Paper ID #20511

Student Editors Improve a Strength of Materials Textbook

Dr. Barry Dupen, Indiana University-Purdue University, Fort Wayne

Dr. Dupen is an Associate Professor of Mechanical Engineering Technology at Indiana University – Purdue University Fort Wayne (IPFW). He has nine years' experience as a metallurgist, materials engineer, and materials laboratory manager in the automotive industry. His primary interests lie in materials engineering, mechanics, and engineering technology education. He is also an experienced contra dance caller.

Student Editors Improve a Strength of Materials Textbook

Abstract

Commercially-published technical textbooks are periodically revised using feedback from technical experts (primarily professors), resulting in technically excellent works. However, these books are not edited for understandability by the target audience, so many undergraduates find college textbooks difficult to read. In spring 2012, I spent a sabbatical semester writing a Strength of Materials textbook for sophomore engineering technology students at Indiana University – Purdue University Fort Wayne, in Fort Wayne, IN. The textbook is available online as a free pdf file. The students are required to submit recommendations for improvement as part of their homework assignments. I use these recommendations to update the textbook every semester. Now in its 11th edition,[1] the textbook is significantly easier to read, has far fewer typographical errors, and includes new material the students requested. This paper discusses the process of continual improvement and the effects the textbook has had on student success over the 5 years of its use.

Introduction

Within the last half century, Continual Improvement Processes (CIP) have become part of the culture in manufacturing and service industries. A key part of Kaizen and other CIP methods is to solicit and implement ideas from the employees, rather than from costly outside consultants.[2] Involving and empowering employees can reinforce a sense of teamwork and improve employee morale, leading to higher productivity and organizational efficiency. By visibly implementing CIP in the classroom, college professors are in a prime position to help students adopt this culture, enabling students to be ready for the workplace upon graduation. One way to demonstrate CIP is to solicit and implement textbook revisions from students. Traditionally-published engineering textbooks rely on editorial review by experts in the field (other professors) and editorial employees of the publishing house. Typically, a textbook is reviewed for technical content on the publishing cycle – perhaps once every 5 to 7 years – a punctuated improvement process rather than a continual one. Therefore, any errors or omissions in an edition go uncorrected for half a decade or more. What other industry knowingly sells defective products for such a long period of time without correction?

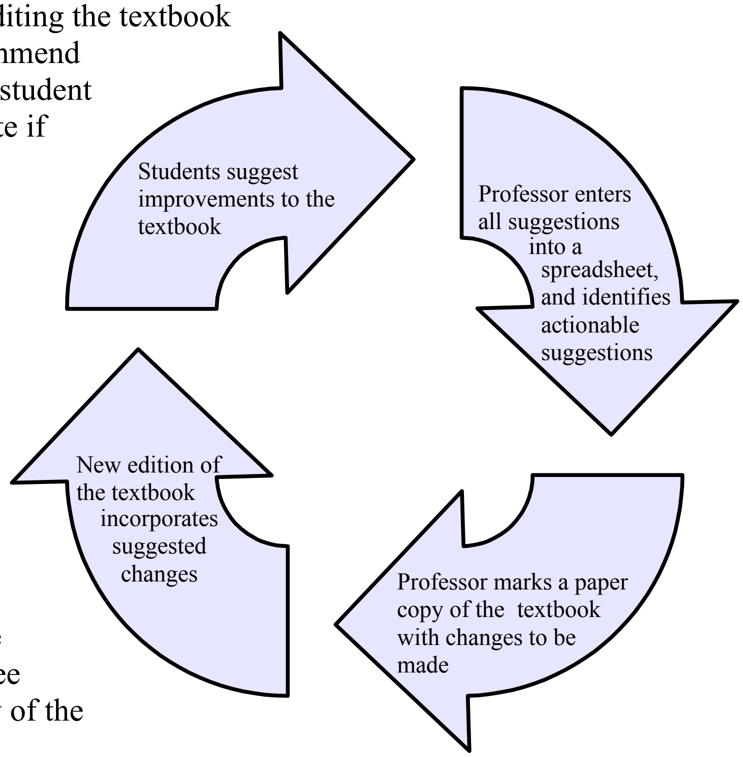
One alternative to the conventional model of textbook writing and revision is to have the students write and edit an online textbook.[3] This strategy is ideally suited for a course comprised of short, independent, qualitative topics (such as an introductory Materials Science course), but is not likely to work well in a highly mathematical course like Strength of Materials.

Student acceptance of online textbooks is dependent on ease of use and perceived usefulness.[4] This paper offers a model for editorial review that addresses these concerns by relying on undergraduate students for chapter-by-chapter feedback every semester. The result is that students are more engaged in the topic, while many improvements and corrections are made at the end of each semester to an open-access Strength of Materials textbook. Each edition includes, on average, 80 changes and additions from the previous edition.

Continual Improvement Cycle

I spent a sabbatical semester writing a textbook for students in my class who major in either mechanical engineering technology (MET) or construction engineering technology (CNET), then I implemented the textbook in the classroom in the fall of 2012. In the spirit of ABET Criterion 4 (Continuous Improvement),[5] I offered extra credit points in exchange for improvement ideas from students. Unfortunately, the feedback response rate was poor, as was the quality of the responses, because only the most desperate, low-performing students needed the points. The next semester, I improved the feedback cycle by including this question in each homework assignment: "How would you rewrite this chapter to make it more understandable?"

The continual improvement cycle for editing the textbook comprises four steps: [1] students recommend changes for the textbook; [2] I enter all student comments into a spreadsheet, with a note if the student either did not answer the question (left it blank, or replied "no changes are needed") or did not submit the homework assignment; [3] after selecting the most appropriate changes, I mark them in a printed copy of the textbook; and [4] as the semester progresses, I modify next semester's version of the textbook, then issue a new edition at the beginning of the new semester.



Most student editorial suggestions fall into six broad categories. The first three categories focus on content; the last three focus on structure, format, and usability of the textbook.

1. Add or change example problems (generally, in a particular unit system, or for a specific topic).
2. Clarify or explain a concept.
3. Correct an error (either typographical or mathematical).
4. Link the text and example problems with reference material (tables, appendices, and formulas found elsewhere in the textbook).
5. Move reference material (tables, appendices) from one place to another.
6. Change the formatting (of diagrams, headings, labels in figures, and colors).

Here are some verbatim examples of student editorial suggestions in each category, along with the additions or corrections to address these suggestions.

Category 1: Add or change example problems

These suggestions are not specific, and therefore are difficult to address:

> More examples.
>
> More homework problems with different examples.
>
> I think a few more detailed examples would help out a lot. Ones that contain more calculations.

Typically, the students who submit these types of comments are not actually reading the text; they prefer examples which are nearly identical to homework problems, so they can plug numbers into preexisting equations.

More useful recommendations include:

> Maybe give a metric problem example of the eccentric loading.
>
> I didn't think there were enough examples on timber beams.
>
> An example with fillets.
>
> An example of two loads on top of beam.

These very specific recommendations were easy to implement. I responded to the first suggestion by ensuring that half the examples are in U.S. Customary units, and the other half are in SI units.

Several students requested a particular type of example problem in one chapter of the 3rd edition:

> Chapter 8 could benefit from having an example on uniformly distributed load that doesn't extend the length of the beam.
>
> If I were to change anything in this chapter, I would recommend altering some of the examples. Most distributed loads are all going from edge to edge or from a point to the edge. This does not fully prepare us for some problems that are assigned.
>
> To make this chapter more understandable, I would include more examples with the overhanging beams. That is where I made most of my mistakes.
>
> I think you could have went over the uniform distributed load moment diagrams a little better finding area of parabolas and stuff.
>
> I had some issues with a uniform load on a cantilever beam; everything else was fine.

