Chapter 6

INCORPORATING EVIDENCE-BASED TEACHING TECHNIQUES INTO CALTECH CLASSROOMS

6.1 Introduction

As we do research to understand new and old discoveries, through experiments, theory, and simulation, we learn both about the underlying explanations for these phenomena and how to improve our methodology. New techniques in science and engineering allow us to uncover physics on the subatomic scale and on the galactic. By iterating, trying new processes, and sometimes succeeding, sometimes not, we grow as a scientific community with new knowledge and expertise.

Much as we experiment in our laboratories, we can also experiment in our classrooms. As more instructors engage in trying new teaching techniques and documenting the results, the field of pedagogy develops guidance on best practices and how we can use evidence-based teaching techniques to improve our classrooms. Research on teaching demonstrates that implementing inclusive and structured improvements into the classroom benefits all students, particularly those that are often underserved in college classrooms (first-generation students, racially and ethnically minoritized students, women and gender minorities, students with disabilities).[1–7]

In this chapter, I will introduce evidence-based teaching techniques motivated by pedagogical research literature and use examples from my teaching experiences to demonstrate these techniques and their impact, while reflecting on how to iterate to improve the implementation of the technique.

6.2 Backwards Design

Technique and Motivation

Traditionally, many courses were designed around teaching to cover a specific set of content over a term, to use a particular textbook, and to consist of a specific number of lectures per week. As syllabi and other formal requirements for courses were introduced as a part of cross-course curricula, intended learning outcomes were retroactively ascribed to fit those prior choices.[8]

In "backwards design," learning outcomes—goals for knowledge and skills students should have acquired by the end of course—are constructed first, keeping in mind that learning outcomes should be clear and measurable. Assessment is then structured to measure to what extent these outcomes have been achieved. Content, teaching methods, and supporting materials are then designed and chosen to directly address one or more of those learning outcomes.[8,9]

Backwards design leads to intentional course structuring, which benefits both instructors and learners, and assists students in acquiring the knowledge and skills they need to retain from the course to proceed into future education and careers.[9]

Implementation

In my second time as a teaching assistant for heat transfer, I sought to use backwards design and learning outcomes to better structure assessment in the course. At the start of the term, we laid out the learning outcomes that would be expected for students entering the next course in the series (fluid mechanics) and for chemical engineers in the workplace (Figure 6.1). I then went through all of the existing homework assignments for the course and looked for how these learning outcomes intersected with the problems that were posed (Figure 6.2).

Learning Outcomes

Problem-Solving Skills

- Approximation: Apply appropriate approximations to make quick estimates
- Assumptions: Specify assumptions that make problems solvable, while still applicable
- Reasoning: Explain problem solutions using physical and mathematical reasoning
- Reality Check: Assess reasonableness and accuracy of answers

Problem-Solving Toolkit

- Dimensional Analysis: Assess the relative importance of different phenomena based on different values of a dimensionless group
- Differential Equations: Solve ordinary and partial differential equations for scalar dependent variables, using techniques like separation of variables and Fourier analysis to address partial differential equations
- Boundary Conditions: Identify and justify appropriate boundary conditions for physical situations
- Methods of Solution: Implement analytical, numerical, and computational methods to solve governing equations

Transport Phenomena

- Conservation Principles: Use conservation principles to derive governing rate equations, using techniques such as shell and macroscopic balances
- Macroscopic Applications: Apply conservation principles to broad-scale situations, like the Earth's atmosphere, where microscopic details are either unknown or more complex than the desired model requires
- Microscopic Applications: Apply conservation principles to small-scale situations, where microscopic details about the system are desired, including positional information
- Constitutive Equations: Relate fluxes to driving forces for transport through constitutive equations

Heat Transfer

- Conduction: Apply Fourier's "Law" and solve 1D and 2D conduction problems in solid and fluid materials with a variety of sources and sinks of energy
- Convection: Apply Newton's "Law" of Cooling with appropriate heat transfer coefficient correlations to convection problems
- Radiation: Identify roles of absorptivity, emissivity, reflectivity, and view factors in radiative heat transfer problems
- Multimode: Solve problems in which conduction, convection, and/or radiation coexist and "compete" and assess the relative importance of different routes of heat transfer

Figure 6.1: Example of syllabus learning outcomes for a heat transfer course.

1. **Atomic Bomb Energy** *(15 points)*
Learning Outcomes:

- Apply dimensional analysis to find dimensionless groups
- Estimate values of dimensionless groups from data

Scientists took high-speed photographs of an atomic bomb blast during a test in 1945 at Alamagordo, NM. After the war, these high-quality photographs appeared in a 1947 issue of *Life Magazine*. The U.S. military worked hard to protect the secrets of the bomb program for many years, and they unknowingly gave away vital information. British and Soviet scientists estimated the energy of the test bomb using only these *Life Magazine* pictures and some knowledge of the physics of explosions and shockwaves.

