

RIT



Exploring Connections: Geometry Independence of Stress-Strain Curves

AKA

Designing Hands-On Activities to Tackle
Troublesome Knowledge

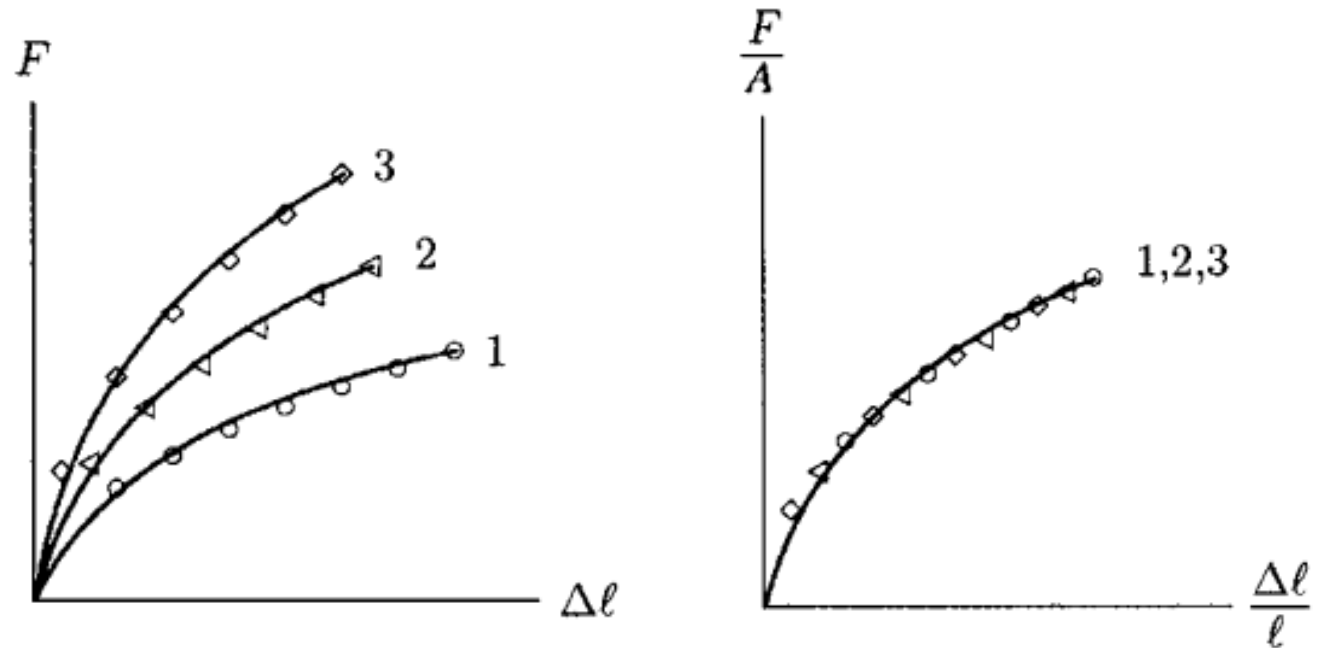
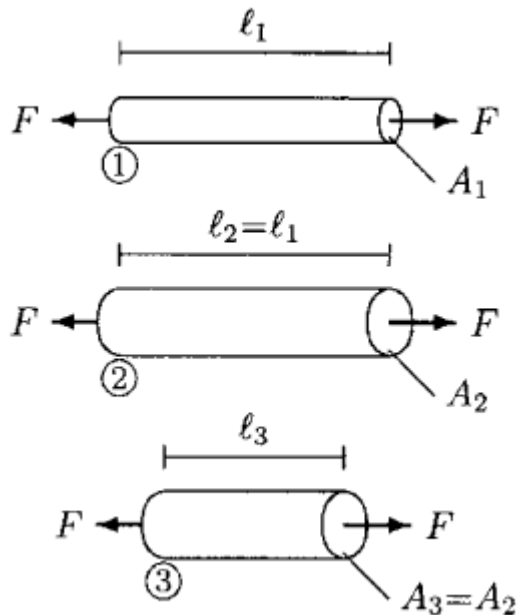
Dr. Travis Meyer

Lecturer and Masters Program Director, RIT BME

BEEC Share and Learn – 03/19/2026

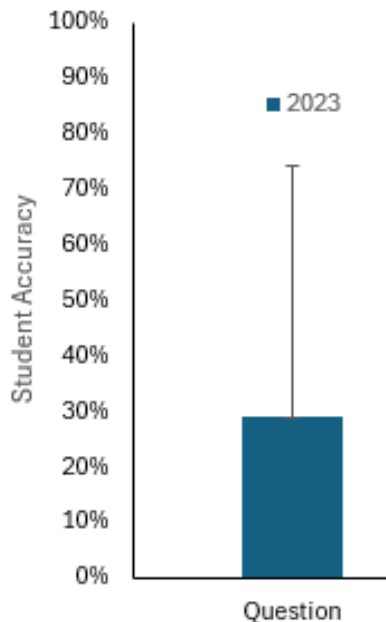
Background/Context

- Teaching 2nd Year Biomechanics Course (Statics+Dynamics+Deformable Materials) for 1st time
- Introducing Stress and Strain



Exam Question

- “How would the stress-strain diagram of a metal shaft used for prosthetics change if the diameter is doubled but the material/testing conditions stay the same? **(3 points)**”



The curve would become less steep since stress is inversely proportional to the area πr^2 so it would increase slower while strain would stay mostly the same as it depends on length

The line for the doubled diameter will be lower than the original line since the strain will stay the same but since stress is F/A the increase in diameter will increase the cross sectional area, decreasing stress

$$\sigma = \frac{F}{A} \quad A = \pi r^2 = \pi(2r)^2 = \pi 4r^2$$

If the diameter is doubled but the material stays the same, the maximum stress would be $\frac{1}{4}$ the size of the original, since the stress is dependent on the area of the cross-section.

