Board 34: Work in Progress: Simple, Scalable Interventions to Address Academic and Mental-Health Barriers in Engineering Undergraduates

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Abstract

The 2021 return to face-to-face teaching and proctored exams revealed significant gaps in student learning during remote instruction. The challenge of supporting underperforming students is not expected to abate in the next 5-10 years as COVID-19-related learning losses compound structural inequalities in K-12 education. More recently, anecdotal evidence across courses shows declines in classroom attendance and student engagement. Lack of engagement indicates emotional barriers rather than intellectual deficiencies, and its growth coincides with the ongoing mental health epidemic. Regardless of the underlying reasons, professors are now faced with the unappealing choice of awarding failing grades to an uncomfortably large fraction of classes or awarding passing grades to students who do not meet learning objectives and seem ill-prepared for the workforce or adult life in general. Faculty training, if it exists, addresses neither the scale of this situation nor the emotional/identity aspects of the problem. There is an urgent need for pedagogical remediation tools that can be applied without additional TA or staff resources, without training in psychiatry, and with only five or eight weeks remaining in the semester.

This work presents two work-in-progress interventions for engineering faculty who face the challenges described above. In the first intervention, students can improve their exam scores by submitting videos of reworked exams. The requirement of voiceover forces students to understand the thought process behind problems, even if they have copied the answers from a friend. Incorporating peer review into the assignment reduces the workload for instructor grading. This intervention has been successfully implemented in sophomore- and senior-level courses with positive feedback from faculty and students. In the second intervention, students who fail the midterm are offered an automatic passing exam grade (typically 51%) in exchange for submitting a knowledge inventory and remediation plan. Students create a glossary of terms and concepts from the class and rank them by their level of understanding. Recent iterations of the remediation plan also include reflections on emotions and support networks.

In February 2023, the project team will scale the interventions to freshman-level Introductory Programming, which has 400 students and the college's highest fail/withdrawal rate. The large sample size will enable more robust statistics to correlate exam scores, intervention rubric items, and surveys on assignment effectiveness. Piloting interventions in various environments and classes will establish best pedagogical practices that minimize instructors' workload and decision fatigue. The ultimate goal of this project is to benefit students and faculty through well-defined and systematic interventions across the curriculum.

Introduction

Academic under-preparedness and student mental health are growing concerns for engineering faculty and staff [1]. Continued fallout from the COVID-19 pandemic has exacerbated previous trends [2], [3]. As an illustrative example, Figure 1 shows midterm distributions from sophomore-level thermodynamics and senior-level controls classes in Summer and Fall of 2021

(both hybrid synchronous). A third of the class scored over 85%, demonstrating that students had been taught the technical content and that the exam was of reasonable difficulty and length. However, an abnormally high fraction of the class scored in D-F range, considering the typical pass/fail cutoff of 50%. Neither a course failure rate nor a course passing cutoff of 20% felt acceptable to the authors.

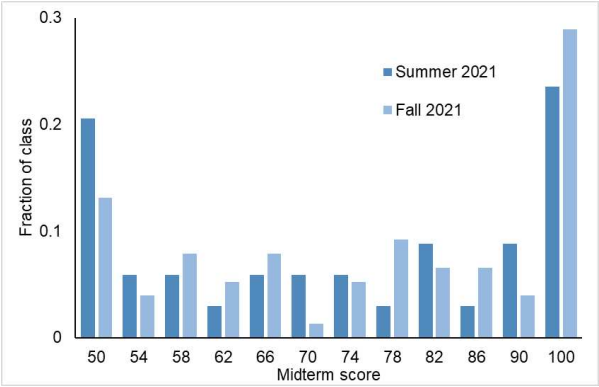

Figure 1: Midterm scores immediately after return from online teaching.

Remedial work is a commonly accepted solution for struggling students to improve their grades. However, simply asking students to submit exam corrections or to complete alternative problems is vulnerable to academic dishonesty, which violates ethical codes and diminishes effectiveness. On the other extreme, individually coaching students is not feasible for most faculty. Similarly, alternative grading schemes or replacing traditional exams with mixed assessment methods rarely makes sense mid-semester.

Remediation tools employed by busy faculty must be a) simple to use, b) require minimal extra grading burden or face-to-face meeting time, and c) compatible with the typical exam-based infrastructure that already exists in most courses. This work-in-progress aims to develop tools that maximize student impact while meeting these constraints. We seek feedback on the two interventions described below.