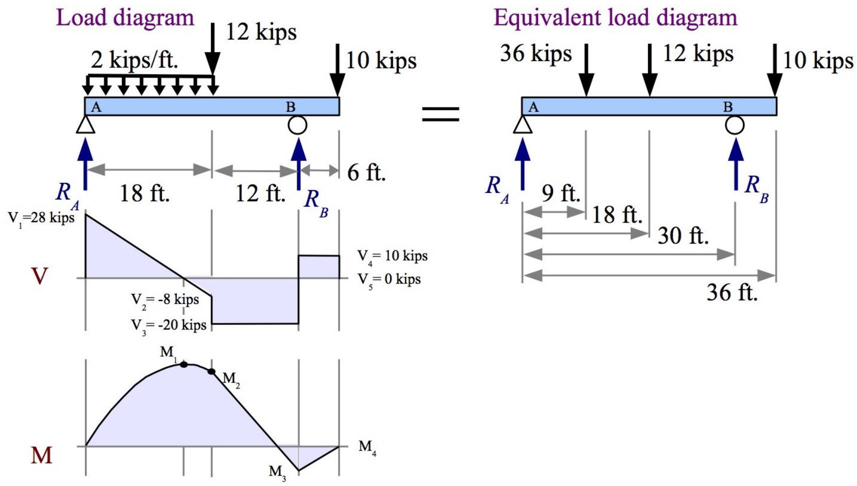
The new example problem in the 4th edition addresses these recommendations by including a uniform distributed load which extends over a portion of the length of an overhanging beam:

Example #22

Draw complete shear and moment diagrams for a 36 foot long overhanging beam having a uniform distributed load and two point loads as shown.

Solution Draw an equivalent load diagram, placing the equivalent point load at the centroid of the distributed load, which is 9 ft. from point A.

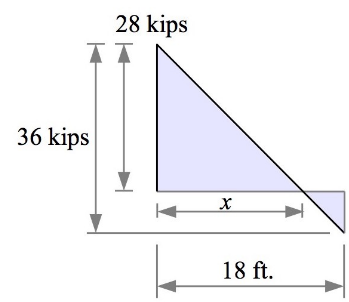
Use the equivalent load diagram to find the reaction forces, then draw the shear and moment diagrams below the original load diagram.



$$R_B = \frac{36\,\text{kips}\cdot 9\,\text{ft.} + 12\,\text{kips}\cdot 18\,\text{ft.} + 10\,\text{kips}\cdot 36\,\text{ft.}}{30\,\text{ft.}} = 30\,\text{kips}\ ,\ \ R_A = 36\,\text{kips} + 12\,\text{kips} + 10\,\text{kips} - 30\,\text{kips} = 28\,\text{kips}$$

Calculate the shear values: $V_1 = R_A = 28\,\text{kips}$, $V_2 = V_1 - \frac{2\,\text{kips}}{\text{ft.}}\,18\,\text{ft.} = -8\,\text{kips}$, $V_3 = V_2 - 12\,\text{kips} = -20\,\text{kips}$, $V_4 = V_3 + 30\,\text{kips} = 10\,\text{kips}$, $V_5 = V_4 - 10\,\text{kips} = 0\,\text{kips}$

The moment curve starts with a parabola going up until the shear curve crosses zero; once the shear is negative, the moment curve drops parabolically until the end of the distributed load. In order to calculate the moment values, we need to know where the shear curve crosses the zero line. Use similar triangles to find *x*, then calculate the area of the left-hand triangle in the shear diagram: $x = 18\,\text{ft.}\,\frac{28\,\text{kips}}{36\,\text{kips}} = 14\,\text{ft.}$



The area of the left-hand triangle is $M_1 = \frac{28\,\text{kips}\cdot 14\,\text{ft.}}{2} = 196\,\text{kip}\cdot\text{ft.}$

Subtract the area of the right-hand triangle to find $M_2 = M_1 - \frac{8\,\text{kips}\cdot 4\,\text{ft.}}{2} = 180\,\text{kip}\cdot\text{ft.}$

Subtract the lower rectangle to find $M_3 = M_2 - 20\,\text{kips}\cdot 12\,\text{ft.} = -60\,\text{kip}\cdot\text{ft.}$ Add the upper rectangle to find $M_4 = M_3 + 10\,\text{kips}\cdot 6\,\text{ft.} = 0\,\text{kip}\cdot\text{ft.}$

In this problem, $|M|_{max} = 196\,\text{kip}\cdot\text{ft.}$

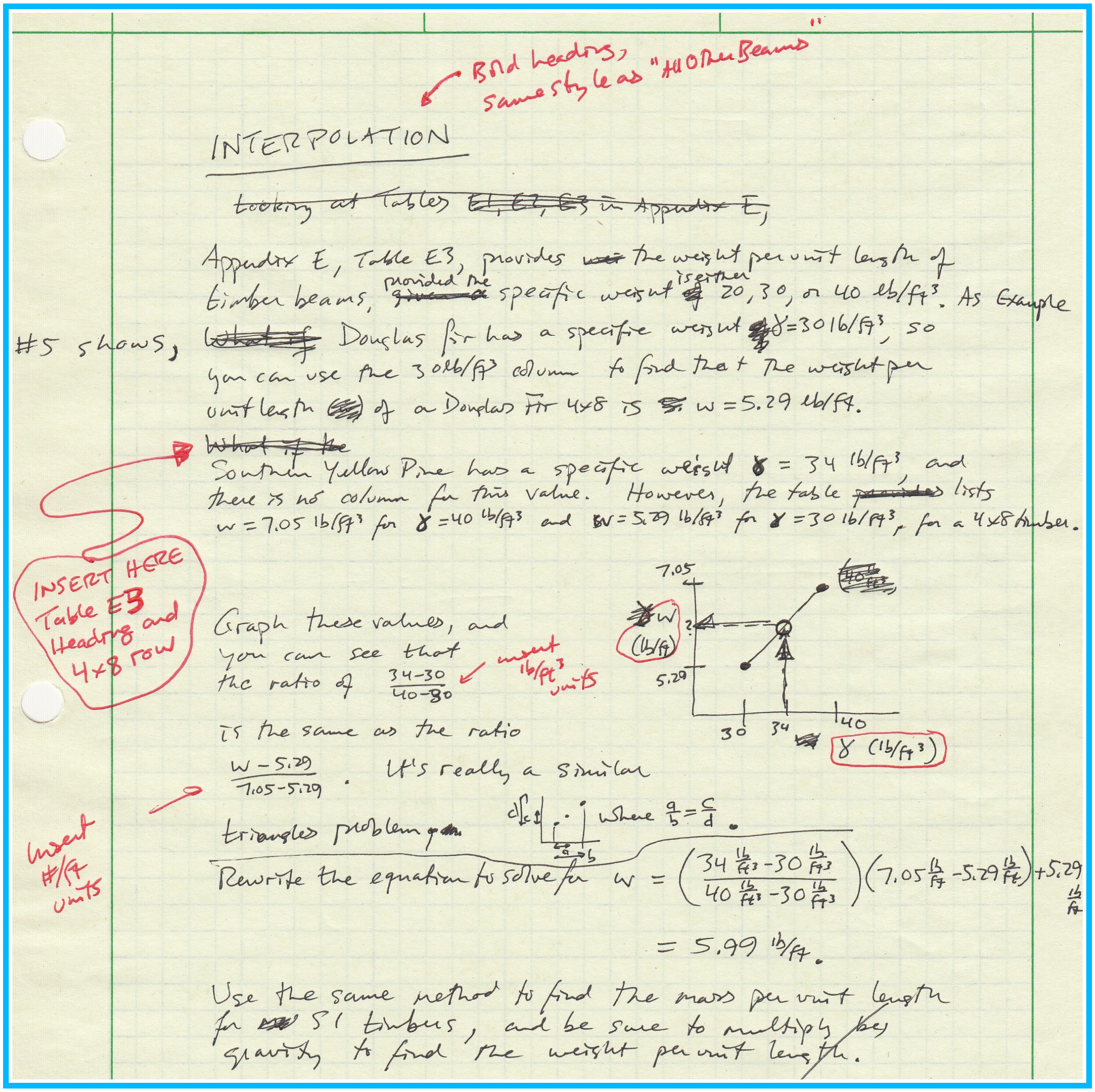
Category 2: Clarify or explain a concept

One of the necessary skills in this course is the ability to interpolate numbers in a table, such as the weight per unit length of a timber beam. Up through 2015, most students in this class understood how to interpolate, but in spring of 2016 (9^{th} edition) it became clear that many students were unfamiliar with the process. Typical suggestions were:

> Put in an example of interpolation into the chapter so problem #3 works out easier.
>
> Incorporate interpolation along with more distributed load examples.

