

An assessment of blended learning in mechanics of materials

Ana Dyreson, P.E., Research Assistant, Mechanical Engineering, University of Wisconsin - Madison

Corinne Henak, Professor, Mechanical Engineering, University of Wisconsin - Madison

Abstract

Instructors are often uncertain if their efforts to design a blended course are warranted by improved student outcomes compared to a lecture-based course. The first goal of this study was to find out if students benefit from a blended course compared to a traditional course in our mechanics of materials class. The average exam scores were not statistically different in two cohorts we studied, but we found that simply comparing averages ignored effects of major, year in school, and gender. Such student characteristics are important to consider when measuring the outcome of a course redesign. The second goal was to assess students' progress in Bloom's taxonomy in the blended course. The results suggest that students quickly learned how to solve problems, but did not understand fundamental concepts following lecture and online reading assignments. A final goal was to understand students' perceptions of the blended course. We found that most students thought that the format was effective.

Introduction

One section of mechanics of materials changed from a traditional to a blended format. This is a medium enrollment course (N=68, traditional and N=73, blended) in the mechanical engineering (ME) department. It is required coursework for ME, biomedical (BME), civil, and some other engineering majors and is typically taken during the sophomore year. Other engineering students can take the course as an elective; prerequisites include statics and calculus. The traditional course used the three 50-minute weekly class meetings for lecture. The blended course used the same class meetings for a mixture of lecture, in-class activities, and problem solving (Table 1). The two non-lecture days were held in a classroom specifically designed to facilitate group work and active learning. The two classes used the same online homework and exam formats.

Table 1: Weekly course structures for Traditional and Blended courses in this study

| | Before class | Monday | Wednesday | Friday |
|-------------|---------------------------|---------------|---|---------------|
| Traditional | Reading assignment | Lecture | Lecture | Lecture |
| Blended | Online reading assignment | Lecture | Worksheets, group projects, case studies, or homework time. Held in active learning space working with peers and instructors. | |

To answer the question, *Do students benefit from the blended course?*, we compared exam scores from the traditional and blended courses. To answer the question, *How do students progress on Bloom's taxonomy in the blended course?*, we used worksheets that served both as learning

activities and measurements of Bloom's taxonomy progress. We focused on two concepts that students typically have difficulty with: transverse shear and stress transformations. Each of the two concepts occupied one week approximately mid-semester. Finally, we use a survey to assess *student's perception of the blended course's effectiveness*.

Background and literature

Active learning formats have been shown to improve scores and decrease failure rates (Freeman et al., 2014). Blended learning frees up a portion of class time for active learning by using a combination of face-to-face and online delivery of material. Even more active than a blended course, in a 'flipped' course, all material is delivered out of class (typically online), and all class time is active. In this literature review, studies of flipped classrooms were more common. Because the flipped and blended formats are related, we find studies of flipped classrooms useful. O'Flaherty and Phillips completed a review of flipped classroom studies in higher education and found that academic performance is improved over traditional classrooms (O'Flaherty & Phillips, 2015). However, they did not find improved long-term learning. They also found that students like the flipped approach. In engineering, Olwi compared flipped and traditional fluid mechanics courses (Olwi, 2006). They found that the students in the flipped classroom scored higher on exams and were more confident in their knowledge. Mason et al. compared a traditional and flipped course structure in an upper level engineering course (Mason, Shuman, & Cook, 2013). They concluded that the flipped classroom approach was at least as good as, and possibly better than, the traditional approach in terms of academic marks. Thus, we expected students in our course to benefit from, or at least not be harmed by, the blended format.

Both transverse shear and stress transformation concepts require an understanding of shear stress, which is often a difficult topic for mechanics students. Crone and Creuziger investigated why shear stress is consistently difficult for students and what activities students find most helpful (Crone & Creuziger, 2006). The study used a survey and interviews to answer these questions. Students said that the most helpful activities were homework, lecture, and discussion. The textbook and supplementary materials were rated lower. They suggested that peer teaching may be an effective strategy since the students had difficulty with different topics. Active learning was also suggested as a helpful strategy. These results suggest that the blended classroom could be useful as it emphasizes active learning and gives opportunities for peer teaching.

Bloom's taxonomy is a well-known way to categorize cognitive knowledge structures (Crowe, Dirks, & Wenderoth, 2008). Though the taxonomy is not necessarily chronological and there are various definitions, here we will use the following levels in order of increasing complexity (as in Crowe et al.): knowledge, comprehension, application, analysis, synthesis, and evaluation. In computer science, one study considered how student's knowledge and comprehension levels relate to actual programming, which is considered application level (Cabo, 2015). Cabo found that basic knowledge and comprehension levels are a pre-requisite to good programming. This aligns with our hypothesis that students would first access the comprehension level and then progress to application level as they learn to solve problems.

Study design and methods

We studied the three evaluation questions with exams, worksheets, and surveys. Exams in both courses included multiple choice questions and problem solving. Worksheets were created specifically for the blended course to meet content learning objectives and to cover three Bloom's taxonomy levels (comprehension, application, and synthesis). The first worksheet was a short (ten minute) online multiple choice worksheet completed individually to capture only the baseline knowledge from lecture and online reading assignments. The second worksheet was also online but was not time-limited. It had multiple choice and problem solving questions and was completed with the help of peers and instructors. Each worksheet also asked students which class activities they had completed: attending lecture, online reading assignment, or homework. A survey measured student perception and was based on the student assessment of learning gains (SALG) survey format (Seymour, Wiese, Hunter, & Daffinrud, 2000).

Each assessment was designed to measure an evaluation question and to support student learning. Assessments are related to the hypotheses in Table 2 and learning objectives in Table 3. The schedules for the two weeks that were studied for Bloom's levels are provided in Table 4. Worksheets and related details are provided in the Appendix.