You'll use dimensional analysis to uncover this secret, too. And you'll only need ***one*** of the published pictures. Assume a total amount of energy, *E*, dumps into an infinitesimal volume very rapidly. Furthermore, assume the resulting spherical shockwave with radius, *r(t)*, expands into the surrounding undisturbed air with density, ρ.

(a) Since there are four variables and three different units of measurement, a single dimensionless number adequately represents the physics. Since there is only one dimensionless number, it remains constant during the expansion of the shockwave. Identify this dimensionless number—not by name, but by the ratio of constants and variables. Show how you arrived at your result and check whether the final result is dimensionless. *(8 points)*
(b) Even though you'll assume that the constant is unity for part (c), describe at least one simple model experiment to estimate the actual value of this constant. *(2 points)*
(c) Use the figure to estimate the value of energy. Assume the value of the dimensionless group from (a) is 1. (Express your answer in T with one significant digit, where T is tons of TNT and 1 T ≈ 4.2×10^9 Joules.) *(5 points)*

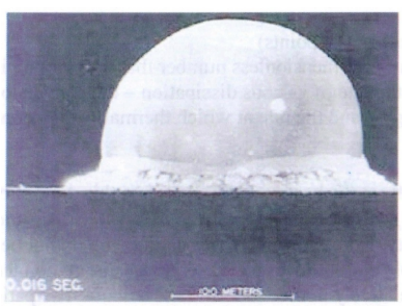

Figure 1.1: Shockwave from the Trinity atomic bomb test. The image shows a hemispherical shockwave. The time stamp on the photo is 0.016 sec. A scale bar indicates a distance of 100 meters. The shockwave is approximately 2.1 times the scale bar in width and 1.3 times the scale bar in height. Source: Taylor, G. The formation of a blast wave by a very intense explosion. II. The atomic explosion of 1945. *Proc. R. Soc. Lond. Ser. Math. Phys. Sci.* 175–186 (1950).

Figure 6.2: Example of highlighting the learning outcomes in an existing assignment.

The result had a two-fold benefit—we eliminated or adjusted homework problems that did not contribute to students achieving learning outcomes, and students were able to connect the practice they did on the homework to the overall goals of the course. Fundamentally, however, this restructuring was not true backwards design—much of the course stayed the same and did not incorporate the learning outcomes as the driving principle.

In designing and teaching a survey course on viscoelasticity for undergraduate students, I was able to incorporate backwards design from the beginning of the course (Figure 6.3). Each learning outcome met three criteria: 1) it was accomplishable with only three hours of total class content a week, 2) it was specific enough to allow for assessment, and 3) it would not require that the students have prior knowledge of topics in fluid mechanics or materials science (because the course had no prequisites and participation crossed many majors).

The learning outcomes in the syllabus then translated into learning outcomes for individual assignments (Figure 6.4). These assignments acted as both the practice and the assessment of working toward learning outcome (formative assessment).

During the term, assignments and class activities structured around the learning outcomes were generally successful: assessment of student learning outcomes demonstrated that students were practicing the desired skills. In contrast, class sessions in which I did not follow backward design were not as successful. For example, my lecture on normal stresses in viscoelastic flows, an important concept in understanding behaviors such as rod-climbing in bread dough, stood out to me as a failure to design towards learning outcomes. As the instructor, I had instead imposed my preconception that the mathematics of normal stresses was essential. I failed to paln for students unfamiliar

Reading Abstracts (Discussion Forum Post)
Due: Sunday, April 8th, 11:59 pm

Learning Outcome:
Students will be able to discuss and assess literature in the field of viscoelasticity.

Task:
Read the abstract provided. Following the guidelines from class (repeated below as a Reminder) on how to break down abstracts, make a post in the Week 1 Forum answering the following (label which part is which!):

1. What is/are the main conclusion(s) you saw in the abstract?
2. What key terms might you need to look up to read this paper? (List the terms, you don't have to look them up for this post.)
3. Why would someone in the field of viscoelasticity care about the results presented in this paper?

Reminder

Suggested steps for breaking down abstracts:

1. Look for keywords in the title.
2. Search for main ideas of abstract.
    a. Motivation: Why would someone care about the results presented in this paper?
    b. Main conclusion(s): What are the 1–2 most important things concluded in this abstract?
3. Make a list of key terms you might need to look up before you could read the paper.
4. Questions to ask yourself (not required for this post):
    a. What evidence would I need to see to believe the conclusion(s)?
        i. If you have prior knowledge, sketch what you might expect a figure with that evidence to look like.
    b. What could I do with the conclusions?