Explaining more of how to interpolate the mass per unit length columns would be helpful and explaining when it's needed would be super helpful.

Here are my notes for updating the 10th edition:



Bold headers, same style as "All Other Beams"

INTERPOLATION

~~Looking at Tables E1, E2, E3 in Appendix E,~~

Appendix E, Table E3, provides the weight per unit length of timber beams, provided the specific weight is either 20, 30, or 40 lb/ft³. As Example #5 shows, Douglas fir has a specific weight γ=30 lb/ft³, so you can use the 30 lb/ft³ column to find that the weight per unit length of a Douglas Fir 4x8 is w = 5.29 lb/ft.

Southern Yellow Pine has a specific weight γ = 34 lb/ft³, and there is no column for this value. However, the table lists w = 7.05 lb/ft³ for γ = 40 lb/ft³ and w = 5.29 lb/ft³ for γ = 30 lb/ft³, for a 4x8 timber.

INSERT HERE Table E3 Heading and 4x8 row

Graph these values, and you can see that the ratio of $\frac{34-30}{40-30}$ (insert lb/ft³ units)

is the same as the ratio $\frac{w-5.29}{7.05-5.29}$. It's really a similar triangles problem where $\frac{a}{b}=\frac{c}{d}$.

(insert #/ft units)

Rewrite the equation to solve for $w = \left(\frac{34\frac{lb}{ft^3}-30\frac{lb}{ft^3}}{40\frac{lb}{ft^3}-30\frac{lb}{ft^3}}\right)\left(7.05\frac{lb}{ft}-5.29\frac{lb}{ft}\right)+5.29\frac{lb}{ft}$

$= 5.99$ lb/ft.

Use the same method to find the mass per unit length for SI timbers, and be sure to multiply by gravity to find the weight per unit length.

The new section in the 10th edition which explains interpolation includes a sample table, sample calculations, and a diagram illustrating how interpolation is a practical example of a principle they have used elsewhere in the course: similar triangles.

Interpolation

The weight per unit length of a steel beam is the specific weight of steel (0.284 lb./in.^{3}) times the cross-sectional area of the beam. For metric sizes, the mass per unit length of a steel beam is the density of steel (7.85 g/cm^3) times the cross-sectional area of the beam. These values are listed in Appendix D.

With timber beams, the weight per unit length for a given timber size depends on the type of wood, because different wood species have different specific weights. Appendix E lists the weight per unit length for three different specific weights: 20, 30, and 40 lb./ft.^{3}. For metric sizes, the mass per unit length is listed for three densities: 320, 480, and 640 kg/m^3. Douglas fir has a specific weight of 30 lb./ft.^{3}, therefore you can find the weight per unit length of a 2×6 Douglas fir timber in Table E3: it is listed as 1.72 lb./ft. in the table.

What if your 2×6 is made of Southern yellow pine? Specific weight $\gamma = 34\,\text{lb./ft.}^3$, which is not in the table...so you need to interpolate to find the weight per unit length w of this beam.

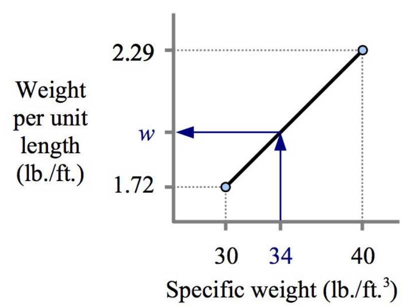
Here are the first few rows of Table E3:

Designation	Width	Depth	Area	Moment of inertia	Section modulus	Weight per unit length γ = 20 lb/ft.^{3}	Weight per unit length γ = 30 lb/ft.^{3}	Weight per unit length γ = 40 lb/ft.^{3}
	b	d	A	I_x	S_x	w	w	w
	(in.)	(in.)	(in.^{2})	(in.^{4})	(in.^{3})	(lb./ft.)	(lb./ft.)	(lb./ft.)
2×2	1.5	1.5	2.25	0.422	0.563	0.313	0.469	0.625
2×3	1.5	2.5	3.75	1.95	1.56	0.521	0.781	1.04
2×4	1.5	3.5	5.25	5.36	3.06	0.729	1.09	1.46
2×6	1.5	5.5	8.25	20.8	7.56	1.15	1.72	2.29

From the 2×6 row, $w = 1.72\,\text{lb./ft.}$ for $\gamma = 30\,\text{lb./ft.}^3$ and $w = 2.29\,\text{lb./ft.}$ for $\gamma = 40\,\text{lb./ft.}^3$. If you graph these values, you can see that the ratio of $\dfrac{34\frac{\text{lb.}}{\text{ft.}^3} - 30\frac{\text{lb.}}{\text{ft.}^3}}{40\frac{\text{lb.}}{\text{ft.}^3} - 30\frac{\text{lb.}}{\text{ft.}^3}}$ is equal to $\dfrac{w - 1.72\frac{\text{lb.}}{\text{ft.}}}{2.29\frac{\text{lb.}}{\text{ft.}} - 1.72\frac{\text{lb.}}{\text{ft.}}}$. The math is essentially the same as a similar triangles calculation.

Rewrite the equation to solve for the weight per unit length:

$$w = \left[\frac{34\frac{\text{lb.}}{\text{ft.}^3} - 30\frac{\text{lb.}}{\text{ft.}^3}}{40\frac{\text{lb.}}{\text{ft.}^3} - 30\frac{\text{lb.}}{\text{ft.}^3}}\right]\left(2.29\frac{\text{lb.}}{\text{ft.}} - 1.72\frac{\text{lb.}}{\text{ft.}}\right) + 1.72\frac{\text{lb.}}{\text{ft.}} = 1.95\frac{\text{lb.}}{\text{ft.}}$$



Use the same method to find the mass per unit length for SI timbers, and be sure to multiply by gravity to find the weight per unit length.

Interpolation is a good skill to develop because it is used in many other technical fields, including physics, chemistry, heat transfer, fluid mechanics, and thermodynamics.

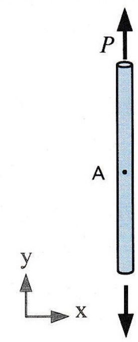
In the textbook, the above explanation is followed by a fully-worked-out example problem. The next semester, the nature of student comments changed:

> It would be nice to have a note saying students need to study interpolation for the specific problem.

Mohr's circle and the concept of stresses acting at different angles is one of the most confusing topics in the course. Many students have difficulty understanding how a stress can act in a direction other than the familiar x and y directions. An example problem in the 9th edition was designed to show that shear stresses can develop at 45° to the axis of bar loaded in uniaxial tension:

Example #1

An aluminum rod with a diameter of 0.5 inches is pulled with a load of 2000 lb. as shown. Calculate the applied stresses σ_x, σ_y, and τ_{xy}. Use Mohr's circle to find the principal stresses σ_1 and σ_2, angle θ, and the maximum shear stress τ_{max} at point **A**.



Solution

The applied normal stress is in the y direction; there is no applied shear stress.

$$\sigma_x = 0$$

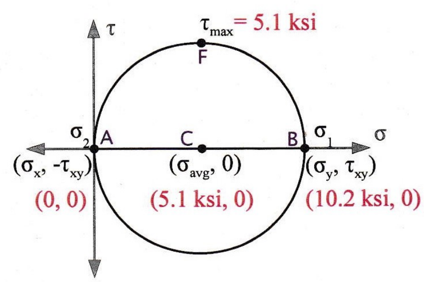
$$\sigma_y = \frac{P}{A} = \frac{4P}{\pi d^2} = \frac{4 \cdot 2000\,\text{lb.}}{\pi (0.5\,\text{in.})^2}\left|\frac{\text{kip}}{10^3\,\text{lb.}}\right. = 10.2\,\text{ksi}$$

$$\tau_{xy} = 0$$

$$\sigma_{avg} = \frac{\sigma_x + \sigma_y}{2} = \frac{0\,\text{ksi} + 10.2\,\text{ksi}}{2} = 5.09\,\text{ksi}$$

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \sqrt{\left(\frac{0\,\text{ksi} - 10.2\,\text{ksi}}{2}\right)^2 + (0\,\text{ksi})^2} = 5.09\,\text{ksi}$$



$$\sigma_1 = \sigma_{avg} + R = 5.09\,\text{ksi} + 5.09\,\text{ksi} = 10.2\,\text{ksi}$$

$$\sigma_2 = \sigma_{avg} - R = 5.09\,\text{ksi} - 5.09\,\text{ksi} = 0\,\text{ksi}$$

$$\tau_{max} = R = 5.09\,\text{ksi}$$

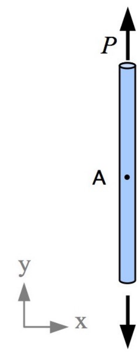
Angle $\theta = 0$, by inspection.