Intervention #1: student-generated screencasts.

Faculty frequently assign students to watch supplemental or remedial videos [4]. The creation of student-generated screencasts is less common, but previous work has found them effective[5]–[7]. The benefits of creating screencasts are intuitive. Synthesis is a higher level on Bloom's taxonomy of learning than application or comprehension. Creating content also requires more time and effort than consuming content. Over the past 18 months, we have completed several iterations of this intervention (Table 1). A sample student assignment is provided in Appendix A. Downloadable assignments can be found at https://engineeringunleashed.com/card/3524 .

Table 1: History of student-generated screencast intervention

Term	Course	Incentive	Eligibility	Assessment method	Participation
Summer 2021	Sophomore thermodynamics	Remedial; unspecified rounding advantage	All students	Professor	65% (22/34)
Fall 2021	Senior controls	Remedial; 8 points on midterm	Midterm <65	Professor	55% (11/20)

Fall 2022	Senior controls	Remedial; variable midterm points (Appendix A)	Midterm <98	Peer	27% (15/54)
Winter 2023	Freshman programming	Preventative; midterm review	Mandatory for all students	Peer	90% (372/414)
Winter 2023	Sophomore/ junior mass transfer	Preventative; midterm, final review	Mandatory for all students	Peer	96% (23/24) 79% (19/24)

Students generally responded positively to the remedial assignment. Most scanned (new) hand-written solutions and recorded audio while screen sharing a pdf on Zoom. A few students animated equations onto PowerPoint, recorded live equation-writing with tablets or filmed themselves writing on paper. Very few students appeared on camera. Generally, problems were completed and explained correctly and thoroughly. Complete exam solutions were not posted, but detailed rubrics were visible to all students. Students were also explicitly informed that they were allowed to collaborate on the videos. In a few cases, the student was asked to redo the video for conceptual errors, missed problems, or unacceptably long videos (> 30 minutes) with many false starts. No instances of academic dishonesty were identified. Several students even stated in the end-of-term course evaluations that they found the exercise helpful.

Discussion with faculty immediately identified that the greatest barrier to implementing screencast interventions is the time of grading. Watching 20 or more ten-minute videos for acceptable quality, even on fast-forward, is not feasible for most professors. We attempted to reduce grading burden in Fall 2022 by incorporating peer-review. Instead of submitting a video link to the professor, students were asked to post their link in the classroom discussion board and to leave constructive comments on two other videos. To avoid a scenario in which participation identified poor-performing students to their peers, a sliding-point scale was implemented to allow any student with a score <98% to participate (Appendix A). Opening the assignment eligibility also increased the level of understanding among student reviewers, making errors more likely to be flagged. The comments were all supportive and generally very thoughtful, such as the examples below (shared with student permission):

- *I definitely really liked the fact that you chose to solve the problems live - it helped understand your thought process for each step. Your explanations were really well explained and detailed. I also like how for question two, for example, you didn't just write the units, but you explained the meaning of Kp, the equation and how you got your final units.*
- *The explanation was very thorough and the exam solutions themselves were very neat and easy to follow. the only error I noticed was that in #5, your math for the limit is slightly wrong, as when s goes to 0, there is still the + 1 in each parenthesis, meaning the terms dont reduce to 0, but the K value instead. I believe there should be an s in the numerator, to properly reach a value of 0. Other than that, some minor issues with the volume of your voice, but good work.*

Despite our efforts to destigmatize the assignment, participation still decreased greatly in this term (Table 1). Informal exit interviews confirmed that some students feared advertising their

poor performance in peer review. Based on the quality of the videos, the positive feedback from students, and the potential stigma of public participation in remedial exercises, we decided to shift the assignment from remediation to prevention in Winter 2023.

For review, students were asked to select a problem that had already been submitted for homework or worked in class and assigned two other student screencasts to review. We hoped that incorporating screencasts as a mandatory midterm review instead of a remedial assignment would help students improve their understanding of conceptual gaps before the midterm and reduce exam /course failure rates. We found that in Mass Transfer, the participation rate in both the midterm screencast review and final exam screencast review exceeded participation in homework assignments, although participation in both decreased towards the end of the term. Informal interviews also revealed that more than half of students found the screencast exercise very helpful and/or motivating. On the other hand, students reported that reviewing peer screencasts was less beneficial. Peer review also added more timing constraints. We are actively working to develop a method that provides students with meaningful feedback without setting unrealistic expectations for instructors.