Table 2: Three hypothesis and related assessments.

| <i>Hypothesis</i> | <i>Assessments and use as measurement</i> |
|---|--|
| Blended learning will improve student performance overall. | <ul style="list-style-type: none"> • Compare blended and traditional cohort exams scores. • Consider cofactors of year in school, major, and gender. |
| Activities used will improve learning by moving students 'up' the Bloom's taxonomy. | <ul style="list-style-type: none"> • First worksheet: short formative assessment measures baseline knowledge. • Second worksheet: longer formative assessment measures success of active learning. |
| Students will perceive learning gains in week. | <ul style="list-style-type: none"> • SALG survey |

Table 3: Learning outcomes and related assessments.

| | <i>Learning outcome</i> | <i>Assessments and use for student learning</i> |
|----------------|--|---|
| Overall | Apply mechanics of materials concepts to solve engineering problems. | <ul style="list-style-type: none"> • Four exams provide feedback through semester. |
| Topic Specific | Apply transverse shear concepts to problems. Employ stress transformation equations and Mohr's circle to analyze stress states. | <ul style="list-style-type: none"> • First worksheet provides immediate feedback and opportunity to identify misconceptions. • Second worksheet allows students to explore concepts and practice problem solving. • Homework completed allows students to explore concepts and practice problem solving. |

Table 4: Schedule of course materials for transverse shear and stress transformation topics in the blended course.

| | Before class | Monday | Wednesday | Friday |
|--|---------------------|---------------|------------------|---------------|
| | | | | |

| | | | | |
|---------------|---------------------------|---------|-------------------------------------|---|
| Trans. shear | Online reading assignment | Lecture | Exam review ¹ | First worksheet Second worksheet |
| Stress trans. | Online reading assignment | Lecture | First worksheet Second worksheet | Free work time for homework or completion of Wednesday activities |

¹ Due to the midterm exam, the transverse shear week had an unusual schedule.

To compare student performance in the blended and traditional cohorts, we began with an unpaired t-test on the average exam scores. A simple comparison of averages does not tell the whole story, though, because the ‘samples’ (students) are not randomized and controlled. Theobald and Freeman show how to incorporate factors for student characteristics to get a more realistic picture of the effect of an educational intervention using multiple linear regression analysis (Theobald & Freeman, 2014) and that method is used here. In our study, the available characteristics were student gender, year in school, and major. Importantly, we did not have a measure of prior student success such as incoming GPA.

Student perception was quantified by counting frequencies of responses in the SALG survey.

To measure student’s progress on Bloom’s taxonomy levels throughout each week, we compared the score distributions on worksheets by Bloom’s level. We also quantified gains by taxonomy level as the difference between each student’s score on the first and second worksheets.

Results

Do students benefit from a blended course?

Although the blended course had slightly higher average exam scores (80.1%) than the traditional course (78.3%), an unpaired t-test did not show a statistically significant difference at a confidence level of 0.05 (p-value=0.116) (Figure 1). The scores were distributed differently, however, with fewer very low scores in the blended course than in the traditional course.

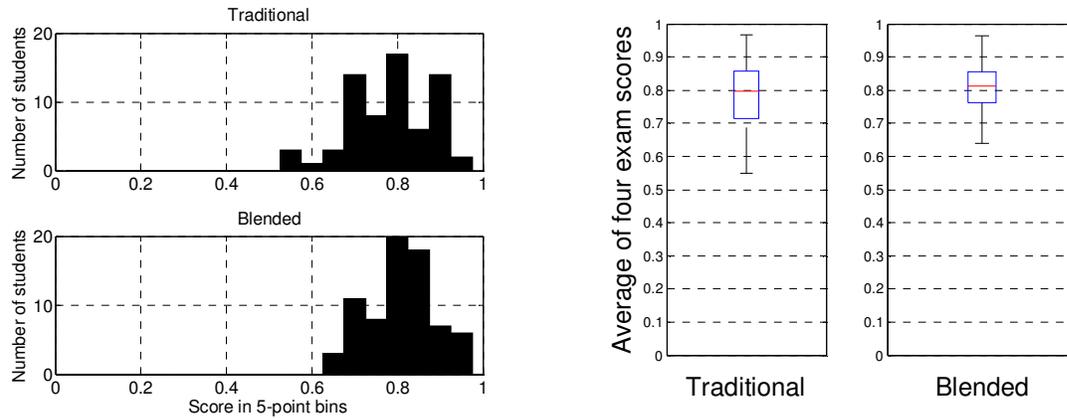


Figure 1: Histograms show how the exams scores were distributed (left). Boxplots of the student exam scores show medians of 79.8% for traditional and 81.3% for blended (right, shown are minimum, 25th quartile, median, 75th quartile, and maximum). Note that exam scores represent the average of each student's four exams.

Before implementing multiple linear regression analysis, we examined the differences in the compositions of the two cohorts. The cohorts were different in student major and year in school. Because we found that ME and BME students scored similarly, we combined those categories. The blended cohort had very few non-ME/BME majors (“non-majors” or “other”), but in the traditional cohort nearly one third of the students were non-majors (Figure 2). The composition of cohorts by gender were similar (Figure 2). The traditional cohort was mostly juniors, while the blended cohort was mostly sophomores (Figure 3).

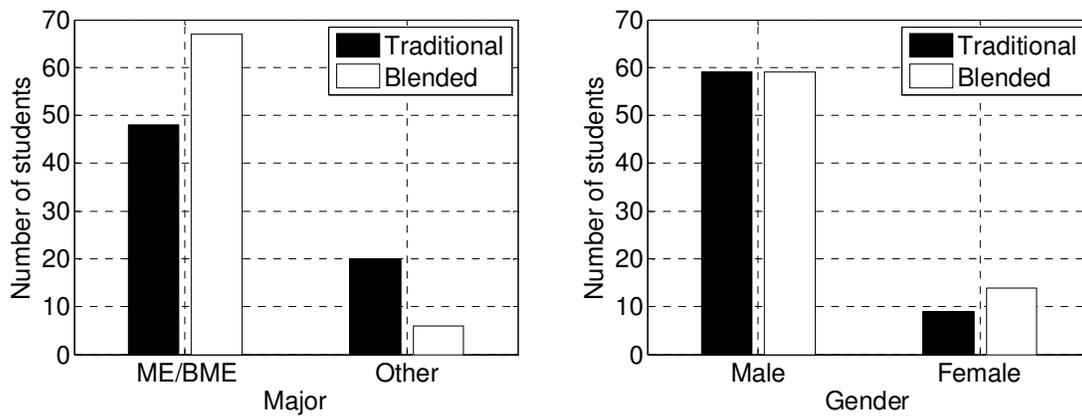


Figure 2: Composition of traditional and blended cohorts by major and gender. Mechanical Engineering and Biomedical Engineering were combined for this analysis.

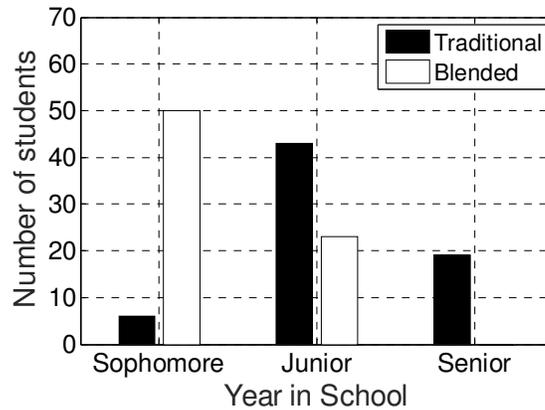


Figure 3: Composition of traditional and blended cohorts by year in school.