Figure 6.3: Example of syllabus learning outcomes for a course on viscoelasticity.

with tensor math, including most of my target audience—first- and second-year non-engineering students. As soon as I gave the lecture, I observed that students left class confused, without developing a deeper understanding of viscoelastic materials. Class sessions that included group discussion of abstract concepts and hands-on labs designed to address specific learning outcomes had greater positive impact on student learning.

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    a. Motivation: Why would someone care about the results presented in this paper?
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3. Make a list of key terms you might need to look up before you could read the paper
4. Questions to ask yourself (not required for this post)
    a. What evidence would I need to see to believe the conclusion(s)?
        i. If you have prior knowledge, sketch what you might expect a figure with that evidence to look like
    b. What could I do with the conclusions?

Figure 6.4: Example of structuring an assignment to address a single learning outcome for a course using backwards design.

Next Steps

Taking the lessons from both restructuring the heat transfer course assignments and building the viscoelasticity course from the ground up, my next steps in teaching a course would be to apply backwards design not just to assignments and activities, but to each individual class period. Evaluating content through the lens of backward design assists in allocating instruction time to the most valuable activities—those that will give students the most insight.

As discussed below in Scaffolding and Transparent Teaching, clear discussion of desired outcomes from course elements also helps students structure their learning time and meet expectations, resulting in a course where diverse students can more readily thrive.

6.3 Scaffolding

Technique and Motivation

Scaffolding is explicit structure in coursework that walks students through the steps needed to complete the tasks requested.[10] In a project setting, it can look like outlining each deliverable and what incremental stages those deliverables need to go through to become final products. In a homework assignment setting, it could include explicitly asking students to setup the problem before solving it, to uncorporate specific details in their solutions, and to analyze if a result seems reasonable.

Scaffolding helps students build metacognition and self-regulation skills—i.e., learning how to learn and how to manage their time while learning.[10] By structuring course assignments with each step intentionally laid out, students can look at the whole assignment and start to make better predictions of how long it will take them, where they can anticipate that they will need to ask questions, and how to schedule out their work time to complete the assignment. In assignments or projects that take place over a longer period, scaffolding gives structured check-in points via intermediate work due prior to the final deadline. These check-ins are additional opportunities for feedback, where students who are confused or lost can get help sooner, and where instructors can intervene if a student is overwhelmed or missing deadlines, instead of at the end of a term where intervention may be too late.

Implementation

In the viscoelasticity survey course, I used writing a paragraph for a *Wikipedia* article relevant to the course material as a term-long project (Figure 6.5). The project began with a brainstorming step, and progressed through outlining, drafting, peer feedback, and revising before the students turned in the final results. The intention of scaffolding the project and deliminating so many incremental stages was to prevent student procrastination from interferring with their ability to give worthwhile feedback before the final due date and to make the project feel meaningful over the course of the term, rather than a rushed project at the end.

Final Project
Due dates throughout the quarter

For the final project for this course, you will write or extend a short *Wikipedia* article on a topic not already well-covered on *Wikipedia*. For this project, expect to find at least 1–2 relevant literature papers as sources and/or accompanying material.

Learning Outcomes:
Students will be able to:

- Differentiate between solid, liquid, and viscoelastic material properties.
- Discuss literature in the field of viscoelasticity.
- Explain the physical behavior corresponding to models of viscoelasticity.
- Hypothesize qualitative behavior of viscoelastic materials.

General Timeline:

- Week 3: Submit list of 2–3 possible topics
- Week 5: Choose topic
- Week 6: *Wikipedia* Course
- Week 6–7: Outline
- Week 8: Draft for peer feedback
- Finals: Final version due

Task:
Through this project, you will contribute approximately 1–2 paragraphs of material towards *Wikipedia* article(s). The goal is to have well-cited text that is accurate in a technical sense, while still accessible to people outside the field of viscoelasticity.

You can either choose a single topic and contribute 1–2 paragraphs of material or add citations and clarify material across multiple articles totaling 1–2 paragraphs.

Grading:
The final project is worth 40% of your grade in total, and is graded out of 100 points total. See the Week-by-Week breakdown for value of individual parts.

Submission:
All portions of this project will be submitted through Moodle. If you would like to, you may make a *Wikipedia* account of your own and submit your modifications to the article(s) you have worked on throughout this project. Editing *Wikipedia* with your final version of the articles is encouraged but not required as a part of this course.

