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Gamification Design for Engineering Statics

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Gamification Design for Engineering Statics:

4 Philosophical Questions, 14 Practical Questions, and 1 Unforeseen Difficulty

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Abstract

Education is increasingly taking a page from video games to provide students with small rewards and visual guides to their progress. During fall 2019 and spring 2020, a team of NC State University instructional designers, multi-media experts, and the instructor redesigned the web content for Engineering Statics to include badges, completion bars, and a visual representation of progress. This paper addresses the series of philosophical and practical questions which the team had to address during the course redesign. Initial student feedback to the new design components of the course is also provided.

Introduction

NC State University is very lucky to have a unit in the Provost's office for distance learning and learning technology applications (DELTA). DELTA maintains the learning technology software used across campus such as Moodle, our Learning Management Software (LMS). DELTA also administers grant programs for faculty. The grant I received matches instructional designers, multi-media experts, and project managers with faculty to redesign portions of their course. The instructional designer on this project was Yan Shen. Ben Huckaby provided graphical design assistance, and David Tredwell was our team lead for multimedia development.

DELTA has added a gamification module to Moodle for use at NC State. Before my grant this module had been used in four courses at the university but all the gamification efforts were still very much designed on demand. We hope all that this module will eventually become one that faculty can use without the year-long project described here.

Gamification can mean a lot of different things. Pandey lists eight elements which are common to most systems: challenges, levels, instant feedback, scores, badges, leaderboards, competition, and collaboration [1]. I have not attempted to provide a literature review of gamification; Instead I would point the reader to any of those referenced here: Caponetto reviews through 2014, Majuri through 2018, and Indriasari through 2020 [2-4]. Milosz reviewed 48 papers in Engineering Education between 2012 and 2019 [5].

This paper will describe the philosophical and practical questions which arose in adopting DELTA's gamification module for use in Engineering Statics at NC State. Each of the questions below could be answered in very different ways in different situations with different instructors; Every solution has pros and cons. This paper states the philosophical questions we agonized over and describes the solutions the team adopted for this version of Statics. Any similar project may have different answers to these questions but will likely encounter the need to answer them one way or the other.

Philosophical Question #1 (Goals): What are your goals for the redesign? Why are you introducing gamification elements into your course? And how much of your course will be included in the redesign?

This class is flipped, and yet student preparation is usually insufficient: only about two-thirds of the students watch the lecture videos before class (even though they take only about 15 minutes), and less than a fifth of the students read the book before class. Secondly, students misunderstand the depth of learning required: students often mistake having understood English sentences in the concept videos for the ability to apply those concepts to novel situations.

We identified three goals for this redesign to combat insufficient preparation and superficial learning. The overall goal is always to have more people pass without lowering standards.

- Goal #1 was *cognitive*: present the material in such a fashion that students learn the material and understand how it is interconnected.
- Goal #2 was *motivational*: inspire students to self-regulate in a flipped environment.
- Goal #3 was *metacognitive*: encourage students to think about what they're learning and how it applies to engineering and the real-world.

Every change in the course was linked to one of these three goals. Gamification is better suited for cognitive and motivational interventions. The team postponed adding metacognitive material for a future semester.

We considered adding just some small elements or redesigning a single module. In the end the course elements were reorganized throughout the course. The course includes:

- Preparation material:
  - textbook readings with skeleton notes
  - occasional supplemental readings (from other textbooks or from the instructor)
  - lecture videos (averaging 5.5 minutes long)
  - learning objectives and separate lists of definitions, concept questions, and calculation types covered on each class day
  - a preparation quiz: about 5 multiple-choice questions with limited calculations
- Classroom content:
  - pre-recorded classroom videos from prior semester flipped classes
  - problem statements in a course pack, as a PDF in Moodle, and as Google slides for groups of students to work through
- Review material:
  - Written class notes (html with embedded videos)
- Homework:
  - Computer-graded quizzes in Moodle
  - New homework problems each semester which students solve on paper and submit in Gradescope

In prior semesters content was accessed by a calendar on the homepage in Moodle. (See Appendix A.) The only major element added during this redesign was to build quizzes for each day for students to take after doing the preparation work and before coming to class. Beyond those quizzes the primary avenue for improvement was to use the gamification elements to remove the student-time cost involved in trying to figure out what to do next.

Philosophical Question #2 (Instructional Design): Will the content be presented in a daily format or in a topical format?