By examining many different possible models from the multiple linear regression analysis, two candidate models were selected that can provide some insight. The first candidate model is a multiple linear regression with no interaction terms (Table 5). Student major is clearly an important consideration. The model estimates that non-majors score about nine points lower than majors. Also quite significant was the year term. Earlier academic career students had about four points higher per year modeled scores. The gender effect is not as significant but the estimated effect is four points lower for women. The cohort coefficient is the least significant.

Table 5: One candidate multiple linear regression model used to describe the average of four exam scores. There were 141 data points used. $R^2=0.25$ (0.23 adjusted). F -statistic versus constant model is 11.4 at p -value $<1 \times 10^{-7}$.

| | Estimate | Standard error | t-statistic | p-value |
|--------------------------------------|----------|----------------|-------------|-------------------------|
| (Intercept) | 0.821 | 0.011 | 72.869 | 7.37×10^{-111} |
| Gender (Male = 0, Female = +1) | (0.039) | 0.018 | (2.132) | 3.48×10^{-2} |
| Major (ME/BME=0, Other = +1) | (0.089) | 0.018 | (5.005) | 1.70×10^{-6} |
| Year (Soph.= -1, Jun. = 0, Sen.= +1) | (0.037) | 0.013 | (2.878) | 4.65×10^{-3} |
| Cohort (Traditional=0, Blended = +1) | (0.025) | 0.018 | (1.445) | 1.51×10^{-1} |

Another candidate model includes interaction terms (Table 6). In this model, backwards elimination was used to eliminate the interaction term between gender and cohort. Many of the interaction terms are borderline for significance, but this model continues to show that student major is important. Interaction terms are shown in Figure 4, which provides the model's prediction of major, year in school, and cohort effects. Though no single model is definitive, examination of these and other candidate models consistently showed that major was the most important factor. Other characteristics such as gender and year in school (and the interactions of those terms) were possibly just as important as cohort. Still, the cohort term is significant, and it

suggests that students in the blended classroom had lower exam scores, controlling for other variables and interactions.

Table 6: After eliminating the gender:cohort interaction, a candidate model with interaction terms is presented. There were 141 data points. $R^2=0.313$ (adjusted 0.266) and F-statistic vs constant model 6.64 for p-value $<1 \times 10^{-7}$.

| | Estimate | Standard error | t-statistic | p-value |
|--------------|----------|----------------|-------------|-------------------------|
| (Intercept) | 0.815 | 0.012 | 68.109 | 3.87×10^{-104} |
| Gender | (0.017) | 0.020 | (0.841) | 4.02×10^{-1} |
| Major | (0.083) | 0.022 | (3.783) | 2.35×10^{-4} |
| Year | (0.018) | 0.020 | (0.881) | 3.80×10^{-1} |
| Cohort | (0.047) | 0.021 | (2.229) | 2.75×10^{-2} |
| Gender:Major | (0.089) | 0.055 | (1.616) | 1.08×10^{-1} |
| Gender:Year | 0.050 | 0.027 | 1.849 | 6.67×10^{-2} |
| Major:Year | (0.039) | 0.031 | (1.262) | 2.09×10^{-1} |
| Major:Cohort | 0.053 | 0.045 | 1.173 | 2.43×10^{-1} |
| Year:Cohort | (0.055) | 0.027 | (2.028) | 4.46×10^{-2} |

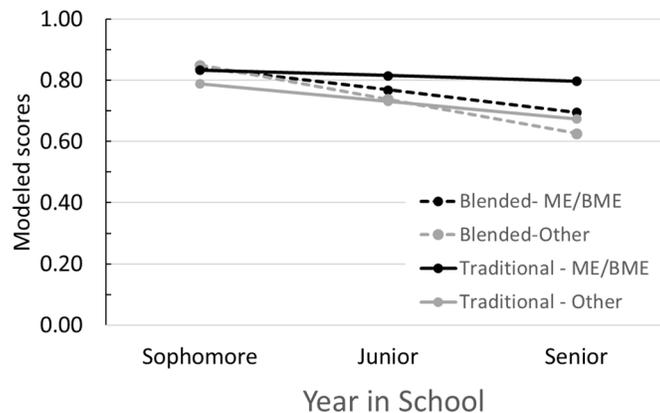


Figure 4: Exam scores predicted by multiple linear regression with interaction terms. The effects of year in school, cohort (blended versus traditional), and major (ME/BME versus other) are shown.

Student perception results show that most students generally rated the activities as helpful with the exception of the online reading assignment (Figure 5). Individual free-form responses (not shown) were also useful in adjusting the class format. For example, students liked the active classroom but felt that the Monday lecture was rushed and so they requested a short mini-lecture on Wednesday.

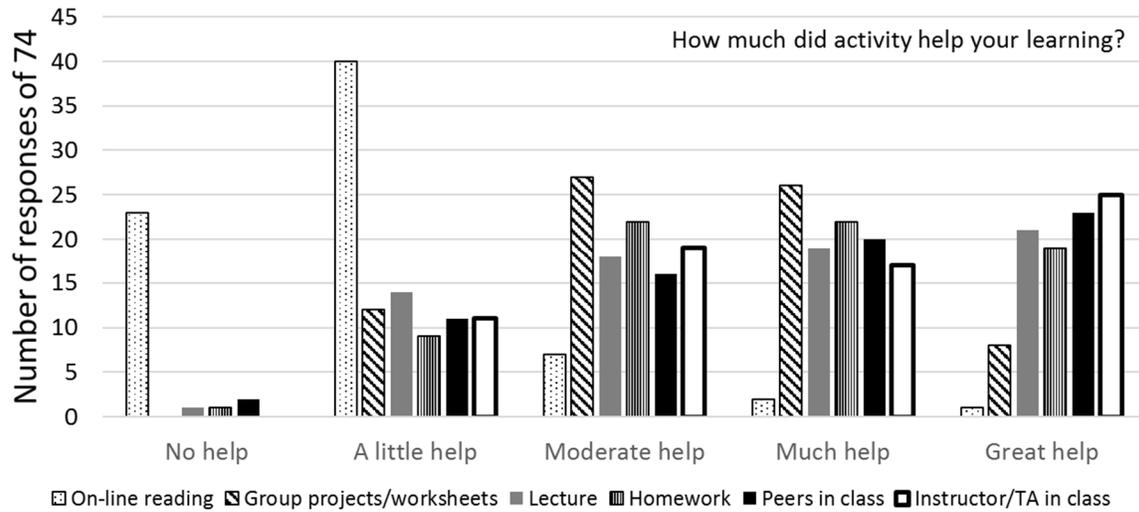


Figure 5: Responses to survey of student perception show that most students rated most activities as helpful except for the on-line reading assignment.