(a) Overall structure of the final project.

Week-by-Week Breakdown

Week 3
Task: Look at *Wikipedia* and come up with at least 2–3 topics that you think would be suitable to write a short article for or add material and sources to
Expected Outputs:
Submit a document containing the following to Moodle:

- List of at least 2–3 topics (and any corresponding *Wikipedia* links)

Due Date: Wednesday, April 25th, 2:00 pm
Grading: Completion—worth 10 points (4% of final grade)

Suggestions for finding suitable topics:

- Start from the articles on viscoelasticity, rheology, or the names of any topics on the syllabus. Look for short or unclear articles, articles with warnings that they need better citations or clarifications, or non-existent articles (usually in red on a page, or not found through a search).
- Look up viscoelastic materials discussed in class or elsewhere and see if they have a section on their viscoelasticity. If the section is nonexistent, confusing, and/or inaccurate, it will likely be a suitable topic.
- If your research field/other interests include topics related to viscoelasticity, try looking up those topics and see if articles exist and contain relevant information on viscoelasticity.
- Talk to Red for suggestions of topics if you aren't finding topics that you think would work.

Week 5
Task: Look at feedback on topics and choose which topic(s) you want to pursue.
Expected Output:
Submit the following to Moodle:

- Topic(s) chosen
- Original versions of article(s) for each topic chosen (pdfs or copy-pasted text)

Due Date: Wednesday, May 9th, 2:00 pm
Grading: Completion—worth 10 points (4% of final grade)

Week 6
Task: Complete course on how to write for *Wikipedia* for students (~1 hour).
https://en.wikipedia.org/wiki/Wikipedia:Training/For_students
Expected Output:

- Submit a screenshot of confirmation of completion on Moodle (note: you are not required to make a *Wikipedia* account—you can instead screencap the last page of the training)

Due Date: Wednesday, May 16th, 2:00 pm
Grading: Completion—worth 10 points (4% of final grade)

(b) Week-by-week breakdown (part 1).

Week 6–7
Task: Outline your writing on your topic(s). Look up literature articles you want to use (note: *Wikipedia* prefers secondary sources, like review articles, instead of primary sources) and prepare citations.
Expected Output:
Submit the following to Moodle:

- Outline of what information you plan on incorporating into the article(s) (does not have to have finalized language).
- Citations/Source documents for information.
- Any questions you have about what you are writing about, how to write the sections, or what sources to use.

Due Date: Wednesday, May 23rd, 2:00 pm
Grading: Rubric provided during Week 6, worth 10 points (4% of final grade)
*Points lost in this phase can be earned back in the Draft phase

Week 8
Task: Draft your contributions to the *Wikipedia* article(s) you chose with citations. Include any surrounding text necessary for clarity and indicate what text is yours. Print out at least 4 copies for peer feedback in class (or email Red your draft by midnight on Tuesday to have Red print them out).
Expected Output:
Bring to class:

- Draft of contributions with citations, along with surrounding text (if applicable).
- Something with which to take notes on peer feedback.

Due Date: Wednesday, May 30th, 11:00 am ****Note that the draft needs to be ready for class and you will need to print copies/email Red your draft beforehand.
Grading: Rubric provided during Week 7, worth 20 points (8% of final grade)
*Points lost in this phase can be earned back in the Final Version phase

Week 9-Finals
Task: Using your draft and any peer/instructor feedback, revise your contributions to the *Wikipedia* article and submit a final version. If you have a revised draft you would like feedback on before submitting, email Red at least 48 hours prior to the final deadline.
Expected Outputs:
Submit the following on Moodle:

- New version of article(s)/article section(s) with and without your changes indicated on the document.
- 1–2 sentences on how you incorporated feedback.

Due Date: Wednesday, June 13th, 11:59 pm
Grading: Rubric provided during Week 7, worth 40 points (16% of final grade)

(c) Week-by-week breakdown (part 2).

Figure 6.5: Example of scaffolding a final project over the course of a term.

Throughout the project, students were able to respond to feedback at each stage and adjust their work accordingly. Students who wanted to go above and beyond had the opportunity to invest more time (one student prepared an entire article, rather than one paragraph); students new to the field and less experienced in writing got support at multiple stages in finding good resources and writing well. As an instructor, I practiced laying out the tasks clearly and setting up reasonable expectations that the students could meet during the allotted class hours, but still facilitated them progressing towards learning outcomes.