Problem

- How to help students internalize *concept* of stress and strain, and not just how to plug numbers into equations?
 - **Connections** between equation and concepts/real-world behavior
- Lab courses can be great for this, but lab was offset from course (taken in subsequent semester)
- Attempted an in-class demonstration, but did not appear to have any impact

Solution – Hands-on, In-Class “Lab”

- Provided students with rubber rods of varying dimensions and asked them to identify if the type of rubber was **the same or different**



- Purchased from McMaster-Carr, lots of different stiffnesses and dimensions

- Asked students to initially propose a hypothesis based on their own experience with the material
- Had students conduct tensile test to collect data on material deformation

Lab Experience

- Work in teams of 3 (mostly a class size/material constraint decision)
- Provided calipers and rulers to measure/record dimensions
- Hung weights from supported rod and measured/recorded new deformed length
- Repeated with different weights and different rods
- Guided problem set to work through analysis step-by-step, submitted for grade



Problem Set

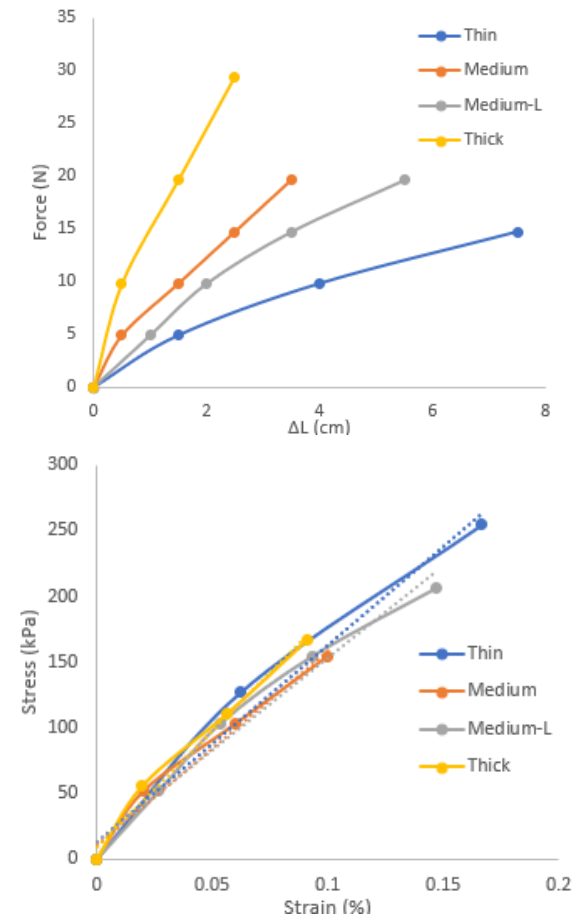
- Places to record data
- Instructions for data processing
- Guided Results/Discussion
 - What was your initial hypothesis from tactile evaluation?
 - Plot force vs deformation and stress vs strain
 - Fit stress-strain and report Young's Modulus
 - Based on data, arrive at conclusion and compare to hypothesis
 - **Compare force vs deformation to stress vs strain data.** Which was more useful for extracting information about material properties?

Thin Rod

Weight	New Length

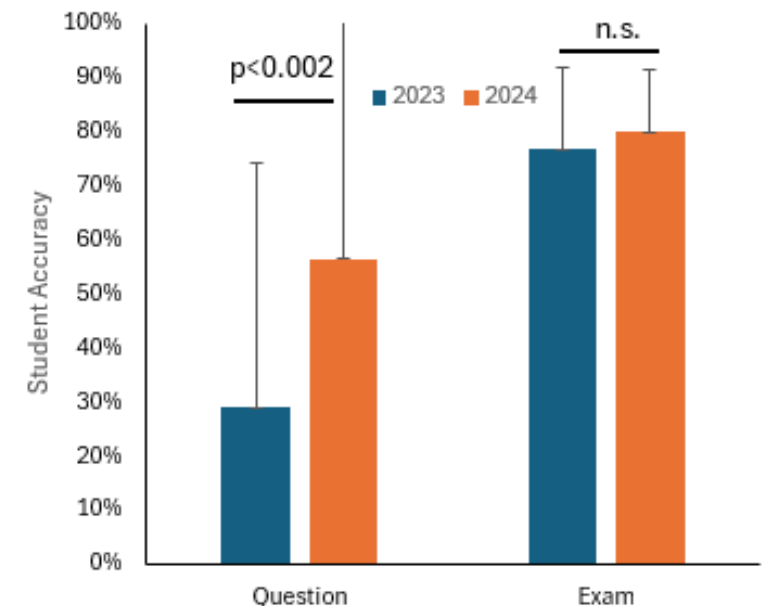
Medium Rod - Short

Weight	New Length



Impact

- Took a whole 75 minute class-period
- Extra graded assessment/feedback
- Seemed to lead to marked improvement in conceptual understanding of stress and strain
- Relatively well-received by students
 - Likert Scale “Enjoyable” – 4.14/5
 - Likert Scale “Useful” – 3.94/5



Issues/Area for Improvement

- Trouble with measurement imprecision
 - Some students ended up with stress-strain curves that did look notably different
- Variability
 - Students would often say material was different if Young's modulus differed by 10% or so

Future Changes

- Include materials that differ in both geometry AND material properties
 - “Which of these rods is made of a different material?” vs “Are these rods made from a different material?”
- Include markings on rods to facilitate more reliable measurement

Questions or Comments?

- Thanks so much!