Show PHOTOGRAPH of intact and broken tensile specimens. Explain how fracture starts in transverse plane due to normal stress, then final fracture starts at 45° due to shear stress.

One semester I brought in a broken tensile sample to illustrate the 45° shear direction in a ductile metal, and the students recommended putting a photograph of the tensile specimen in the book. The new version of this example in the 10th edition explains the shear stress and the angle of that stress, using an additional annotated Mohr's circle figure, followed by a photograph of a classic cup-and-cone fracture.

Example #1

A brass rod with a diameter of 0.5 inches is pulled with a load of 2000 lb. as shown. Calculate the applied stresses σ_x, σ_y, and τ_{xy}. Use Mohr's circle to find the principal stresses σ_1 and σ_2, angle θ, and the maximum shear stress τ_{max} at point **A**.



Solution

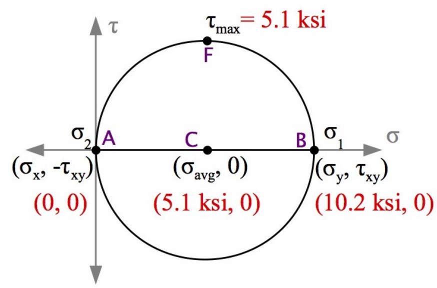
The applied normal stress is in the y direction; there is no applied shear stress.

$$\sigma_x = 0 \qquad \sigma_y = \frac{P}{A} = \frac{4P}{\pi d^2} = \frac{4 \cdot 2000\,\text{lb.}}{\pi (0.5\,\text{in.})^2} \left| \frac{\text{kip}}{10^3\,\text{lb.}} \right. = 10.2\,\text{ksi} \qquad \tau_{xy} = 0$$

$$\sigma_{avg} = \frac{\sigma_x + \sigma_y}{2} = \frac{0\,\text{ksi} + 10.2\,\text{ksi}}{2} = 5.09\,\text{ksi}$$

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \sqrt{\left(\frac{0\,\text{ksi} - 10.2\,\text{ksi}}{2}\right)^2 + (0\,\text{ksi})^2} = 5.09\,\text{ksi}$$



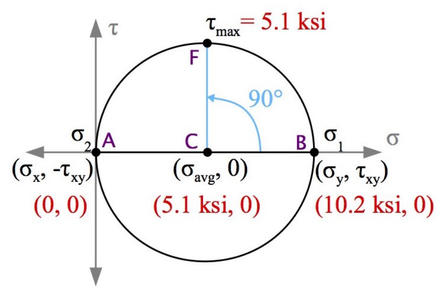
$$\sigma_1 = \sigma_{avg} + R = 5.09\,\text{ksi} + 5.09\,\text{ksi} = 10.2\,\text{ksi}$$

$$\sigma_2 = \sigma_{avg} - R = 5.09\,\text{ksi} - 5.09\,\text{ksi} = 0\,\text{ksi}$$

$$\tau_{max} = R = 5.09\,\text{ksi}$$

Angle $\theta = 0$, by inspection, confirming that the maximum normal stress (principal stress #1) is the normal stress in the y direction.

Rotate line segment **B-C** about point **C** to create line segment **C-F** 90° to the principal stress direction. Since all angles in Mohr's circle are double angles, we see that the maximum shear stress acts 45° to the principal stresses.



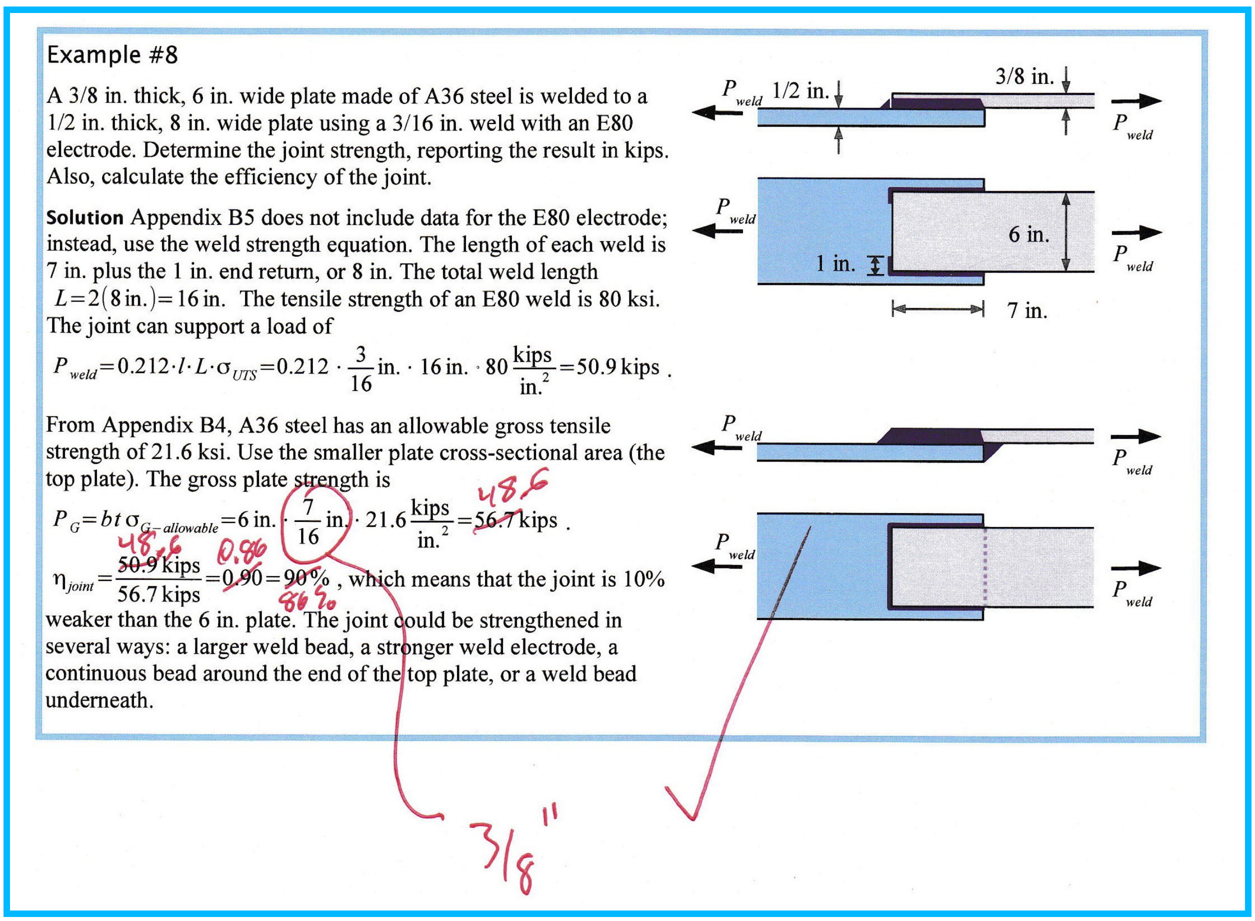
This photograph of a broken tensile specimen proves the existence of the maximum shear stress acting 45° to the axis of the rod. The specimen is pulled beyond its yield strength. Internally, microscopic voids form in a plane perpendicular to the axis; these voids coalesce to form a crack that grows from the center towards the surface of the rod. At some point, there is not enough material to support the load, and the rod shears at 45°, creating the classic cup-and-cone fracture surface of a ductile tensile specimen.

Category 3: Correct an error

These student editorial suggestions refer to the same typographical error.