Even in more advanced courses, students may not structure their time well or feel comfortable asking for feedback early. I attempted to support students who did not fully understand the expectations for a final presentation in a graduate-level polymer physics course, by adding an additional step that enabled me, as a teaching assistant, to identify and help students who were unsure how to craft a presentation. The additional step of creating a single summary slide that outlined their presentation (Figure 6.6) was particularly relevant to the undergraduate and first-year graduate students in the polymer physics course, who did not have much practice in giving technical talks to a professorial audience.

Next Steps

Based on my experiences with scaffolding final projects for students, I plan to implement scaffolding as early as the first homework assignments, particularly in introductory courses with many first-year undergraduate students who need the most structure as they learn how to learn in a college setting. In courses where presentations are the final product, I would use in-class practice mini-presentations at multiple points over a term to identify where students need the

Summary Slide Guidelines

The talk will primarily be composed of 4 sections:

- Background/Motivation
- Problem Framing
- Approach
- Expected Results

The summary slide (due May 28th) should contain the biggest feature of each part (4 quadrants each with an image and/or minimal text is one way to make the slide).

The objectives of this assignment are:

- Solidify your idea(s) of what will go in each section
- Make a summary slide that can be used at the beginning and/or end of your talk
- Provide an opportunity for the TA to give feedback on all major sections of your presentation prior to the final presentation

Make sure you include your references!

Figure 6.6: Example of scaffolding a presentation.

most support in their presentation skills. In future writing projects, I would coordinate with campus resources like the writing center to connect students with expertise outside my domain and to build in additional feedback as a part of the intermediate stages.

6.4 Transparent Teaching

Technique and Motivation

In many STEM classrooms, assignments and exams are structured as a series problem statements in which students are asked to find some unknown quantity given some known information about a situation. The value of finding each solution is often assumed to be obvious—the students will practice a concept directly related to the problem, whether it be a problem-solving approach or incorporating information they have learned through the class. For a student new to a field and not aware of how to organize the information they are receiving or how to prioritize their time spent learning, the implicit aspects of these questions can inhibit their ability to effectively use the problem presented as a learning tool. The concept of transparent teaching seeks to make the implicit expectations and purpose of assignments clear and available to students through explicit discussion of both the motivation of the questions being asked and the grading criteria that will be used to evaluate their work.[3,11]

Making an assignment "transparent" consists of including three components: a specific purpose (tied to the learning outcomes of the course and how it is useful for students in the long-term), a clear outline of tasks (to make explicit what is expected of students), and criteria for evaluation (including examples of critiqued work demonstrating what would be considered excellent). As discussed in Backwards Design, focusing work expected of students on learning outcomes helps instructors ensure that each question contributes to the goals of the course and assists students in seeing the importance of the work in the context of the course, the larger trajectory through the curiculum, and their future life and career. The outline of the tasks expected can be tailored to the level of scaffolding that fits the students and the course, while still stating what is to be done and how to go about it (including what can seem like simple instructions such as "solve this equation by hand" or "include units at all intermediate steps," but might not be assumed by students). Criteria with examples allow students to develop self-assessment skills where they can start to predict how they are doing on a particular problem before they turn it in. Students can then ask for help sooner to address gaps in knowledge or approach. Outlining criteria prior to handing out an assignment also challenges instructors to clearly articulate what they are looking for, which is one way to combat unconscious bias in evaluation.[12]

Transparent teaching improves the experiences of all students, with additional gains for students from minoritized groups.[13] In a large-scale study of 1,800 students across seven institutions, students in courses with two transparently-designed replacement assignments demonstrated gains in belonging, confidence, and job-relevant skills compared to students who experienced traditional homework assignments. In particular, underserved students (underrepresented racial and ethnic identity, low-income, and/or first-generation) showed even larger benefits than their majority peers. Students responded positively to knowing the assignment's purpose and relationship to the course as a whole, and understood what they should do and how they would be evaluated.[3,11,13]

Implementation

As a teaching assistant for the heat transfer course, I included both the learning outcomes and a set of expectations for elements of a problem solution on every homework set (Figure 6.7). By doing so, students knew before they turned in the first assignment what graders would be looking for as a baseline, instead of finding out when the graded assignments were returned to them (usually upon turning in set 2) what our expectations were. In addition, the learning outcomes could direct them to useful reading if they found gaps in their understanding during the assignment.

On the graders' side, I developed rubrics for point-by-point breakdown of many of the problems assigned; however, these granular criteria were not shared with students until after grading was completed, failing to be as transparent as would be desired.

