section and the control section had an enrollment of 47 students. Which 38 students from each section participated in the final test is not known. Nor is it known whether these 38 students actually participated the other demonstrations and/or activities designed for that particular section. Third, while individual students were not tracked, the professor in charge of the two sections noted that sometimes students enrolled in one section would attend the other section. Thus it is possible that some students in the control group actually participated in one or more of the follow-up activities.

Talk among students

From the data collected, it appears that persuasive students may have convinced their neighbors of their point of view, whether right or wrong. As mentioned previously, in Table 6 each student's choice of the failure stress exceeded when the pretzel failed is tabulated along with his/her explanation for the choice he/she made. These data were sorted first by choice of failure stress and then by the sheet number. Interestingly, in both the test section and control section, clusters of similar explanations for choice of failure stress are apparent. These clustered answers correspond to the order in which their work was submitted, indicating student proximity in seating.

Test section. In the test section, among the students choosing tensile stress as the failure stress, those completing sheets 9-12 all had similar explanations. In addition, among the students choosing shear stress as the failure stress, students completing sheets 20-22 had one explanation in common, students completing sheets 23 and 24 had a second explanation in common, and students completing sheets 23 and 24 had a third explanation in common. Likewise, among the students choosing torsion as the failure stress, students completing sheets 16 and 17 had one explanation in common, and students completing sheets 30 and 31 had another explanation in common.

Control section. In the control section, among the students choosing tensile stress as the failure stress, those completing sheets 3 and 5 had one explanation in common, those completing sheets 27 and 28 had a second explanation in common, and those completing sheets 29-33 had a third explanation in common. Among the students choosing shear stress as the failure stress, those completing sheets 16-18 had one explanation in common, those completing sheets 20 and 21 had a second explanation in common, and those completing sheets 23-26 had a third explanation in common. And finally, among the students choosing torsion as the failure stress, those completing sheets 6 and 7 had one explanation in common while those completing sheets 11 and 13 had another explanation in common.

Course sequence

When looking at the wrong answers provided, it is noteworthy that in each section the most frequent answer given by students was the standard misconception: the pretzel failed in shear stress because torsion produces shear stress. These students did not properly synthesize the torsional material and stress transformation material. The concept of stress transformation is difficult for students to grasp and, in this case, it was presented toward the end of the semester. Some research has shown that covering stress transformations early in the semester may enhance student ability to synthesize this material with other topics covered in the course.[1]

Recommendations

Several modifications and improvements to the study are recommended. First of all, the sample size should be addressed by working with more sections of Mechanics of Materials. Second, three factors – student performance, student participation, and crossover from section to section – should be controlled in the future. Third, it is recommended that in the future students work alone on the final test. Finally, thought should be given to the order in which the material is being presented in the class.

Conclusion

It was hypothesized that students who participate in demonstrations followed by purposeful activities designed to reinforce and build upon the demonstrations would show an increased ability to synthesize the concepts and apply them to new situations. The hypothesis was tested in two sections of Mechanics of Materials on the concepts of axial loading, torsional loading and stress transformations. Students from both the test section and the control section participated in demonstrations of axial loading and torsional loading. Then students in the test section worked through follow-up activities devised to reinforce the concepts of axial loading and torsional loading and relate them to stress transformations. Finally students in both sections participated in a torsion test of a pretzel stick. The students were asked to record their observations, choose the stress that had been exceeded at failure, and explain their reasoning. Results did not support the hypothesis. Rather, of the small number of students correctly selecting tensile stress for the failure stress, twice as many did so from the control section than from the test section. In addition, the majority of students in each section seemed to have trouble relating the concepts of stress transformation to the torsion test. In both the test section and the control section, the majority of the students incorrectly chose shear stress as the failure stress for the brittle pretzel. While the data presented did not support the hypothesis, several issues were identified that could have affected the outcome of the experiment. Sample size was small, and the experiment did not control for student performance, student participation, or student crossover from section to section. In addition, students were allowed to work together on the final test, thus allowing persuasive students to influence their peers, whether correctly or incorrectly. Finally, the very layout of the course may have inhibited students' ability to synthesize the material. Further study that addresses these issues is needed before any solid conclusions can be drawn.

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