> In example #8, calculating for the gross plate strength it says the thickness of the thinner plate is 7/16". However the picture shows the thickness of the thinner plate is 3/8", which is 6/16".
>
> When calculating a weld strength, example 8 has two plate sizes. It then assumes t=7/16 in. (which I believe is just half the total t) but the paragraph prior states using the smaller plate (3/8 in.).
>
> The one improvement to make this chapter more understandable is to fix example #8, in equation P_G it should be 3/8" instead of 7/16" for thickness.
>
> More on example #8 would be helpful, explaining how t was found for P_S and P_G.

The first three students clearly understand what the mistake is; the last is less sure, but is aware that there is an error somewhere. Here are the handwritten changes in the paper edition of the 9th edition:



Example #8

A 3/8 in. thick, 6 in. wide plate made of A36 steel is welded to a 1/2 in. thick, 8 in. wide plate using a 3/16 in. weld with an E80 electrode. Determine the joint strength, reporting the result in kips. Also, calculate the efficiency of the joint.

Solution Appendix B5 does not include data for the E80 electrode; instead, use the weld strength equation. The length of each weld is 7 in. plus the 1 in. end return, or 8 in. The total weld length $L=2(8\text{ in.})=16\text{ in.}$ The tensile strength of an E80 weld is 80 ksi. The joint can support a load of

$$P_{weld}=0.212\cdot l\cdot L\cdot\sigma_{UTS}=0.212\cdot\frac{3}{16}\text{in.}\cdot 16\text{ in.}\cdot 80\frac{\text{kips}}{\text{in.}^2}=50.9\text{ kips}.$$

From Appendix B4, A36 steel has an allowable gross tensile strength of 21.6 ksi. Use the smaller plate cross-sectional area (the top plate). The gross plate strength is

$$P_G=bt\sigma_{G-allowable}=6\text{ in.}\cdot\frac{7}{16}\text{in.}\cdot 21.6\frac{\text{kips}}{\text{in.}^2}=56.7\text{ kips}.$$

$$\eta_{joint}=\frac{50.9\text{ kips}}{56.7\text{ kips}}=0.90=90\%$$, which means that the joint is 10% weaker than the 6 in. plate. The joint could be strengthened in several ways: a larger weld bead, a stronger weld electrode, a continuous bead around the end of the top plate, or a weld bead underneath.

The checkmark indicates the change was made to the next edition of the textbook.

Category 4: Link the text and example problems with reference material

Early editions of the textbook lacked references to specific appendices:

> In all the chapters, it would be nice if the example would reference what table the needed material info was on. There is a lot of wasted time searching for the information needed to solve equations.
>
> I would maybe add some references to which appendix (or page where info could be found) to search for values required to solve problem.
>
> To make this chapter easier to understand, I would suggest adding which appendix to reference in Example #3 & #4.
>
> One improvement that I would suggest for this chapter is to mention what appendix copper tubing is located in.
>
> Would like more examples of each situation & reference to the appendix to show where the materials properties are.

This issue was easy to fix by including a reference to the specific appendix needed for each example problem, and by listing the appendices needed for each set of homework problems. Usually, these types of recommendations only appeared in the first few weeks of the course, until students developed the habit of looking up numbers in the appendices.

Some students wanted specific page number references:

> At the end of the chapter in the Key Equations, reference what page the equation was first introduced.
>
> It would be helpful to add the page number as reference after mentioning an appendix in the problems. I will tab them in my copy.
>
> Maybe when you reference the allowable plate stress table, note the page number.
>
> I would make the formulas more obvious to its users. It is obvious which formulas we need to use but locating the *[word missing?]* takes too much time and makes you need to re-find your place. At the very least put a page or appendix number at the end of each question.
>
> On p.51 at the bottom, if you could give a quick page number reference on where to find shear modulus, that would be great! It doesn't have to be just this chapter either.
>
> A reminder that r_G can be found in Appendix C with the properties of areas would be great.

Providing specific page numbers is probably counterproductive; the textbook is not particularly long, and I want students to learn how to use the appendices and index effectively.

Category 5: Move reference material

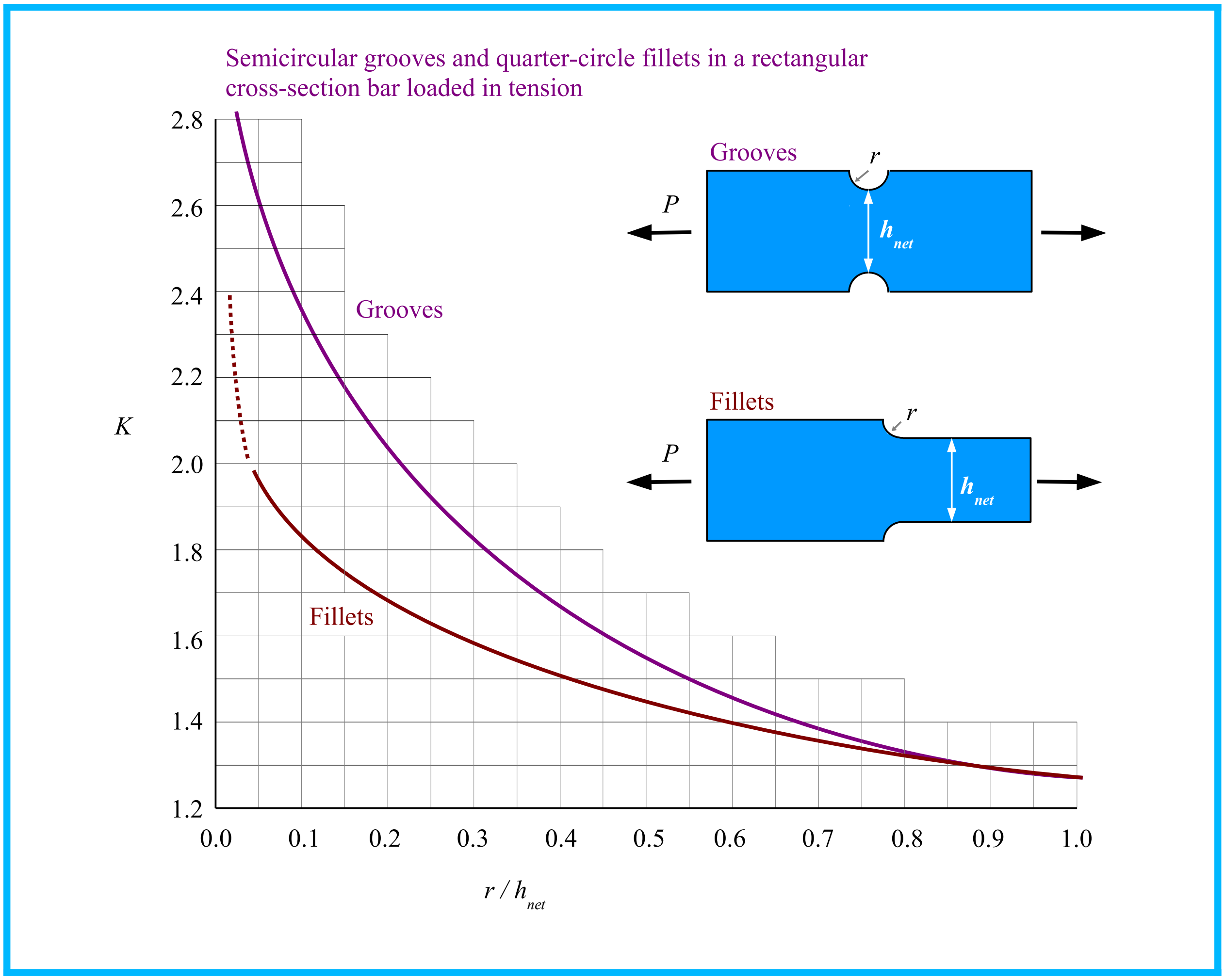
Some students asked to have all reference materials at the end of the book, in the appendices. Others wished the reference material could be moved to the first chapter where it is used, so they could avoid flipping pages.

> Move charts on p.57, 31, & 29 to an appendix so we do not have to look for them.
>
> I would prefer to have the Appendix C equations in the front of the book.
>
> To make it easier I wish the table in Appendix B were in or at the end of this chapter so when I'm looking at an example I don't have to flip all the way to the back to get the information that I need.
>
> Put all tables *[of bolt and plate properties]* on the same page for ease of reference.