How do students progress on Bloom's taxonomy in the blended course?

The hypothesis that students first gain comprehension, then application, then synthesis levels as they learn new material was not supported by the worksheet results. Instead, the worksheets showed that students first achieve the application level. Figures 6 and 7 below show the score distributions by Bloom's level for the two worksheets in each topic. In the first worksheets, the comprehension level questions had lower overall scores than application level questions. There was no clear trend in synthesis level questions on the first worksheet for transverse shear in Figure 6 (the question was binary). The synthesis level questions on the first worksheet in stress transformations scored low (Figure 7). The second worksheets showed that during in-class activities with the help of peers and instructors, students could both solve problems (application) and demonstrated an understanding of fundamental concepts (comprehension) as well as larger context within the course (synthesis). Students in general did very well on the second worksheet and are able to demonstrate mastery at each level by the end of the week.

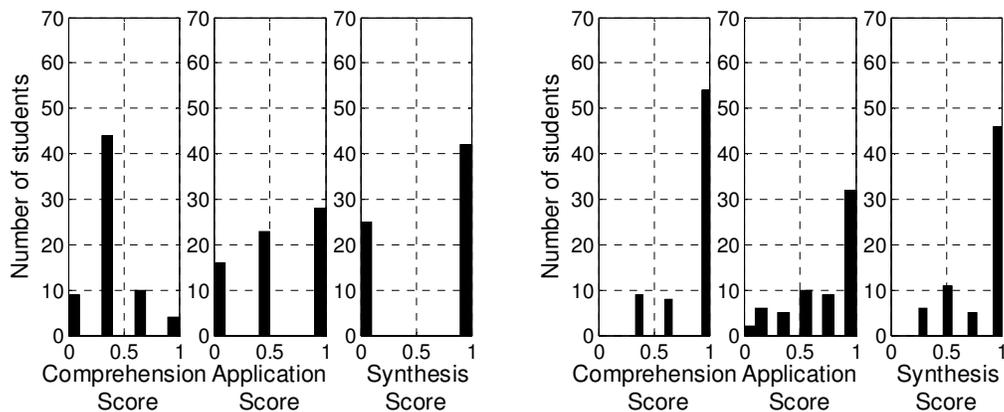


Figure 6 Transverse shear formative assessment results by Bloom's taxonomy. Left: first worksheet. Right: second worksheet.

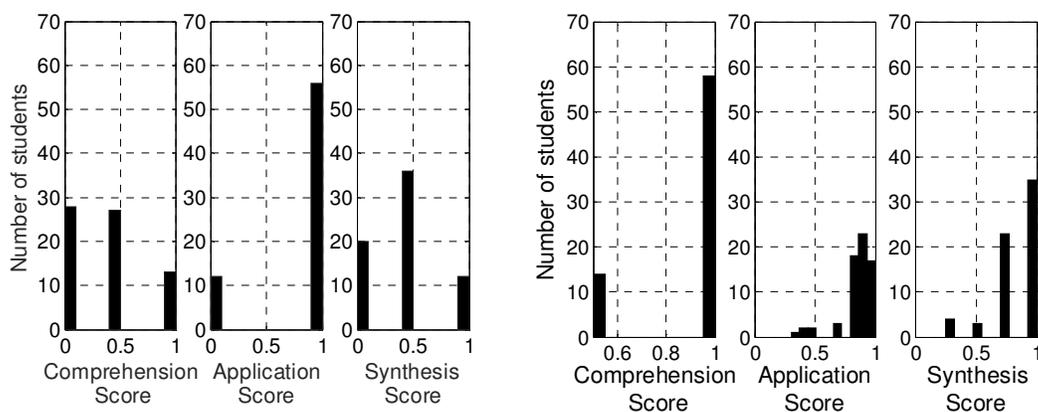


Figure 7: Stress transformation formative assessment results by Bloom's taxonomy. Left: first worksheet. Right: second worksheet.

Gains in Bloom's taxonomy for each of the two concepts are shown along with 95% confidence intervals in Figure 8. The gains tell the same story as the comparison of score distributions: students come into the classroom with a relatively good ability to solve simple problems (application level) but do not have conceptual understanding, so their gain in comprehension is on average higher than application or synthesis.

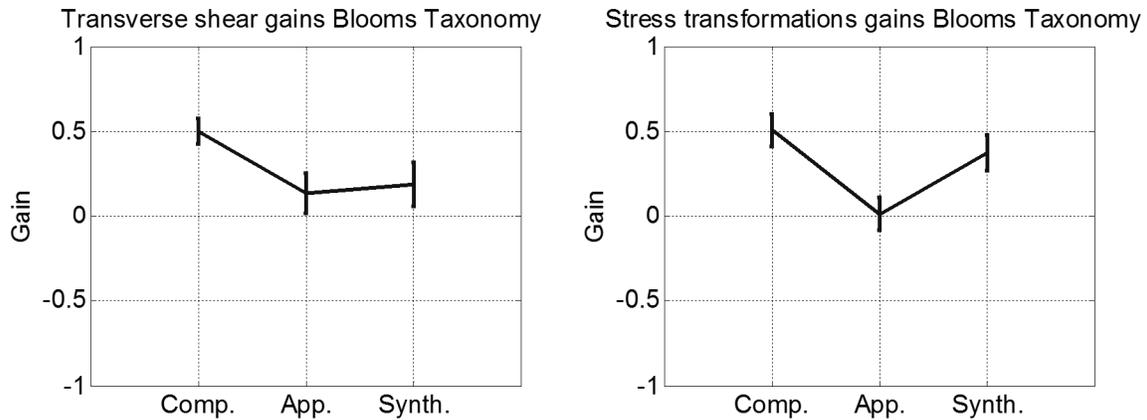


Figure 8: Gains (average of individual difference between second worksheet and first worksheet) by Bloom's level.