In Winter 2023, we also initiated a formal education research study in which the intervention was scaled up from discipline-specific courses to Freshman Programming, which enrolls approximately 400 students. IRB approval was obtained for this (exempt) study. The planned peer review rubric and end-of-term survey (Appendices B - C) will provide additional data to rigorously assess the effectiveness of the intervention and relate it to student demographics.

Intervention #2: reflective knowledge inventory and remediation plan.

Expert learners know that new skills are best built on existing knowledge, and that big problems should be broken into smaller tasks. Novice learners are more likely to feel overwhelmed and panicked, especially when they know they are underperforming. We attempted to design a remedial assignment (Appendix D, downloadable at https://engineeringunleashed.com/card/3524) that scaffolds students through the process of identifying technical strengths to build on and breaking weaknesses into manageable chunks. This intervention is currently in its third iteration (Table 2).

Table 2: History of reflective knowledge inventory intervention

Term	Course level	Incentive	Eligibility	Participation
Summer 2021	Sophomore thermodynamics	Remedial; midterm score of 51	Midterm score <50	86% (6/7)
Fall 2021	Senior controls	Remedial; midterm score of 51	Midterm score <50	60% (6/10)
Winter 2023	Junior mass transfer	Remedial; 8 points or midterm score of 66, whichever lower	Midterm score <65	28% (2/7)

Over three courses, 14 students submitted the remedial assignment. 2/14 subsequently dropped the class and 12/14 continued to pass the course. Of these students, 10/12 scored passing grades

on the final. The final exam grade was worth 40% of the term grade, such that a near-passing grade was necessary to pass the class. Although students could and did gain large increases in their midterm scores (e.g., from 23% to 51%), the midterm was weighted as only 25% of the course grade. Thus, the actual point increase on the midterm impacted students' final grades by half a letter grade at most (e.g., D → C- or C- → C). Even though the impact of the midterm grade on final term grades was relatively small, our initial effort to develop an intervention was motivated by the fear that students who struggled to obtain <50% on a midterm might well give up and quit. We hypothesized that taking action to improve a low midterm grade would encourage students to maintain hope and effort yet wanted to avoid simply awarding points without meaningful reflection.

Student submissions for the knowledge inventory intervention were less consistent than the screencast intervention. Some submissions gave detailed entries, such as the examples below (shared with permission):

- *I know how to solve steam table problems. This mean if I was given a specific enthalpy, temperature, pressure; I would be able to depict the properties given one of the other properties. I also understand that there is a formula given to find a certain property if it lies between two properties. E.g. between two temperatures and at a specific pressure; you would use the intupalation formula and also can input it through excel.*
- *Reversible and irreversible processes: I understand that there is a form of calculator for work reversible, and that there are more steps to the energy balance. But, I believe I don't really know how to approach these problems conceptually. I do understand that it follows the same format of mass balance, energy balance, and entropy balance, but more practice should help.*

Other students did not provide the level of detail above but simply listed terms from the course or provided re-worked problems from homework assignments. Because this type of assignment is so unfamiliar to students, the description in Appendix D was subsequently updated to include more detailed examples. The assignment was also modified with a list of suggested topics, which had already been posted before the midterm. Without this list, students spent time describing many irrelevant concepts from previous classes, or provided too few entries. With these improvements, students provided better detail, although there were exceptions. After submission, the instructor reviewed each student's submission for major conceptual errors and suggested one or two items from the students' list to prioritize. The time to review the reflective concept inventories was usually less than ten minutes per student.

Timing is an ongoing challenge for the reflective concept inventory. The lag from exam grading, extra credit assignment, and student submission of the remedial assignment typically takes more than a week and may allow students to fall even further behind while they wait for feedback. On the other hand, we are unaware of remedial interventions that do not face this limitation. Future offerings may experiment with posting the extra credit before exam grades have been returned. We also recognize a need to require students to redo vague submissions that do not actually reflect on their knowledge, such as *"I know how to apply Equation X"*.

Early responses also sometimes included personal details about work obligations, caretaking responsibilities, or (most frequently) inadequate study habits. After interviews with academic support staff, we recognized the incredible importance of these non-cognitive aspects and attempted to acknowledge them in Part 1 of the assignment. We should not ask faculty to serve as therapists or counselors. At the same time, we must acknowledge that students who score below the pass/fail cutoff on exams are frequently limited by something other than intellectual ability. Our goal is to encourage students to identify support networks, reflect on their barriers, and use the many support services available on campus.