In structuring the final project for the viscoelasticity course, I incorporated transparent teaching practices at each stage of the writing process (Figure 6.8). Each section of the project sets out the task to be accomplished, what I expected the student to take action on, and the rubric (grading criteria)

ChE103a: Heat Transfer
Problem Set # 1: Dimensional Analysis; Fourier's "Law" of Conduction
Due: **Monday, 02 Oct 2017 in class**

Completing this set is practice for:

I. Dimensionless Groups
   Suggested Reading: See Folder on Moodle—<u>Short Version of Dimensional Analysis Tutorial</u> [DAT] highly recommended, others optional
   a. Applying dimensional analysis to find dimensionless groups
   b. Estimating values of dimensionless groups from data
   c. Scaling a given equation to find an appropriate dimensionless group
   d. Judging the relative importance of different phenomena in a situation based on different values of a dimensionless group

II. Conduction
   Suggested Reading: <u>BSL 9.1</u>
   a. Defining thermal conductivity (in symbols and words)
   b. Estimating thermal conductivity from data
   c. Evaluating qualitatively the relative flux and temperature drops in different materials based on thermal properties
   d. Finding temperature profiles using Fourier's "Law" of Conduction

Expectations for each problem:

- Restate the problem
  - Write down any given information
  - Sketch a picture or diagram
  - Label/define all variables/symbols used
- State your assumptions
- Clearly write out your solution
  - Include helpful notes about your steps, especially if you tried multiple tactics to a problem or if you made new assumptions during a problem
  - Usually more than just equations is needed—show the flow between different steps and explain why
- Evaluate whether your answer is reasonable
  - If numerical, is the order of magnitude in the right range?
  - If numerical, how many significant digits? (How precise is your answer?)
  - If symbolic, does the dependence on the different variables make sense?
  - If numerical or symbolic, what are the units/dimensions? (Is it a length with units of meter/second? If so, something has gone wrong.)
- Cite your sources (if sources outside of the problem set are used)
- Unless otherwise stated, software packages such as Mathematica should only be used to CHECK your work, and should not replace your own solution to a problem

Figure 6.7: Example of outlining expectations.

for that section, and the project as a whole was motivated using the course learning outcomes (Figure 6.5).

Final Project Draft
Due Wednesday, May 30th, 2018, 11:00 am

Task: Draft your contributions to the Wikipedia article(s) you chose with citations. Include any surrounding text necessary for clarity and indicate what text is yours. Print out at least 4 copies for peer feedback in class (or email Red your draft by midnight on Tuesday to have Red print out).
Expected Output:
Bring to class:
- Draft of contributions with citations, along with surrounding text (if applicable)
- Something with which to take notes on peer feedback

Due Date: Wednesday, May 30th, 11:00 am ****Note that the draft needs to be ready for class and you will need to print copies/email Red your draft beforehand.
Grading: Worth 20 points (8% of final grade)
*Points lost in this phase can be earned back in the Final Version phase

Content:
You are expected to compose your full contributions to the Wikipedia article(s). It needs to be written clearly enough that I can understand it and be accurate according to your sources.

Language:
Your contributions should be written in such a way that they could be submitted to their Wikipedia article. My expectations are:
- Tone is formal (think an encyclopedia, not a journal article, or look at good Wikipedia articles)
- Minimize jargon and overly technical language
- Is your contribution understandable to a layperson in the context of the whole article?

See https://en.wikipedia.org/wiki/Wikipedia:Writing_better_articles if you need more guidelines

Sources/Citations:
Sources should be appropriate for Wikipedia—secondary sources like review articles or textbooks and properly cited (see https://en.wikipedia.org/wiki/Wikipedia:Tutorial/Citing_sources for how to format the citations). These sources may be the same sources from the outline stage if they were accepted at that stage.

Address Feedback:
Address all feedback from the outline stage by either implementing suggestions or by providing (sufficient) justification for why your contribution will be better/more accurate/clearer/etc. by not implementing the feedback (please do challenge my suggestions if they don't work for you). This part is where you earn back points from the Outline stage. Please indicate what changes you made in response to feedback.

(a) Transparent teaching structured assignment

Rubric: Intermediate points can be earned for intermediate work and points lost can be earned back by addressing issues when submitting Final Version

	Excellent (full points)	Acceptable (half points)	Missing (no points)
Content (Max 5 points)	Enough content is present to fill 1-2 paragraphs of material). Information is accurate and clear	Enough content is present to fill 1-2 paragraphs, but information is inaccurate and/or unclear OR information present is not enough to compose final article	No content present
Language (Max 6 points)	Article content is primarily written in Wikipedia-appropriate style/language	Article content is partially written in Wikipedia-appropriate style/language	Draft is exclusively in jargon
Sources (Max 2 points)	Appropriate source(s) present (1-2 at least, from secondary source) and cited using Wikipedia's citation tools	Appropriate source present but not cited, or citation present for an inappropriate source	No sources present
Address Issues (Max 5 points plus additional points lost at Outline)	Addresses all feedback from outline stage, either by modifying the work or providing sufficient justification	Addresses some feedback from outline stage	Did not address feedback from outline
Peer Feedback (Max 2 points, earned in class)	Participated in giving peer feedback	Was present, but not engaged in giving feedback to peers	Did not give feedback to peers