We also asked students about their prior exposure to the material via lecture attendance, completion of reading assignments, other material, and homework. Lecture attendance (self-reported) was high, typically at least 90%, so we did not attempt to quantify any differences between attending and non-attending students. The students were more split on their preparation by reading assignments, other material, and homework. We looked for differences in worksheet scores between the prepared and un-prepared groups, but did not find significant differences.

Discussion

The blended cohort had the same average exam scores as the traditional cohort (statistically), but we found that the two cohorts were made up of very different students. Student major was one student characteristic that was strongly related to exam performance. This is not surprising as students whose background or interests are most closely related to the subject matter may be better prepared and interested in succeeding. Though not as significant as student major, the models showed that the blended cohort tended to score lower than the traditional cohort. This is contrary to our hypothesis that the blended format would benefit students, but the significance of this factor in the models is weak, suggesting that other factors are more important. Though the analysis is by no means definitive, it is helpful to observe the possible impacts of student characteristics for future study.

To better understand the benefits or drawbacks of the blended course compared to the traditional course, a future study could include characteristics such as incoming GPA, subject area interest, a measure of incoming preparation specific to the mechanics content (e.g., statics scores or a content survey), previous coursework, current course load, first-generation status, etc. In addition, though the exams in this study were similar, exam equivalence could be validated. The study could also be repeated to increase the sample size.

The Bloom's taxonomy-based analysis of learning in the blended classroom was instructive; one cannot assume that if students have been introduced to material that they have absorbed the underlying concepts. Too often, students are adept at finding formulas and learning to solve

problems without much conceptual understanding; students take the ‘surface’ or ‘strategic’ approach to learning rather than the ‘deep’ approach as defined by Momsen et al. (2013).

To create a more robust study of Bloom’s taxonomy in mechanics of materials, the question set and the Bloom’s levels could be validated. In addition, a longer question set that had more questions at each taxonomy level would make the results less reliant on any single question. Worksheet questions could also be matched to exam questions to measure if the gains from the first worksheet to the second were maintained in the exams.

Shear stress continues to be a perplexing topic for students in their first semester of mechanics of materials. Though we did not seek to uncover the reasons, experience in this course leads us to suspect that the shear stress concept is difficult because students are asked to use what is expert-level knowledge of stress components and strong spatial visualization skills that they likely have not yet mastered. This is similar to the barrier mentioned by Forbes-Lorman et al. in regards to biology concepts (Forbes-Lorman et al., 2016).

Conclusion

The suggestion that students can master application level work without conceptual understanding is a useful caution against problems that are easily solved using equations but do not require understanding (i.e., “plug-and-chug” problems). The comparison of average scores in the traditional versus blended course showed no difference, but simply comparing average scores between diverse cohorts of students is not a fair comparison. Most importantly, the traditional cohort had many more non-major students and we found that the exam scores for non-major students were on average lower than for major students. The results also indicate, though less clearly, that earlier academic career students performed better than later career students, and students in the blended course performed worse than those in the traditional course. This does not suggest that blended approaches are not useful (see the body of literature on flipped classes) but rather points out the importance of other student characteristics that make it difficult to categorically determine that one approach was or was not effective.

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Appendix: Worksheets

Tables A1 and A2 show the student learning objectives mapped to specific assessment questions on the first worksheet (after lecture) and second worksheet (during active learning). The first worksheet needed to be shorter due to time constraints, so it had fewer questions and used more multiple choice questions, while the second worksheet included solving problems. Note that some learning objectives for the lesson were not included in the worksheet but appeared on the homework and exams. The actual worksheets are provided after the tables.

Table A1: Transverse shear formative assessments and learning objectives

| Learning outcomes | First Worksheet Bloom | First Worksheet Question | Second Worksheet Bloom | Second Worksheet Question |
|---|-----------------------|--------------------------|------------------------|---------------------------|
| Illustrate the planes where shear stresses in beams develop. | | | | |
| Explain under what loading transverse shear in beams develops. | Comprehension | ws5a Q5 | Comprehension | ws5 Q6 |
| Demonstrate how transverse loads on a beam generate shearing stresses | | | | |
| Identify the correct area for calculation of Q. | Application | ws5a Q6 | Application | ws5 Q9 |
| Identify the location of the maximum transverse shear. | Application | ws5a Q7 | Application | ws5 Q7 |
| Determine transverse shear in a beam. | | | Application | ws5 Q8,10,11 |
| Determine the shear flow on a horizontal section in a beam. | | | | |
| Determine the shearing stresses in a thin-walled beam. | | | | |
| Identify the differences between transverse shear and shear due to torsion. (planes, distributions) | Synthesis | ws5a Q8 | Synthesis | ws5 Q12-15 |

Table A2: Stress transformations formative assessments and learning objectives

| Learning outcomes | First Worksheet Bloom | First Worksheet Question | Second Worksheet Bloom | Second Worksheet Question |
|--|-----------------------|--------------------------|------------------------|---------------------------|
| Apply stress transformation equations or the alternative Mohr's circle approach to perform plane stress transformations. | Application | ws6a Q9 | Comprehension | ws6 Q1 |
| | | | Application | ws6 Q3,4 |
| | | | Application | ws6 Q9-11 |
| Extend Mohr's circle analysis to examine three-dimensional states of stress. | | | Comprehension | ws6 Q2 |
| | | | Synthesis | ws6 Q6-8 |
| Recognize when stress transformations are required. | Synthesis | ws6a Q7-8 | | |
| Explain stress transformations. | | | Synthesis | ws6 Q5 |
| Define principal stresses, maximum shear stress, principal planes | Comprehension | ws6a Q5,6 | | |

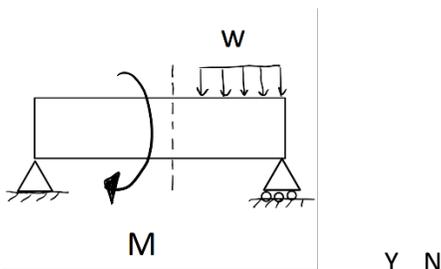
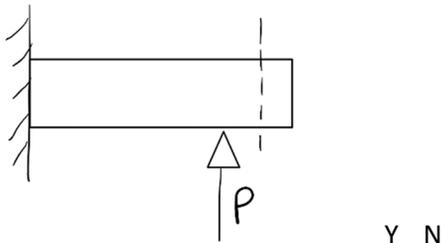
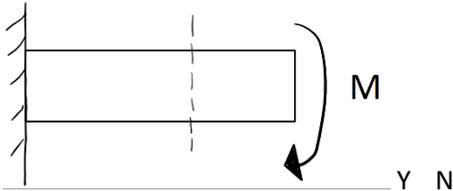
WS5a: Transverse shear

This worksheet is graded for participation only as it is part of the educational study. It will be open until 9AM. Complete this worksheet to the best of your ability, you will not be penalized for wrong answers or sections which you didn't have time to complete.