It was surprisingly difficult to settle on an answer to the daily-vs-topic debate. The daily schedule used previously in Statics has historically resulted in fewer students missing assignments or trying to cram them all into the night before the due date (with subsequent loss of quality and sleep.) However, the daily schedule also reduces the overall concept-based nature of the class: Homework becomes about "Day 14" rather than about "Two-Dimensional Rigid Body Equilibrium."

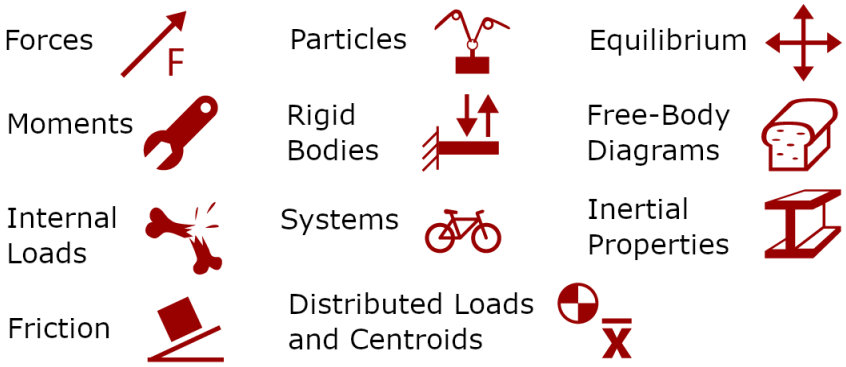
In the end the daily schedule was retained. A daily schedule reduces the organizational cost to the student of trying to figure out how long a specific task will take. The redesigned course makes it obvious what is suggested to do next while allowing a shallow navigation.

Experts look at a new problem, categorize what kind of problem it is, make appropriate and valid assumptions, and recall the steps to solve that kind of problem at the speed of thought. A daily approach can help a novice learn a step-by-step approach, but can also leave that novice without the skill set to solve new, uncategorized problems. Our team struggled with this question throughout the redesign especially once the move to a daily schedule was decided upon.

The tendency of students to believe they can learn by looking at example problems can limit their ability to apply core concepts to new scenarios. I address this limitation in part by writing new on-paper homework problems every semester so that students can't just look up the answers from last semester. New problems are a step but are probably insufficient to teach expert thinking. This philosophical question remains one we did not find a good answer to.

We also developed topic icons to help students connect individual problems and concepts to topics.

Figure 1: Topic Icons used in Statics Redesign



Practical question: If you're using daily organizations, does prep work go with the day or at the end of the last day?

Students experience a rhythm of class-homework-class-homework etc. But a flipped class must have class-homework-*prep*-class-homework-*prep* etc. Students ask, "What's my homework?" Teachers answer, you need to do these problems AND this prep before the next class.

A course designed around days obscures the need to do both the homework problems and the preparation for the next day. For example, does the preparation for Day 6 go with Day 5 or Day 6? If it's with Day 5, the preparation material is hard to find when reviewing Day 6 material. But if it's with Day 6, it doesn't look like homework to do on Day 5. Appendix B shows a preliminary sketch from the team showing the learning objects with various break points.

We decided to leave the prep work with the day it went with so that students could easily find the videos to review material. We added small quizzes (multiple choice, few calculations) that were due at the start of class. Students were also told that taking the quizzes on-time earned a star and 100% of credit; Quizzes are open until the last day of classes but preparation quizzes taken after class had a 25% penalty applied.

Philosophical Question #3 (Goals and Instructional Design): Are you redesigning for A students or C students?

Of course, we want any design to work for all students. But each redesign must identify whether the immediate goal is to lower the drop-withdraw-fail (DFW) rate or to provide extra material for your best students to explore. Many believe gamification is nothing other than a vehicle to incentivize students to go beyond what is required. But it can also be used to illustrate what needs to be done and provide a bit of motivation to do it.

While we did not wish to impede the best students, our principal goal was to assign all the tasks needed for a struggling student to pass. A spectacular student who grasps the core concepts and who has developed the skill of applying those concepts to new situations likely requires very little homework and will encounter more assignments than necessary in this class. However, a student who has not yet developed those skills needs to do more homework. Limiting false confidence without instilling self-doubt is a difficult dance.

We chose to make most (but not all) assignments required. The philosophical question led to many practical questions, each of which left us feeling like we were renegotiating whether we were designing for the very best students or the ones who might otherwise struggle.

Practical question: Will you offer enrichment content, adventures where students can be drawn into the rabbit hole of learning tangential material? Or will you stick to the basics so student time is spent on course learning objectives?