(b) Example of a grading rubric available to students

Figure 6.8: Example of transparent assignment

As an instructor, I noticed that grading using a rubric improved my consistency between students and removed moments of doubt as to whether I was giving the student the grade they deserved. Additionally, students met my expectations more consistently, particularly when revising for later versions, as they knew what I would be looking for.

Transparent teaching is beneficial to instructors as well as to students. As a part of preparing class materials for hand off to the next teaching assistant for a polymer physics course, I wrote up a set of suggestions for giving feedback to students, as I also struggled with knowing how to guide them in the project. Having explicit criteria to check for can prompt efficient time spent giving feedback and prevents loss of institutional memory during gaps in the teaching of the course.

Next Steps

In transparent teaching, an important component in addition to clear grading criteria is examples of critiqued student work. As a new instructor, I did not have examples of past student work to use in my viscoelasticity course. Going forward, a goal each time teaching a course would be to collect useful student example work that exemplifies the overall expectations, but still has room to be critiqued using the rubric. In science courses with problem sets, this process can be difficult because of reuse of problems from year to year in order for assignment quality to benefit from iterating. Responses to practice or past year exam problems may be a route to collecting good examples while not compromising students' abilities to use problems as a way to evaluate their own learning. In projects or presentations where the topics are chosen by the students, a prior year's work can be used for demonstrations without interfering with assessing student responses to new problems.

Summary Slide Feedback Guidelines
The summary slide is the last chance for formal feedback before the final presentation. Students who did not have much at this stage did not do as well in their presentations.
For each section, look for the following:

- Background/Motivation:
  - Cartoons/figures that relay the main concepts
  - Setup for why the topic is of current interest
  - Polymer focus (versus biological, colloid, etc.)
- Problem framing:
  - Clear and specific question(s) to address
  - Convincing reason why the problem is important and relevant
  - An answer for what is missing/insufficient in the literature
- Approach:
  - A feasible and clear plan of approaching the problem
  - Something substantially new/original
    - Avoid “just simulate it” (If they are proposing a simulation, what new elements compared to the literature would they be introducing?)
    - Going at least one step beyond their sources or taking a very different tactic to the literature
  - Theoretical tactic (not only experimental, but experiments can be a supplement)
  - Reasonable set of parameters and explanations for why they are included (and not others)
- Expected Results
  - Qualitative behavior changes (regimes of behavior based on parameters in the problem for example)
    - Sketching comparison curves is one good way to look at it
    - If they have taken issue with a quantitative flaw in the literature, their expected results will need to be more quantitative in nature
  - Specificity in expectations (vague descriptions are easy to tear apart/question, more specific predictions help give the approach weight and help students avoid pitfalls around over-claiming)
  - Avoiding “too expected” of expected results (i.e., “this will behave just like another system”—why do we want to do the approach if the results are exactly the same as the other one?)
  - Comparison to literature results (experimental and theoretical ideally)

Students are not likely to be able to fit all of these parts on the summary slide, but you’ll want to prompt the other parts in your feedback.

Emphasize to students that they don’t actually have to solve the problem (by simulation or fully solving the theory).

Figure 6.9: Example of transparency for a teaching assistant for giving feedback to students.

6.5 Peer Interaction

Technique and Motivation

In a traditional classroom experience, an instructor primarily lectures, with occasional pauses for students to ask questions and calling on students to respond to instructor questions. The interaction is primarily between a single student and the instructor, although student questions and responses benefit the whole classroom. In alternate models of classroom engagement, students can be asked to interact directly with each other as well as with the instructor. Three possible implementations of interactive teaching are discussed below: think-pair-share, teamwork, and peer review.

Implementation

Think-Pair-Share (TPS) is a documented and researched model of peer-based interactive teaching, in which students are given a question to think about their response to (Think), then asked to discuss their thoughts with a neighbor or small group (Pair), and students have an opportunity to convey their group responses (Share). TPS has been shown to increase engagement and confidence of students who may not otherwise feel comfortable with speaking in class due to a variety of reasons, such as personality, perceived ability, or previously experienced microaggressions, although the share step must still be carefully tailored to the classroom environment.[14–16]

In recitation sections as a teaching assistant for heat transfer, I used TPS as a tool for assessing where students were confused about the material. During lectures, students often did not speak up about where they did not understand the approach to solving the problems. In recitation, posing smaller problems and floating between groups to listen to the discussion often told me much more about what had been missed during class time. The peer teaching that occurred between students also helped address gaps in learning that would be difficult to identify until after an assignment was turned in.