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Appendix A: Screencast intervention, extra credit version (Fall 2022)

Appendix B: Screencast peer review rubric (Winter 2023)

Appendix C: Screen cast student survey (Winter 2023)

Appendix D: Knowledge inventory intervention (Winter 2023)

Appendix A, Extra Credit Screencast Assignment

If you scored:	You can increase
Below 50 (D grade cutoff)	By 10 points
Below 65 (C grade cutoff)	By 8 points or up to 65, whichever is lower
Below 80 (B grade cutoff)	By 5 points or up to 80, whichever is lower
Below 90 (A grade cutoff)	By 3 points or up to 90, whichever is lower
Below 100	By 2 points or up to 100, whichever is lower

*note that the cutoffs do not include plus/minuses

<u>Part 1</u>, make a video redoing your exam

- Make a video explaining WHAT equations you are using and WHY you are using them
- **Do the whole exam, not just the questions you got wrong**. This is for practice learning and student privacy.
- Use any software you like. Animations or high production values not required.
- You can use the Gradescope rubric to check your work, but detailed solutions will not be posted
- You can use any resource you want (including other people) to solve the problems, but the video must be your own visuals, words, and audio.
    - If you copy someone else's video or script, you will get zero credit, and I will report cheating.
- You don't have to appear on camera. Please be aware that some of your classmates will see the video.
- Practice before you record. Your video should be no longer than 15-20 minutes. If you try multiple takes and still end up over time, write yourself a script.
- Post the video on Drexel Streams, YouTube, or another video hosting service.
- In the Extra Credit folder of BBLearn, create a new post in the discussion board and put your link in the post by *[deadline]*.

<u>Part 2</u>, provide feedback on other students' videos.

- Wait until the window starts
- Watch <u>two</u> of your classmates' videos from the Extra Credit folder of BBLearn and leave a comment in the discussion board.
- The comment should be constructive criticism, e.g. "X was explained well, there is a mistake in Y, etc."
- If you think the problem was done incorrectly, please say so politely.
- <u>If there are already two comments on the video, pick a different video</u>
- There is an "example" link and comment from *[professor]*
- Complete watching and leaving comments by the [*deadline*].

Appendix B, Screencast peer review rubric

1. Enter the [*identification*] of the student who created the video you are assessing
2. Choose the assignment that this video shows from the dropdown menu
3. Did this video show a complete assignment?
    a. Yes
    b. No
4. Was the audio/video good enough to understand?
    a. Yes, it was good enough to see and hear
    b. No, the sound or resolution was so bad that I could not understand it
5. Was the explanation clear?
    a. Yes, the video helped explain the exercise
    b. It was ok
    c. There were many parts that were not explained clearly or at all.
6. Was the solution to the problem technically correct?
    a. Yes. There were no errors.
    b. Mostly. There were one or two minor errors.
    c. No. There were one or more big mistakes.
    d. I do not understand the material well enough to judge if it was done correctly.
7. Please provide one piece of constructive feedback to the student who made this video.

Appendix C, Screencast Learner Experiences Survey

Description: The goal of this survey is to examine your experiences with the screencast review assignments. It takes approximately 10 minutes to complete. The data collected through the survey will be used to improve the quality of the course and assignments. The survey also asks three demographic questions. This data will be used to understand how the assignment is effective for different groups of students. Your completion of this survey will be recorded, but responses are automatically shuffled and anonymized. Completion of the survey is optional and will not affect your assignment grades.

1. Please indicate your level of agreement: The instructions for creating the screencast assignment were clear.
    a. Strongly Agree
    b. Agree
    c. Neither Agree nor Disagree
    d. Disagree
    e. Strongly Disagree

2. Please indicate your level of agreement: The instructions for completing peer evaluations of other students' screencasts were clear.
    a. Strongly Agree
    b. Agree
    c. Neither Agree nor Disagree
    d. Disagree
    e. Strongly Disagree

3. Please indicate your level of agreement: The peer evaluation rubric was easy to use.
    a. Strongly Agree
    b. Agree
    c. Neither Agree nor Disagree
    d. Disagree
    e. Strongly Disagree