Several students recommended moving the tables of bolt and plate properties. Up through the 5th edition, these tables were scattered throughout the chapter on bolted joint problems. Starting with the 6th edition, all of these tables moved to the same page in an appendix.

Category 6: Change the formatting

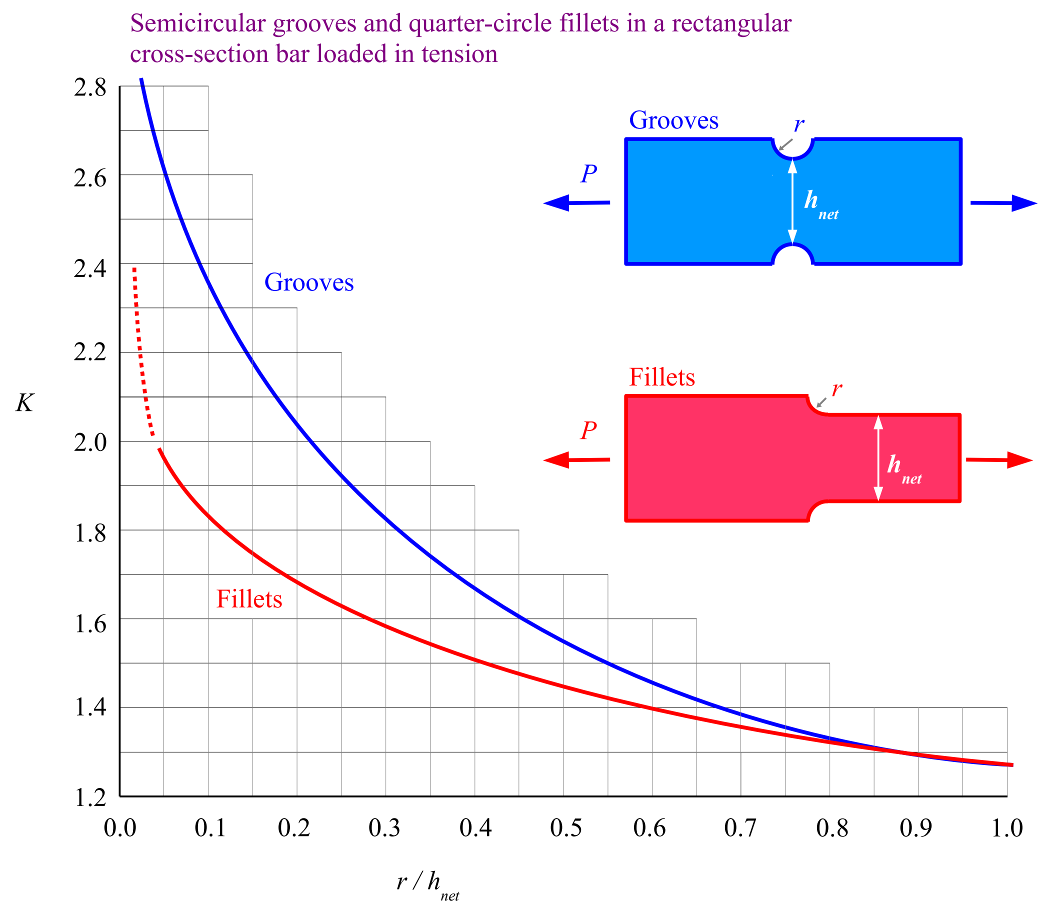
One advantage of online publishing is that colors are free. Over the years, students have requested more of the diagrams to be in color. Some students have recommended that different variables in equations be shown in different colors. I have used color to respond to a number of student editorial suggestions. For example, one chapter discusses stress concentrations due to holes, grooves, or fillets in flat plates which are loaded in tension. Each type of stress concentration requires a graph to determine the stress concentration factor for the given geometry. The graph for holes stands alone, but for space reasons, the groove and fillet curves are shown on the same graph. Each curve corresponds to the color of the label used for its respective plate. This diagram is from the 6th edition:



Many students used the wrong curve in their homework solutions, despite the labels on the curves. One cause may be the poor choice of color for the plates...the blue color does not correlate with either curve. Students had these editorial recommendations:

> Separate the grooves and fillets graph. Have two separate graphs.
>
> I would split the fillets graph from the grooves graph. This could eliminate the chances of mixing up the two types.
>
> Make it VERY clear that grooves & fillets are not the same. A picture & explanation would help.

I chose not to plot the curves on two separate graphs because I want students to learn how to read a graph with more than one curve. Many engineering graphs contain multiple curves (such as temperature-entropy charts in thermodynamics, and the Moody diagram for fluid friction in circular pipes), so learning to read the stress concentration graph is good practice for future courses. The new version of the graph in the 7th edition shows the two plates in the same colors as the curves, which are now red and blue rather than purple and brown. About 0.5% of females and 8% of males of northern European ancestry have some degree of colorblindness,[6] and the most common type is red-green colorblindness. For this reason, color contrast in this graph and in most of the textbook is between shades of red and blue.



As a result of these improvements to the graph, fewer students chose the wrong curve when solving homework problems.

Another formatting change is symbol choice.

> If a different symbol is used for radius of gyration it could lower some confusion in my brain.
>
> What symbol represents weld efficiency? I couldn't find anything in Chapter 4 about it. I just went off of the example in our notes.

The first student was confused because the symbol for radius of gyration was r, which many students easily confused for radius. Subsequently I changed the symbol for radius of gyration to r_G, eliminating the confusion. Responding to the second student, I introduced a new symbol for welded joint efficiency.

Results

One result of this continual improvement process is an average of 80 changes in every new edition of the textbook, either to correct errors or to explain topics in better ways.

Two other measurable results are engagement (as measured by the length of the responses) and course grades.

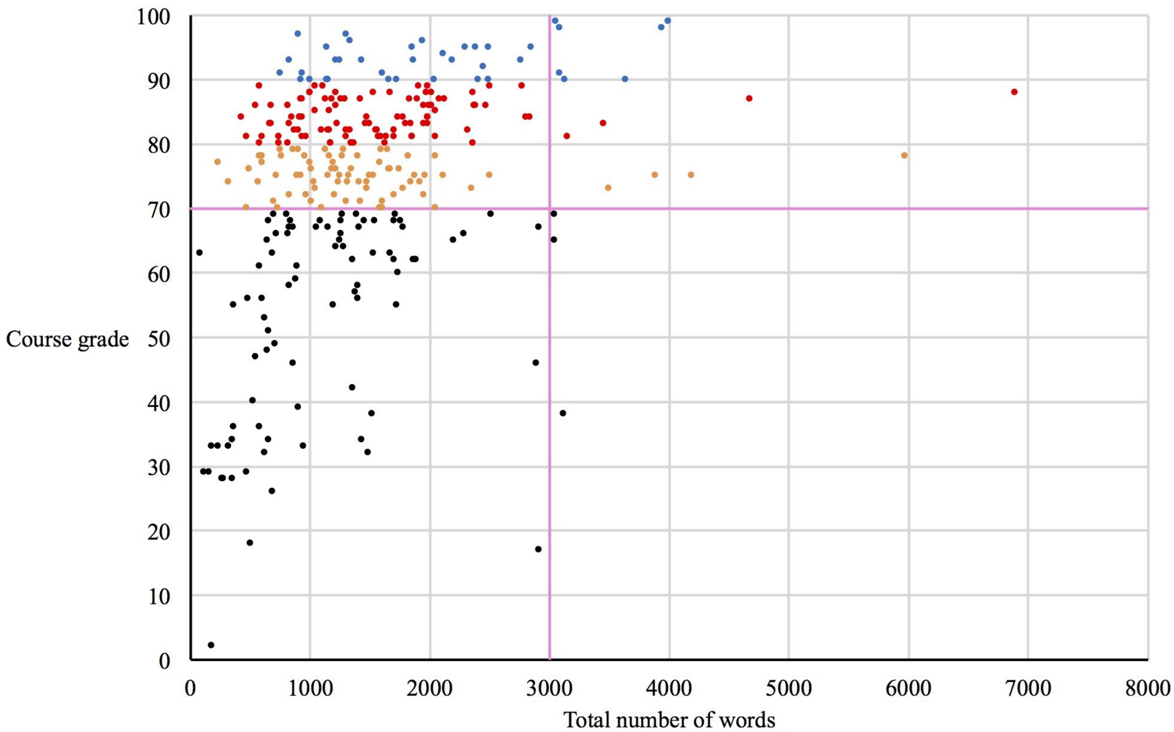
Response Length

Over the last 5 years, the number of words in each student recommendation ranged from 2 to 213 words. Here are the two extremes:

> More examples.
>
> One improvement, though you may disagree, but for some of us older students that it has been a while since we took the algebra classes, a very brief review of the important / useful algebraic methods that will be needed for this course would be great. For example, where to put the variables when you need to switch them to the other side of the equation. If you are wanting this to be like an actual stand-alone book, I would also add in somewhere a full list of conversions. Also, so far for this chapter, I think it would be easier to understand and relate it to real world experience if the examples were more described as if it were about a real situation or object. Like example #3, for instance; instead of just saying what the formula is ($\delta=\alpha\ L\ \Delta T$), and what each symbol is, and then asking what the ΔT is, explain the problem as a real situation. More like in the problem sets, but then go into detail on how to solve it using real world examples. I am confused in Example 3, step 2, how you can separate the unit label (°F) from its value ($5x10^{-6}$), putting the °F in the numerator and leaving the value in the denominator.