We have all had the rabbit hole experience of reading one thing, clicking on a link to read another, scrolling down, etc. There is a good argument for providing tangential material for students to encourage this free-form learning which provides frameworks for topics and helps build connections to previous experiences and possible jobs later in life. Enrichment material can lead to a deeper learning where students see the applications of the concepts they're learning.

On the other hand, rabbit hole opportunities can also be extremely stressful for students who aren't getting the required work done. In the end the team decided to streamline this particular course rather than offering explicit or even rewarded opportunities for leaving the beaten path.

Practical question: How will you balance the students' requests for more examples with the need to teach modeling of new systems?

Providing examples to each type of required calculation with explicit steps was considered. In the end we were unclear whether this would be good or whether it would reinforce "solving by example" behavior rather than teaching students to characterize a problem and apply a core concept to solve it.

Some students take a practice exam and assume that everything on the exam will look like the practice exam. In this way a practice exam can short-circuit the studying students need to do and instill false confidence. No practice exam can ever touch on all the kinds of problems that might occur on an engineering exam, but students ask for them every semester. A place holder was built into the course for future sample exams, but they have been put on hold until the pros and cons are better understood.

Practical question: Are students held to lock-step deadlines or is flexibility built in for illnesses or other absences?

The best students we have can easily manage all their time including making up work while not falling behind on the next material, but many students struggle when timelines are flexible. In this present course we decided that it was easier for a great student to succeed even though the timing was not as flexible as desired so that the C students would be less likely to fall behind and fail.

Practical question: Will you use a leaderboard?

A common feature of many gamified systems is a list of which students in the class have earned the most points for one reason or another. We discussed this at length in the planning meetings. Finally we decided that leaderboards were less useful in a class where we want every student to succeed. The team believed that it was not useful to a student to find out that they were student #297 out of 400. Also, the gradebook functions quite adequately to show whether students are doing well or not. We were concerned that student rankings could impede teamwork: We did not want to limit a student's willingness to help another student for fear of dropping in the rankings.

Practical question: How do you encourage students to adopt beneficial behaviors without requiring them?

There is still some content in the course which is not required for a grade. For example, skeleton notes for the readings are provided in the course pack, but the decision was made to make these optional and not collected. Solutions are provided in the preparation for exams. Similarly flash cards are available for practicing vocabulary, but they are not required.

Badges are used to encourage students to do extra work as is common in gamification instances elsewhere. We use two types of badges: encouragement badges and topic badges. See Appendix

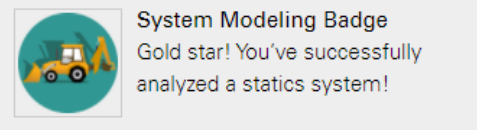
C for the specific badges. Each badge had a picture and a message for the students. Badges are collected on each student's Achievements Page.

Encouragement (or what we called pat-on-the-head achievements) were given for course improvement either for finding an error in the course or finding excellent supplemental material which gets added to the course. Encouragement badges were awarded for accessing the flash cards or attending office hours; repeating these behaviors earned higher levels of the badges.

Three times over the semester students are required to write something: an ethics response on day 01, written instructions for using the right-hand-rule for three-dimensional moments on day 15, and a project report on day 40. Some students believe that becoming an engineer means they never have to write anything again; while assigning writing assignments can disabuse them of this notion, we hoped that assigning badges would highlight some of the places where engineers use writing skills. The writing badges also have levels: a pencil, a ball-point pen, and a fancy fountain pen.

The final type of badges were awarded for specific assignments which corresponded to topics in the course. Our Modeling a system from the real world for example is an over-arching topic which underlies much of what we're trying to teach the students to do. These badges are linked to a specific kind of homework to encourage students to think about where they are in the course.

Figure 2. Example Badge



Practical question: Can students earn badges by checking off their own "I did that" box?

The advantage of having students be able to check and uncheck completion is that they can mark what they need to come back to. An uncolored bubble could become flagged content that a student wanted to review in the future. And yet earned achievements feel different than claimed achievements. We chose not to award any badges or colored bubbles for self-assessed behavior, but we did not feel that the team came to a philosophical conclusion about which was better.

Practical question: How do you avoid upsetting students who must have every box checked off?

Check boxes next to optional things can make some completionist students feel like they are required which is detrimental to the metacognitive skills we are trying to instill. Students must learn themselves how to identify and correctly assess the values of an adventure task that incline students to spend more time with a subject.