4. Please indicate your level of agreement: The technology used to create screencasts was easy to use.
    a. Strongly Agree
    b. Agree
    c. Neither Agree nor Disagree
    d. Disagree
    e. Strongly Disagree

5. Please indicate your level of agreement: The assignment was engaging.
    a. Strongly Agree
    b. Agree
    c. Neither Agree nor Disagree
    d. Disagree
    e. Strongly Disagree

6. Please indicate your level of agreement: Creating a screencast review was useful for understanding programming concepts.
    a. Strongly Agree
    b. Agree
    c. Neither Agree nor Disagree
    d. Disagree
    e. Strongly Disagree

7. Please indicate your level of agreement: Reviewing screencasts from other students was useful for understanding programming concepts.
    a. Strongly Agree
    b. Agree
    c. Neither Agree nor Disagree
    d. Disagree
    e. Strongly Disagree

8. Please indicate your level of agreement: The comments from other students on my screencast were useful for understanding programming concepts.
    a. Strongly Agree
    b. Agree
    c. Neither Agree nor Disagree
    d. Disagree
    e. Strongly Disagree

9. What did you like most about this assignment?

10. What did you like least about this assignment?

11. Is there anything you would like to change about this assignment?

12. Would you like to see similar assignments in your future courses?
    a. Yes
    b. No

13. Please indicate your level of agreement: I feel comfortable using computer and software technologies.
    a. Strongly Agree
    b. Agree
    c. Neither Agree nor Disagree
    d. Disagree
    e. Strongly Disagree

14. What is your gender?
    a. Male
    b. Female
    c. Nonbinary
    d. Transgender
    e. Prefer not to respond

15. Which category describes your age?
    a. 17 or younger
    b. 18-19
    c. 20-29
    d. 30 or older

16. How would you describe yourself in terms of race/ethnicity?
    a. American Indian or Alaska Native
    b. Asian or Asian American
    c. Black or African American
    d. Hispanic, Latino, or of Spanish Origin
    e. Middle Eastern or Arab American
    f. Native Hawaiian or Pacific Islander
    g. White
    h. Multiple races or ethnicities
    i. Prefer not to answer

17. Are you a first-generation college student?
    a. Yes
    b. No
    c. Unsure
    d. Prefer not to answer

Appendix D, Knowledge Inventory and Remediation Plan Extra Credit

Students who scored below 55 (passing grade) can increase their score to a 56 by completing the following three parts. The completion times are estimates to help you plan. Try not to rush this assignment and be nice to yourself. Building these skills takes a lifetime.

Part 1. Self-assessment: what's holding you back?
Estimated time: 30 minutes

It's almost impossible to do hard things without a supportive environment, so first we are going to think about what you need to succeed and the strengths and assets you can use to get that. Anyone is allowed to help you on this part.

1. Privately, list people who care about you and would support you in a tough time. They don't have to be from Drexel. Family, friends from home, members of a faith or community organization, etc. all count. Virtual connections from an online community (e.g. Reddit, Discord) are also great.
2. Privately, list your personal barriers to doing well in class. They may be time constraints, for example if you have a job or caretaker duties. Some may be distractions, for example if your game system is right next to your study desk. If you are not attending class, or if you struggle with procrastination, try to ask yourself why. Do you dislike your major? Are you worried that other students will see you looking dumb? Are you so worried about other things that it's hard to focus on engineering exercises? These details may not be appropriate to share. They are important for you to identify.
3. Look at your weekly schedule and figure out your "chemE catch up time" for the rest of the quarter. Write down the times and places that you will study. Be realistic.
4. Pick one barrier from your second list that you are comfortable sharing and write down one action item you can take to reduce that barrier or avoid the situation. Then pick one person/group from your first list and write down one way that they can help hold you accountable. Finally, make sure this plan works with your schedule. Some hypothetical examples:
    - *"When I'm home I get pulled into stuff around the house or goofing off instead of studying. I can help avoid this by staying on campus after class on Monday and Wednesday until 7 instead of going straight home. My friend A will help me stick to this goal by meeting me after class in the student lounge and we agreed to keep each other on task instead of socializing"*
    - *"I need my laptop to work but apps give me alerts on the corner of the screen and then I get distracted reading and messaging. I can help prevent this by going into the settings of my computer and disabling all the popup alerts. I asked my group text string to help and they agreed to go dark between 4-6pm every weekday so I'm not as tempted to chat in those study hours."*
    - *"I've been feeling pretty isolated since starting college and thinking about classes when I'm doing so poorly just makes me feel worse. I can help myself get over this by going to Student Group X meetings to meet people / make friends. The meetings are Tuesday at 5 and my mom will call at 4:30 to remind me to go."*
    - *"I look at the news or Twitter and that turns into doomscrolling and then it's been an hour and I feel so terrible that I just crawl back into bed. I installed LeechBlock on my browser and completely blocked Twitter and other news sites that make me feel so terrible. When I have the*

urge to check feeds I am going to text my sister instead and she knows this and is going to reply with something supportive."