Clearly, the second response indicates a great deal more thought than the first response. It includes four distinct recommendations, every one of which is specific enough to be actionable.

The graph below shows the final course grades for the past five years plotted as a function of the total number of words each student submitted. Each of the 276 points represents a student enrolled in the class in a particular semester, therefore any student repeating the course appears as more than one point on the graph. The points are color-coded according to course grade: A = blue, B = red, C = orange, and D or F = black. The passing grade in this course is a C.

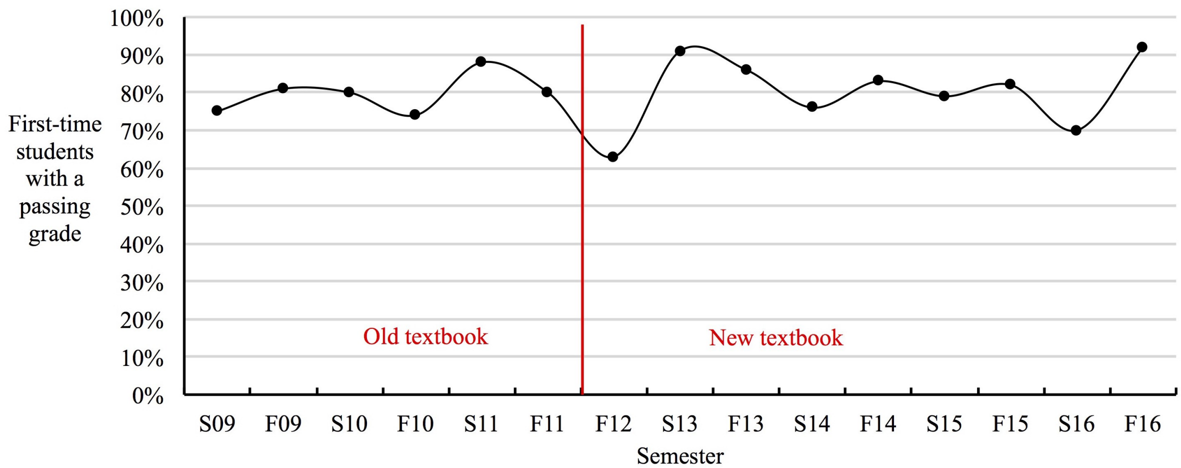


We can rank the students by the total number of words they wrote: less than 1000, 1000 to 2000, 2000 to 3000, and more than 3000. The table below shows that students who wrote the most were more likely to earn higher grades (two fifths earned an A); students who wrote the least were more likely to earn low grades (nearly half failed the course with a D or an F).

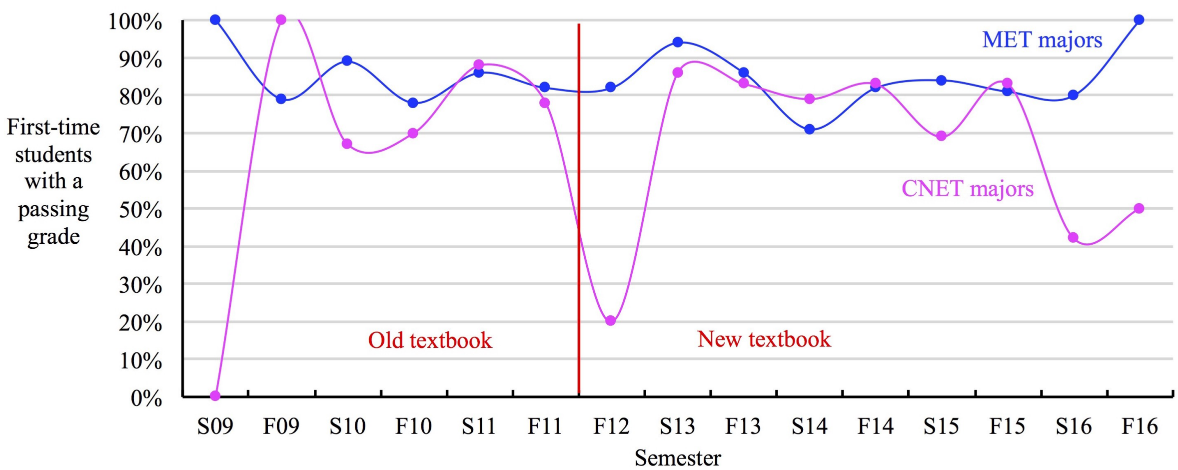
Grade distribution for each range of total words written	A	B	C	D or F
Less than 1000 words	5%	26%	22%	47%
1000 to 2000	10%	37%	31%	22%
2000 to 3000	29%	42%	13%	16%
More than 3000 words	39%	22%	22%	17%

Course Grades

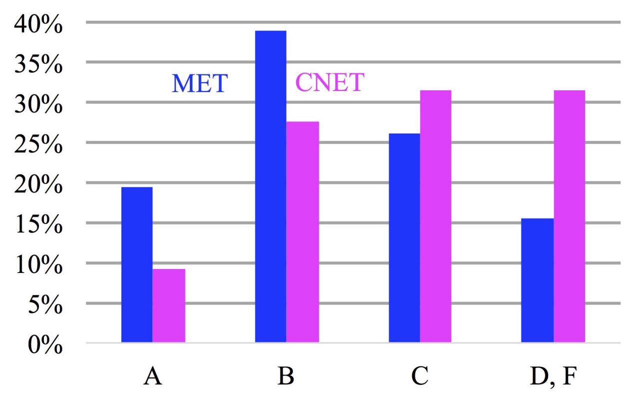
The percentage of students passing the class varies from one semester to the next. Success depends on such factors as a student's maturity and dedication, how many classes the student is taking, employment, proficiency in Statics, and whether the student is repeating the class or taking it for the first time. The following graph shows the percentage of students who passed the course on the first attempt. The dataset includes 6 semesters using the old textbook, and 9 semesters using the new textbook. Introduction of the new textbook in Fall 2012 appears to have made only a small improvement in the passing rate for this course.



Another variable affecting the first-attempt success rate is the student's major. This next graph shows that MET students are usually more successful than CNET students in passing the course on the first try.



The performance gap is evident in the grade distribution between the two majors, illustrated at the right. MET students are more likely to earn higher grades than CNET students. One reason for the performance difference is that MET students are more skilled at unit conversions, so their grades on the first exam are, on average, 10 to 15 points better than CNET students. This gap gradually closes during the semester, so that by the third exam, the average grade between the two groups of students is nearly the same, indicating that both



groups of students are equally capable, therefore the difference in performance must be due to background rather than ability. Unfortunately, by the third exam, the damage to CNET students' grades is done, and many CNET students must repeat the class for a passing grade.

In the U.S., manufacturing industries use both U.S. Customary and SI units, so MET students are familiar with both unit systems. In contrast, SI is rarely used in the U.S. construction industry, so CNET students treat SI units as a foreign language; their lack of understanding of SI units is evident in their homework submissions. While students of both majors struggle with algebra, the CNET students struggle more than the MET students with unit conversions.