Practical question: What comes first? The application of the concept or the concept itself? Will the content let students discover the learning objectives, or do learning objectives encourage students to explore the content?

In other words, do you provide a problem and let the solution of that problem illustrate the problem-solving steps and then point out the core concept demonstrated OR do you explicitly present the core concept and then follow on with examples? Time is linear: students will

encounter material in an order. But knowledge is a cloud of connections. Do we provide the scaffolding explicitly and then flesh out the cloud with examples? Or do we use a project-based-learning approach where students incidentally discover the core concepts while they're solving a specific challenge?

In the end, the explicit list of learning objectives covered each day was moved into the review material. But the preparation page included a list of definitions, concepts, and types of calculations from that class day. (I hedged my answer to this philosophical question.)

Practical question: Will gamification affect individual questions or individual quizzes?

A perfect setup for student learning is a guardian instructor sitting at an elbow ready to help a student remember and review topics as soon as needed. Adaptive learning at its best promises to help students make these connections. We considered linking every individual quiz question to previous topics students might need to review, but ultimately we only gamified the individual learning objects for simplicity's sake.

Philosophical Question #4 (Graphical Design): How do you incorporate the instructional design you have decided upon into a web portal that satisfies the instructional design?

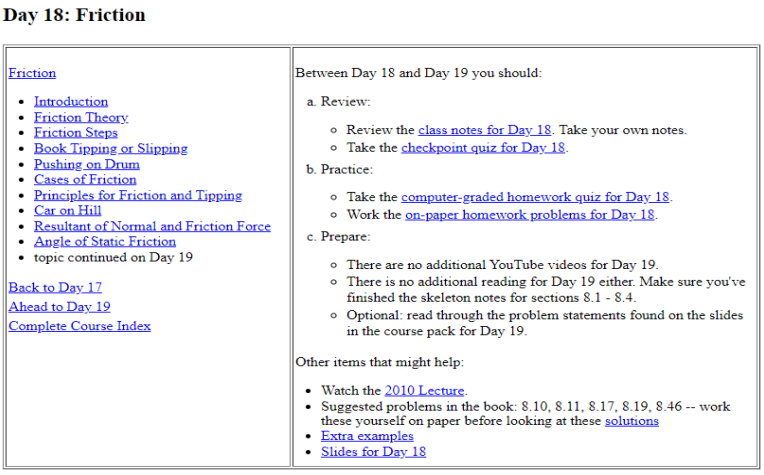
As in any redesign, the challenge remained to keep the instructional design foremost. Pedagogy must lead technology. But many practical questions arose in satisfying the instructional design decisions.

Practical question: Is it important that everything be compactly available? How many clicks is ok to get to the information you need?

This question informs many design decisions and in some cases becomes a matter of personal preference. My personal preference is a design which is shallow making everything accessible with only a few clicks but keeps all those clicks available without excessive scrolling.

In past years this preference took the place of a very long html page with hyperlinks to other places on the same page as shown in Figure 3.

Figure 3. Old Design Being Replaced by New Course



Day 18: Friction

Friction

- Introduction
- Friction Theory
- Friction Steps
- Book Tipping or Slipping
- Pushing on Drum
- Cases of Friction
- Principles for Friction and Tipping
- Car on Hill
- Resultant of Normal and Friction Force
- Angle of Static Friction
- topic continued on Day 19

Back to Day 17
Ahead to Day 19
Complete Course Index

Between Day 18 and Day 19 you should:

a. Review:
- Review the class notes for Day 18. Take your own notes.
- Take the checkpoint quiz for Day 18.

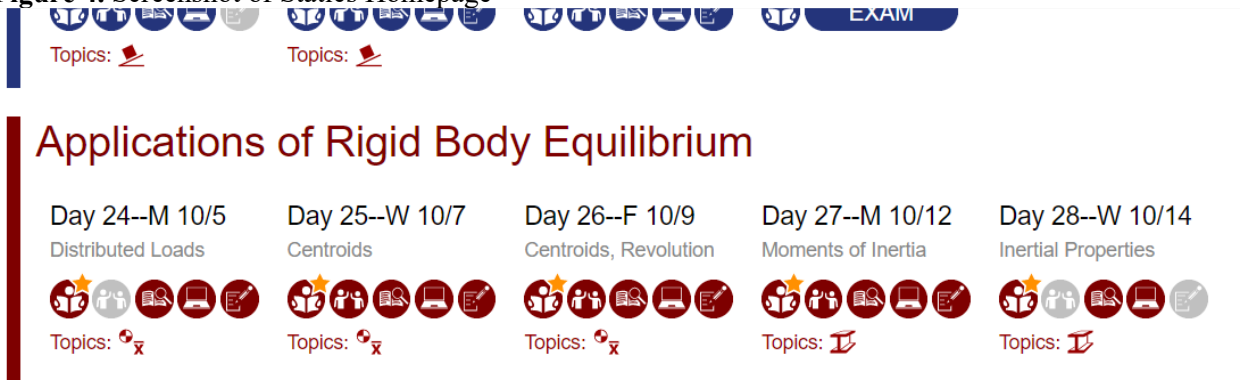
b. Practice:
- Take the computer-graded homework quiz for Day 18.
- Work the on-paper homework problems for Day 18.