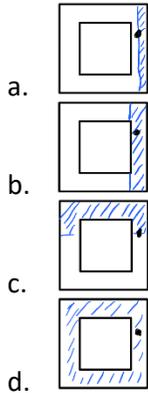
The first four questions ask what activities and materials you have used so far.

1. Did you go to lecture on Monday? Y N
2. Have you completed LearnSmart 7? Note that it is not due until next week. Y N
3. Have you consulted other materials on you own regarding this topic? For example textbook or MEC Movies. Y N
4. Have you completed HW 7? Note that it is not due until next week. Y N

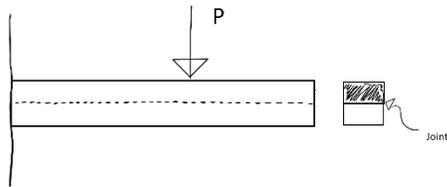
5. **[Comp.]** Three different beams are shown. Indicate if the beam would have transverse shear stresses in the cross section indicated.



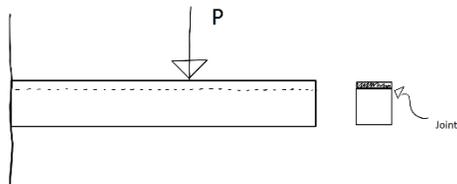
6. **[App]** A cantilever beam with an open square cross section is loaded as shown. We are interested in the transverse shear stress at location A. CIRCLE the cross section which correctly shows the shaded area to use in determining Q for calculation of transverse shear at point A.



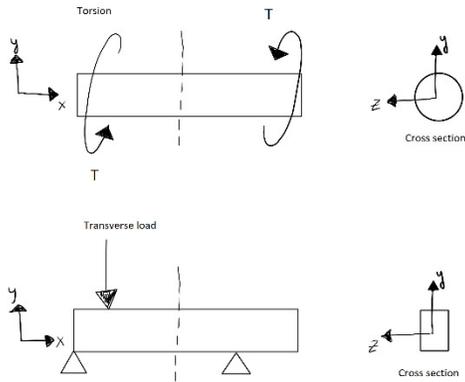
7. **[App]** The beam shown has rectangular cross section and is made up of two separate materials joined together. The joint is the weakest point (in other words the joint has a lower maximum shear strength than the materials on either side). The joint can be made at one of two different locations. The total beam size and loading does not change. Under the same transverse load P , and considering only transverse shear stresses, which would fail first? CIRCLE CHOICE.



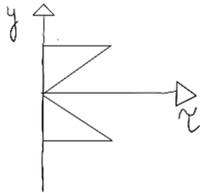
- b. The beam that has a joint near the edge would fail first.



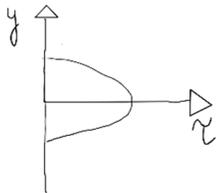
8. **[Synth]** The shaft shown is loaded two different ways. Shear stresses develop in both situations at the cross section indicated.



Indicate which shear stress distribution corresponds to which case.



Choose: Torsion shear Transverse shear



Choose: Torsion shear Transverse shear

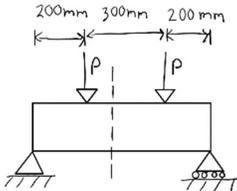
WS5 Transverse Shear

This first four questions in this worksheet do not impact your grade. The remainder of this worksheet is graded as any other worksheet.

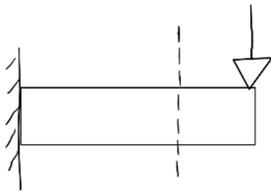
The first four questions ask what activities and materials you have used so far.

1. Did you go to lecture on Monday? Y N
2. Have you completed LearnSmart 7? Y N
3. Have you consulted other materials on your own regarding this topic? Y N
4. Have you completed HW 7? (Type yes or no). Y N
5. [App] This question uses an online game to practice identifying the correct area for calculating the first moment of area for transverse shear calculations. (Your score is not important; just go through the round until you think you have a good feel for it.)
6. [Comp] Three different beams are shown. Indicate if the beam would have transverse shear stresses on the cross section indicated. Hint: Begin by drawing a V-M diagram to determine if there is internal shear, and thus transverse shear stress, at the location indicated.

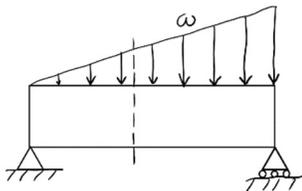
Four point bending. Y N



Cantilevered. Y N



Simply supported with distributed load. Y N



7. [App] For the beam shown, where will the maximum shear stress be in cross section n-n? Choose the picture which has a red dot at the point of maximum transverse shear stress. CIRCLE YOUR CHOICE.

[insert problem from textbook – beam cross section and simply supported beam view with single transverse load.]

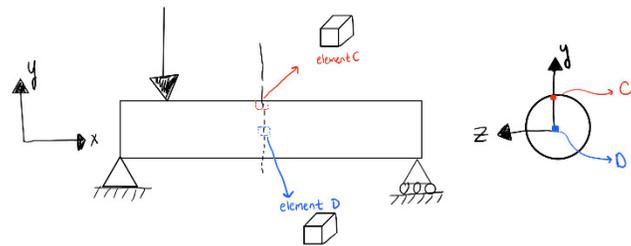
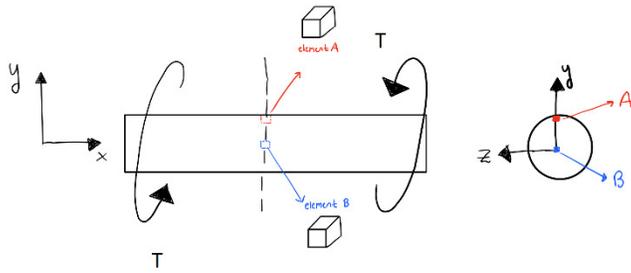
- a. **Vertically centered, right side.**
- b. **Top, right side.**
- c. **Right side, near top.**
- d. **Horizontally centered, on horizontal section.**

8-11 **[App] For the beam and loading shown, consider section n-n and determine the largest shearing stress in that section in MPa.**

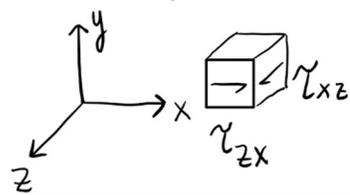
[same beam loading as previous problem with a cross section n-n indicated].