Teamwork between students can also act as a way to facilitate peer teaching. For low-stakes, in-class activities, students working together to brainstorm and solve problems can act as an extended TPS. In the viscoelasticity course, students worked in pairs on in-class labs, designing their own procedures to assess materials (Figure 6.10). In addition to completing the required analysis, students brought up their own experiences and independent research, which enhanced the discussion with their peer and supplemented the required pre-lab reading.

As a part of the on-going final project for the viscoelasticity course, I also set up a structured peer review session in which students read each other's work and gave constructive feedback (Figure 6.11). By directing students to consider different aspects of their peers' work, we collectively worked to avoid some pitfalls common to mentoring and feedback.[17] Students were able to hear a mixture of positive, critical, and neutral thoughts from their peers, and then make choices about what they wanted to implement, and justify their choice if they decided to not implement a piece of feedback.

Next Steps

As learned throughout teaching the viscoelasticity course, I seek to teach in a mode dominated peer work, either through TPS, in-class activities, or models like flipped classroom (where lectures are pre-recorded and students work on homework problems in class). Brief periods of in-class lecture can be used to recap topics, frame discussions, address common misconceptions, and wrap-up key points to remember, which keeps them short enough for students to pay attention to and primarily utilizes class time to be interactive.

Ice-Cold Silly Putty (Lab 2)
Due Dates: Hypothesis due May 9th, 2018, 11:00 am
Write-up due May 16th, 2018, 2:00 pm

Learning Outcome:
Students will be able to hypothesize qualitative behavior of viscoelastic materials, then perform experiments to test those hypotheses.

Task:
In this lab, you will manipulate the temperature of silly putty to demonstrate how viscoelastic properties change with temperature.

Expected Outputs:
You should prepare a document (or documents) with the following and submit it to the assignment on Moodle by the due dates and time.

- Hypothesis [Due before the lab, see Moodle] (10%)
- Observations [Scan/readable photo of handwritten copy or typed] (50%)
- Answers to Questions (10% each)

In addition, participation in the lab will be part of your participation grade.

Introduction:
Time-temperature superposition is the concept that the time scale of perturbation and the temperature of a sample of viscoelastic material contribute to the measured properties in a coupled way. Raising the temperature of a sample decreases the relaxation time, while decreasing the temperature increases the relaxation time, allowing experiments to be conducted over a range of effective time scales for the sample, even if your equipment is limited in the range of time scales it can perform experiments over.

Collaboration and Participation:
Please formulate your hypotheses on your own—they are graded on completion, not accuracy. (See the Moodle)
You will be expected to work together in teams for this lab for collecting observations. You are encouraged to work together on recording observations and evaluating your hypotheses. Please submit your own answers to the questions, though you may discuss the answers with each other.
Participation in the lab itself will be part of your participation grade. Please let Red know ASAP if you will be absent so that they can organize a make-up session.

Figure 6.10: Example of collaboration and participation instructions.

Peer Feedback Prompts

You will have 4 mini-meetings over the course of the class, 1 for each prompt. With each new person, read the prompt and spend a few minutes reading their contribution(s). Then, each take a turn talking about the prompt for the other's contribution, while the author records notes about their contribution under the prompt on their sheet.

1. Look at the content of the contribution(s). Does the content make sense? Are there any spots you are confused or unsure? What parts seem ambiguous, if any?

2. Look at the language in the contribution(s). Evaluate how accessible the article is you and how accessible the article is to a layperson. Look for: jargon, highly technical sentences, or required field-specific knowledge.

3. Look at the context of the contribution(s). Does it make sense in context, either as part of an article or as a new article?

4. Look at the contribution(s). What is the strongest part? What is the weakest part? Ask the author what sections they are worried about.

Figure 6.11: Example of peer review instructions.

6.6 Striving Toward Inclusive Classrooms

My driving motivation in implementing each of these techniques is to be a better teacher and include all of my students in my instruction. I try to accomplish these core goals by iterating and learning. No two groups of students are identical—as the world around us changes, so too do our students and so can our teaching. Adopting evidence-based teaching practices into our classrooms can help us better serve students with diverse backgrounds and identities, while overall raising the bar for instruction and learning.

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