In an effort to close the performance gap between these two groups of students, the CNET curriculum has recently added a freshman class which teaches, among other things, the factor-label method of unit conversion. That course has been required in the MET program for many years; the hope is that CNET students will become more proficient in unit conversions, especially with SI units.

This table shows that first-time MET students fared measurably better and first-time CNET students fared significantly worse with the new textbook. The first group of CNET students to take the unit conversion course are just now showing up in Strength of Materials; it will be interesting to see if the negative trend in CNET performance is reversed in the next few years.

	MET		**CNET**	
	Old book	New book	Old book	New book
Total number of first-time students	134	178	37	78
Number of students passing the course on the first attempt	105	151	29	53
Percent of students passing the course on the first attempt	78%	85%	78%	68%

Conclusions and Future Work

This paper presents a model for conducting Continual Improvement in textbook editing by undergraduate engineering technology students. Over 5 years, more than 900 editorial changes have resulted in a better textbook with fewer errors, better example problems, and clearer explanations. Although student success is mixed, careful analysis of the data led to a change in the Construction Engineering Technology curriculum which should lead to greater student success in this course within the next few years.

Future work includes an open-access textbook on Materials Engineering for engineering technology students, using the same CIP model, but with two coauthors from industry.

Acknowledgements

I would like to acknowledge 270 undergraduate student editors who contributed suggestions for improving the textbook, from the portions of the rough draft in fall 2011 to v.10 in fall 2016.

Jacob Ainsworth
Aaron Alexander
George Allwein
Matthew Amberg
Jared Archer
Mark Archer
Mark Armstrong
Justin Arnold
Stuart Aspy
Caleb Averill
Alex Baer
Ryan Baughman
Eric Baumgartner
Trenton Barnett
Jacob Beard
Neil Beauchot
Mitchell Bellam
Aaron Bender
Emily Bendix
Maverick Birch
Kevin Black
John Blankenship
Connor Bleke
Jason Bobay
Tyler Bolinger
Daniel Bone
Kyler Boots
Crystal Boyd
Valerie Bratten
Cole Bruick
Aaron Bryant
Brady Bryant
Gregory Bunn
Nicholas Burchell
Justin Byerley
Blake Cain
Brody Callaghan
Esperanza Castillo
Richard Chadwick
Tyler Chambers
Brian Chaney
Daniel Christian
Zachary Clevenger
Ryan Clingenpeel
Mitchell Comparet
Chelsea Cox
Uriel Contreras
Jordan Cook
Logan Counterman
Stephen Cox
Dillon Craig
Chad Crosby
Daniel Cummings
Tayler Cummings
Brian Daley
Christopher Davis
Patrick Davis
Ross Dillion
Garrett Duhnovsky
Joshua Dunlap
Joshua Dynes
Jared Elliott
Stephen England
Cameron Eyman
Jacob Falk
Joshua Farlee
Christopher Faurote
Tyler Faylor
Taylor Fear
Austin Fearnow
Benjamin Fiechter
Alexander Fisher
John Fisher
Misael Flores
Charles Foreman
Bryce Forrester
Ian Forslund
Camden Fox
Dominick Franco
Michael Friddle
Nathan Frye
Austin Furnas
Jacob Gaerte
Brett Gagnon
Joseph Gallmeyer
Matthew Gamble
Daniel Geimer
Carl Garringer
Tyler Geesaman
Shane Giddens
Andrew Gordon
Almario Greene
Michael Gresley
Ryan Guiff
Lucas Hahn
James Harris
David Halpin
Charles Hanes
Adam Hanford
Christian Harmeyer
Brian Harper
Matthew Hauter
Skyler Hayes
Alexander Heine
Cody Hepler
Kaleb Herrick
Cameron Herring
Matthew Heyn
Spencer Hille
Paul Hilterbrand
Benjamin Hinora
Tyler Hinora
Frank Hoffman
James Hoppes
Bradley Horn
Derick Hostetler
Josef Ifer
Sujinda Jaisa-Ard
Ariana Jarvis
Daniel Johns
Jason Joyner
Lucas Kaiser
John Keene
Adam Kelling
Adam Kennedy
Joseph Kent
Nate Kipfer
Hannah Kiningham
Patrick Kirk
Andrew Kitrush
Rachael Klopfenstein
Martin Koeneman
Austin Kraner
Joel Kumfer
Branden Lagassie
Kyle Lagemann
Doug Lambert
Brandon Lane
Justin Lantz
Taylor Lantz
Patrick Laroy
Venus Lee
Christopher Leek
Daniel Lewis
Jonathan Lewis
Park Lickliter
Eric Liles
Joseph Lortie
Andrew Loughborough
Jonah Mack
Kyle Macke
Cullan Magnuson
Evan Malic
Linda Manduka
Austin Mann
Dalton Mann
David MarcAurele
Lucas Martin
Sterling Martin
Alex Mason
La Keisha Mason
Jason Mayes
Jacob Mazurek
Joel McBain
Adam McCarty
Tori McGairk
Michael McLinden
Riley McMurray
James McVicker
Angela Mendoza
Tedd Miller
Estelle Mills
Jedd Minnich
Kaitlin Moore
Derek Morreale
Senaid Mrzljak
Travis Mullendore
Blake Nicol
Kyle Noll
Ivory Nnaji
Michael Nusbaum
Adam Oberley
Mitchell Olney
Jordan Owens
Jason Pace
Ryan Pearce
Jacob Penland
Nicholas Penrod
Luis Perea
Tad Pfefferkorn
John Pham
Clayton Philips
John Pogue
Gabe Powell
Braxton Powers
Nathan Pratt
Trey Proper
Dakota Rassman
Justin Reece
Matthew Rejak
James Rensberger
Shawn Reuille
Daniel Reynolds
Daniel Rieman
Charles Rinehart
Jason Ringer
Derek Ripley
Matthew Roell
Jennifer Royer
Connor Ruby
Brandon Rude
Austin Rumsey
John Ryan
Billie Saalfrank
Zachary Saylor
Zackory Schaefer
John Schafer
Riley Schuette
Zeke Schultz
Austin Schweitzer
Justin Self
Ryan Sellers
Brad Shamo
Philip Sheets
Nathan Sheneman
Keith Shepherd
Scott Shifflett
Matthew Shimko
Kenneth Short
Eric Shorten
Trenton Shrock
George Siddons
Travis Singletary
Shane Slone
Jacob Smarker
Ellen Smith
Taylor Snavely
Matthew Somerlott
Joshua Sorge
Matthew Steiner
Jason Strole
Jonas Susaraba
Troy Sutterfield
Robert Swanson
Christopher Swygart
Kyle Tew
Zach Thorn
Nathaniel Timmons
Tyler Tippman
Jason Tonner
Eric Trabel
Chandler Tracey
Cody Turner
James Upton
Jason Vachon
Thadius Vesey
Dakota Vogel
Scott Vorndran
Charles Wadsworth
Travis Weigold
Sam Weisser
Jay Wehrle
Brock Westergaard
Grant Wilson
Kenneth Win
Scott Wolfe
Michael Woodcock
Lindsay Wright
Matthew Young
Tang Zhong

[1] Barry Dupen, *Applied Strength of Materials for Engineering Technology*, 11th ed., available at http://opus.ipfw.edu/mcetid_facpubs/52/. The most recent edition (updated every semester) is available at http://www.etcs.ipfw.edu/~dupenb/ET_200/StrengthOfMatHome.html.
[2] Masaaki Imai, *Kaizen: The Key to Japan's Competitive Success*, McGraw-Hill, New York, 1986.
[3] Edward F. Gehringer, "Experience with Software Support For Managing Student-Authored Wiki Textbooks", proceedings of the ASEE Annual Conference & Exposition, June 2011.
[4] Charles Birdsong, John Chen, Marilyn Tseng, & Christine Victorino, "Student Acceptance of Online Textbooks Across Multiple Engineering Courses", Computers in Engineering Journal, Vol. XXV No. 3, July – September 2015, p. 64-86,
[5] See http://www.abet.org/accreditation/accreditation-criteria/accreditation-policy-and-procedure-manual-appm-2017-2018/ (accessed December 2016).
[6] See the National Eye Institute website, https://nei.nih.gov/health/color_blindness/facts_about (accessed January 2017).