- 8. **Begin by calculating the second moment of area I in m^4 : _____**
- 9. **Next determine the first moment of area (Q) in m^3 : _____**
- 10. **Next determine the thickness t for calculation of transverse shear (in m): _____**
- 11. **Finally determine the maximum shear stress in the cross section. Report the answer in MPa:**

12-15 Two shafts are loaded as shown. Match the beam and cross sectional location to the stress element which correctly shows where the surfaces of shear stress.

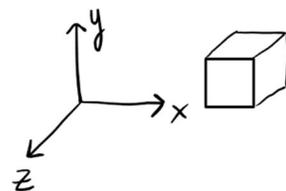


12. Considering shear stresses, which location (A,B,C, or D) does this stress element correspond to? There may be more than one correct answer; choose one. CIRCLE YOUR CHOICE.



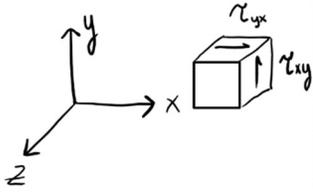
- a. Element A
- b. Element B
- c. Element C
- d. Element D

13. Considering shear stresses, which location (A,B,C, or D) does this stress element correspond to? There may be more than one correct answer; choose one. CIRCLE YOUR CHOICE.



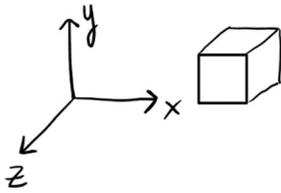
- a. Element A
- b. Element B
- c. Element C
- d. Element D

14. Considering shear stresses, which location (A,B,C, or D) does this stress element correspond to? There may be more than one correct answer; choose one. CIRCLE YOUR CHOICE.



- a. Element A
- b. Element B
- c. Element C
- d. Element D

15. Considering shear stresses, which location (A,B,C, or D) does this stress element correspond to? There may be more than one correct answer; choose one. CIRCLE YOUR CHOICE.



- a. Element A
- b. Element B
- c. Element C
- d. Element D

WS6a: Stress transformations

This worksheet is graded for participation only as it is part of the educational study. It will be open until 9AM. Complete this worksheet to the best of your ability, you will not be penalized for wrong answers or sections which you didn't have time to complete.

The first four questions ask what activities and materials you have used so far.

1. Did you go to lecture on Monday? Y N
2. Have you completed LearnSmart 7? Y N
3. Have you completed HW 7? Y N
4. Have you consulted other materials on you own regarding this topic? For example textbook or MEC Movies. Y N

5. [Comp] Consider a plane stress situation. If the shear stress in a state of stress is maximum, the normal stress is:

Select one (CIRCLE):

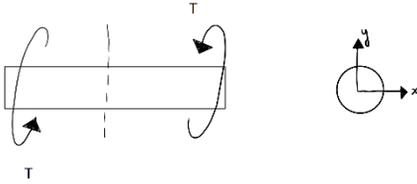
- a. Zero
- b. Maximum
- c. Not enough information
- d. I don't know.

6. [Comp] Consider a plane stress situation. If the normal stresses in a state of stress are the principal stresses, the shear stress is:

Select one (CIRCLE):

- a. Zero
- b. Maximum
- c. Not enough information
- d. I don't know

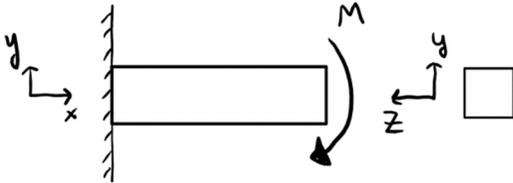
7. [Synth] What are the steps required to calculate the maximum shear stress on the surface of this shaft under pure torsion? Check all that are required.



Select one or more (CIRCLE):

- a. Calculate the shear stress $\tau = \frac{Tc}{J}$
- b. Calculate the normal stress $\sigma = \frac{My}{I}$
- c. Complete a stress transformation.

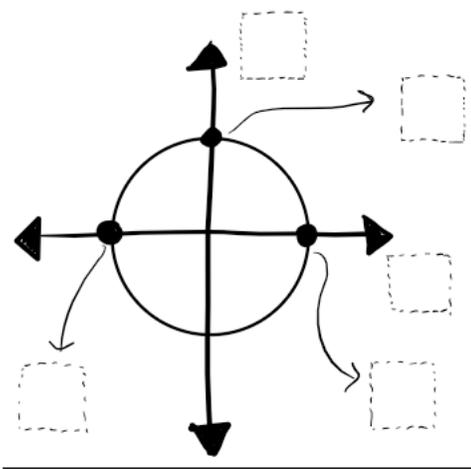
8. [Synth] What are the steps required to calculate the maximum shear stress in this beam under pure bending? Check all that are required.



Select one or more (CIRCLE):

- a. Calculate the shear stress $\tau = \frac{Tc}{J}$
- b. Calculate the normal stress $\sigma = \frac{My}{I}$
- c. Complete a stress transformation.

9. [App] Write each of the labels on their correct place on Mohr's circle.



Labels:

τ

τ_{\max}

σ

σ_{\max}

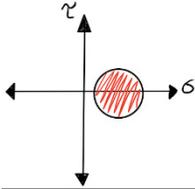
σ_{\min}

WS6: Stress transformations

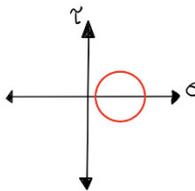
1. [Comp] Select the case that correctly shows the possible stress states for in-plane stress depicted in Mohr's circle.

Select one:

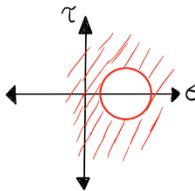
- a. Any location inside the circle is a possible stress state.



- b. Any location on the circumference of the circle is a possible stress state.



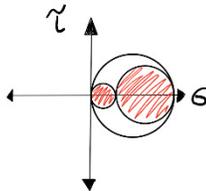
- c. Any location on the circumference of the circle or outside the circle is a possible stress state.



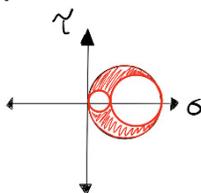
2. [Comp] Select the case that correctly shows the possible stress states for stress depicted in 3D Mohr's circle (including out of plane normal stress).