c. Prepare:
- There are no additional YouTube videos for Day 19.
- There is no additional reading for Day 19 either. Make sure you've finished the skeleton notes for sections 8.1 - 8.4.
- Optional: read through the problem statements found on the slides in the course pack for Day 19.

Other items that might help:
- Watch the 2010 Lecture.
- Suggested problems in the book: 8.10, 8.11, 8.17, 8.19, 8.46 -- work these yourself on paper before looking at these solutions
- Extra examples
- Slides for Day 18

All the links in the calendar took users to a point on the same page. In the redesign this calendar file was broken into multiple pieces for each day in a graphical interface called a roadmap. For example, on the homepage for day 26, a student would see the class number, the date, the topic (both with the subtitle and with the icon below):

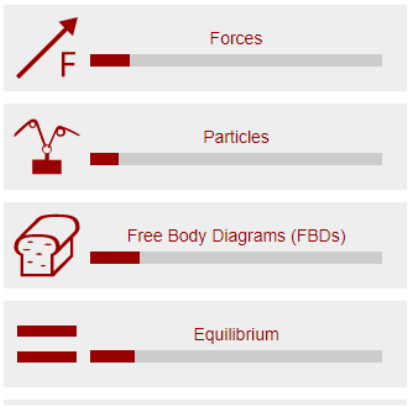
Figure 4. Screenshot of Statics Homepage



The five step icons (the bubbles) are Prepare, Class, Review, Computer-Graded Homework, and On-Paper Homework. Each bubble has rollover text to add words to images; Bubbles turn from grey to red (or blue) when the student has completed each task. (See appendix A for more info.) In Figure 4, the student missed class on Days 24 and 28. The on-paper homework for Day 28 was not graded yet. The bubbles are immediate visual indicators of missing work. The stars on the first daily bubble indicate that the student took the prep quiz before class for full credit.

Completing activities changes the color of a bubble, and it also earns points toward the Learning Progress Bar associated with the topics covered in that activity (see Figure 5.)

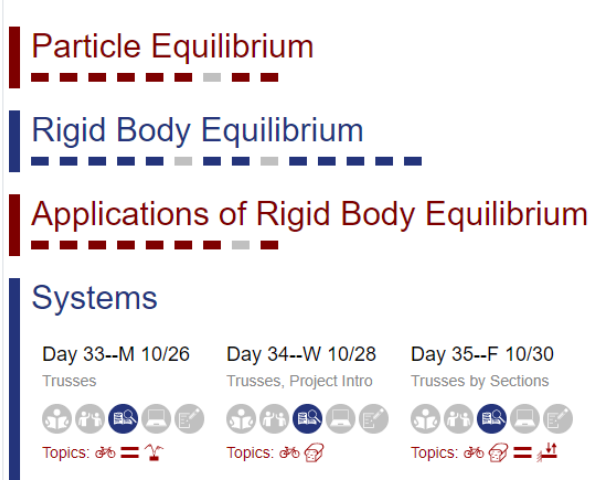
Figure 5. A portion of a Learning Progress Bar



The Learning Progress Bar is always on the top right of the homepage for the course. As the semester progresses, students see immediately what they're working on. The connections between topics like particles and topics like trusses by the methods of joints are graphically illustrated: The Particle bar won't fill up when the first test concludes the Phase dealing with Particles. More points are earned in the Particles bar in the Trusses module.