5. Choose one or more of the following university resources and make an appointment. You don't have to tell the professor which one you pick. ***[confirm list]***
    a. If you feel underprepared from high school or previous classes: peer tutoring ***[link]***
    b. If you struggle with procrastination or time management: academic coaching ***[link]***
    c. If it sometimes feels overwhelming to just get out of bed: student health services ***[link]***
    d. If you just feel unsure of yourself and don't know where you fit: academic advisor ***[link]***

Part 2. Knowledge inventory: what do you know that you can build on?
Estimated time: 30 minutes.

Now that you've thought about the environment you need to succeed, it's time to start on the technical part. By creating an inventory of skills and topics for our class, sorted by how well you understand them, you will identify the things you need to learn. Remember, this will take some time, and that time is an investment. There is no shortcut to learning engineering. ***[delete if schedule does not permit]*** You can also come to office hours with the professor or TA for help with this list.

6. Look at the Midterm List of Topics, ***[provided by professor on course website]***. Find one technical term you know or problem you know how to solve and copy it into Column A on the table of Page 3.
7. Write a few sentences about what you know for that item. Example: *"I can solve ideal gas law problems because PV = NRT. Sometimes we write it P<u>V</u> = RT because <u>V</u> = V/N. The underline means per mole. R is always 8.314 J/molK so if I know P and <u>V</u> I can find T or combinations like that."*
8. Do this for as many items as you can. If you know one technical word, but not the whole bullet point, write just the word in the column, and list the things you do know.
9. Look at your list. Think about how little of these things you knew two years ago and congratulate yourself on how much you have learned so far! If that feels too difficult, ask someone from your list in Part 1 to provide encouragement.

Part 3: Identify the holes. What do you need to work on?
Estimated time: 60 minutes.

10. Go back to the Midterm List of Topics and decide if the remaining items should go into Column B, <u>concepts you have seen but don't really understand</u>, or Column C, <u>Technical terms that float by in a haze.</u> Type each item into Columns B and C. It's ok if you need to split items into different columns.
11. For each item in B, write down the details that you do and don't understand. Example: *"I know that accumulation = in – out + generation – consumption for mass and energy but there are so many versions of the formula that I don't know which one to use whe*n."
12. Finally, do the same thing for Column C. Do your best to come up with something for each item, even if feels trivial. Example: *"I know that entropy is S but I don't understand what it is or why we have it in class"*

13. ***[delete if schedule does not permit]*** Remember you can go to office hours for help with this list.

Email ***[professor]*** with your schedule for # 3, your self-assessment action item for #4, and your table of Columns A, B, and C as a .docx or .pdf attachment by ***[date]***. ***[professor]*** will provide you feedback on your table and suggest which items in Column B and C to focus on.

Part 4: Moving forward.
Estimated time: N/A
After completing the table and sending it to the professor, you will have a list of items to learn in priority order. Your goal is to move items column by column to the left. To make this happen:

1. ***[modify or add resources here]*** Pick a problem that uses the concept from HW solutions, textbook examples, or LearnChemE videos.
2. Review the solution or watch the video. Write down or record audio of the reason for each step.
3. Whenever you get stuck, write down the specific step you get stuck at. Examples: *"I don't understand why they jumped from energy balance to entropy balance at 02:15." "How do they know that Q=0 on page 219?".*
4. Bring your list of questions to office hours with the TA and professor.

Depending on your situation, your follow-up appointment to #5 may identify other action items. Remember to look at your list to #1 when you get stuck or need motivation.

Knowledge Inventory for Part 2 and Part 3. Add more lines as you add items.

Concepts I Understand or Know How To Use In Problems	Concepts I Have Seen But Don't Really Understand	Technical Words That Float By In A Haze