Select one:

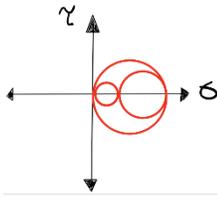
- a. Any location within the two smaller circles is a possible stress state.



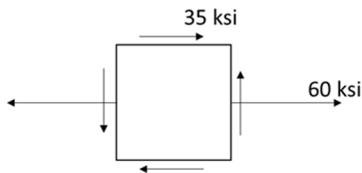
- b. Any location between the inner circles and the outer circle or on their circumferences is a possible stress state.



- c. Only locations on the three circles are possible stress states.



3. [App] An aluminum alloy is under the stress state shown. The alloy fails at 68 ksi normal stress and at 41 ksi shear stress.



In order to determine if the alloy will fail, first draw a Mohr's circle and upload a picture. Remember that a properly drawn Mohr's circle has labeled axis, units, and labels for the untransformed stress states and any other stresses or angles relevant to the problem. {insert or attach a Mohr's circle}

Points: 1 pt: all

0.5 pt: circle is correct but one thing labeled is not (such as maxes). Or circle looked correct but not labeled.

0 : circle isn't correct

4. [App] Will the alloy fail?

Select one:

- a. Yes.
- b. No.

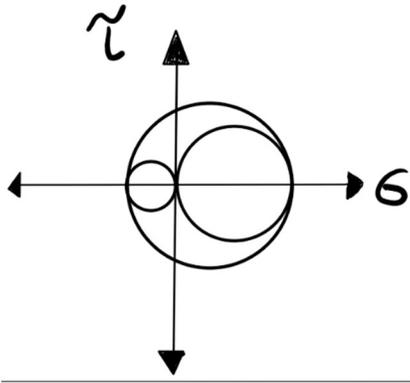
5. [Synth] Each table has a foam section for this demonstration & problem. The foam section has two, one inch squares drawn on it. Twist the noodle to apply torsion. Observe the square elements under torsion. This demonstrates the difference between the stresses in different orientations under the same loading. (The specific locations of the elements are not important; under pure torsion the stresses do not vary with axial position or circumferential position.) Discuss with classmates or ask questions as needed to clarify the stress transformation principle.

Upload a picture of the square under torsion which represents the principal in-plane stresses.

6-8 [Synth] 2D Mohr's circle allows calculation of in-plane maximum stresses. 3D Mohr's circle is used to determine maximum stresses including the out-of-plane stresses. Match the 3D Mohr's circle to the stress state. Only the sign of the untransformed stress state is shown; the magnitudes are not needed to identify the correct Mohr's circle.

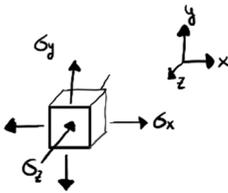
Note that these are schematic Mohr's circle diagrams that do not include all of the labels that you would be required to draw in solving a problem.

6.

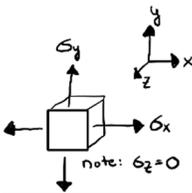


Select one:

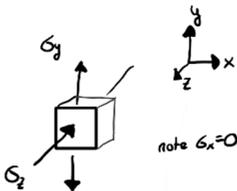
a.



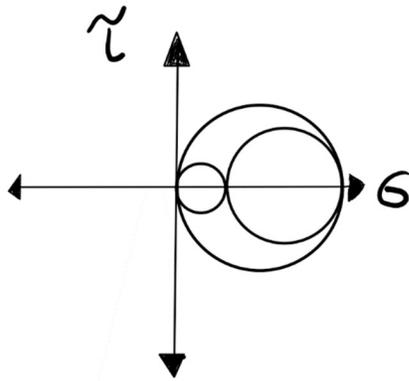
b.



c.

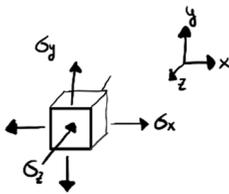


7.

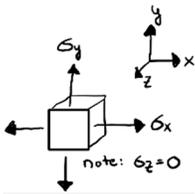


Select one:

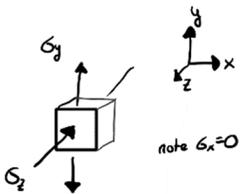
a.



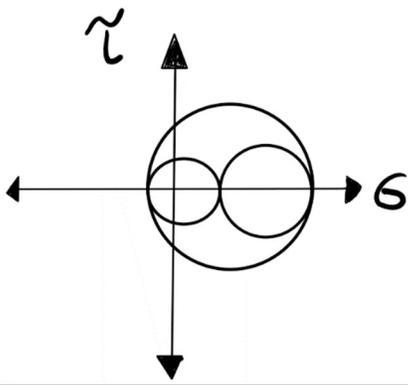
b.



c.

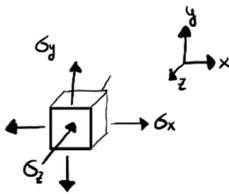


8.

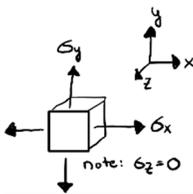


Select one:

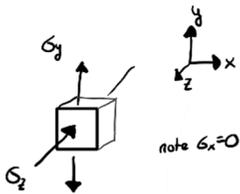
a.



b.



c.



9-11 [App] This problem considers an axially loaded rectangular bar with a joint at angle. You are given cross section dimensions, value of the axial load, and value of joint angle.

9. First, determine the normal stress acting parallel to the applied load P in kPa: _____.
10. Next use Mohr's circle to determine the shear stress parallel to the splice in kPa: _____.
11. And find the normal stress perpendicular to the splice in kPa: _____.

12-18 For the remaining questions, your responses do not impact your grade.

HOW MUCH did each of the following aspects of the class **HELP YOUR LEARNING?**

12. Lectures:

Select one:

- No help
- Moderate help
- A little help
- Great help
- Much help
- Not applicable

13. LearnSmart reading assignments:

Select one:

- No help
- Moderate help
- A little help
- Great help
- Much help
- Not applicable

14. Group projects and worksheets:

Select one:

- No help
- Moderate help
- A little help
- Great help
- Much help
- Not applicable

15. Working with peers during class:

Select one:

- No help
- Moderate help
- A little help
- Great help
- Much help
- Not applicable

16. Interacting with instructor and teaching assistants during class:

Select one:

- No help
- Moderate help
- A little help
- Great help
- Much help
- Not applicable

17. Completing homework:

Select one:

- No help
- Moderate help
- A little help
- Great help
- Much help
- Not applicable

18. This is the last question on this worksheet. Please comment on how the instructional approach to this class has impacted your learning.