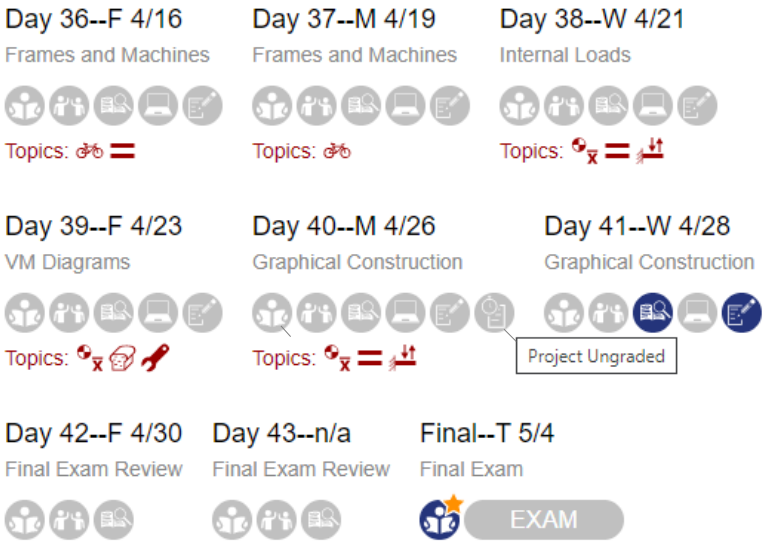
The road map described above was the team's solution to showing topics and daily organization while allowing students to access anything with just a few clicks. The roadmap design was very compact limiting scrolling and scrolling and scrolling. After each exam the phase can be collapsed as shown in Figure 6 to help the current content stay close to the top.

Figure 6. Road Map Showing Collapsed Phases 1-3



Topics resize for bubbles and have a minimum width so they don't disappear or become unreadable. The system works well for mobile devices and desktop. Topics can have additional bubbles added as required as well. For example on Day 40 there are six bubbles so students can submit their grades. (The bubble would be blue once a grade was uploaded.) Also shown in Figure 7 is one of the rollover texts identifying the bubble for the project.

Figure 7. Reformatted Roadmap



Practical question: What do you do for students who don't like images?

A graphic that seems intuitive to some can feel completely obscure to others. The Learning Progress Bar in Figure 5 helps students connect the icons from Figure 1 with the words

describing the topic. The roadmap is very icon-heavy, so we created an Alternate List Format which included all the links to the same places as the bubbles in the roadmap with English words. Objects in the list were named like the rollover text for the bubbles and appeared in the same order. No link was allowed to be in the road map or the list and not on the other to keep them truly optional. The Alternate List Format has check boxes which are checked off using the same logic as whether the road map would be colored in.

Students were surveyed to see which format they were using:

> To access the material in Statics, are you using the Road Map or the Alternate List Format? (327 responses)
> - Road Map 46.8%
> - Alternate List Format 15.9%
> - Sometimes a little bit of both. 37.3%
>
> At the beginning of the semester, did you find the website easy to learn to navigate?
> - Very easy to learn to navigate 36.5%
> - Relatively easy to learn 52.6%
> - Moderately difficult to learn 8.8%
> - Quite difficult to learn to navigate 2.1%

Students once they understood the system found the compressed road map useful. A large majority of them found it very easy or relatively easy to learn to navigate. For a course which has as many pieces available to students, the team felt like this was a success. The number of students using both formats is reassuring as well since it reinforces the decision of using both was a good one.

Practical question: where do you put "more help"?

The uniformity of the road map is a blessing for students in keeping track of what is going on, but it is also limits us when we want to add an extra bit. Where do you put optional material that students may need for some topics / days and not for others? The decision we made was to put enhancements under each bubble. So, supplementary readings go under preparation but supplemental example problems go under review.

Practical Question: How do you balance cute versus distracting?

In working through the graphic design, I provided rough sketches to the illustrator for the topic icons discussed in Philosophical Question #3. This initial drawing was on a white board with follow-up instructor-made graphics:

Figure 8: Free-body Diagrams for a Pin vs a Rainy Witch Hat

Where many readers can identify the first two pictures in Figure 8 as a pin with a beam (even if they're not very good versions of a pin with a beam), the graphic designer saw a rainy witch hat. We debated actually using this as a topic icon – a sort of Easter egg in the course: See if you can figure out why the topic for free-body diagrams is a witch's hat with raindrops below it. This decision is obvious in retrospect: Cutesy has gone too far.

We did end up using bread as an icon because I teach BREAD for free-body diagrams as does the Air Force Academy: body, reaction forces, external applied loads, axes, and dimensions. Students initially might not know why there is bread there, but after learning about the acronym the image itself helps to reinforce the topic. Each design decision must balance cute versus distracting.

Unforeseen Difficulty: How do you compare Fall 2019 to Fall 2020?

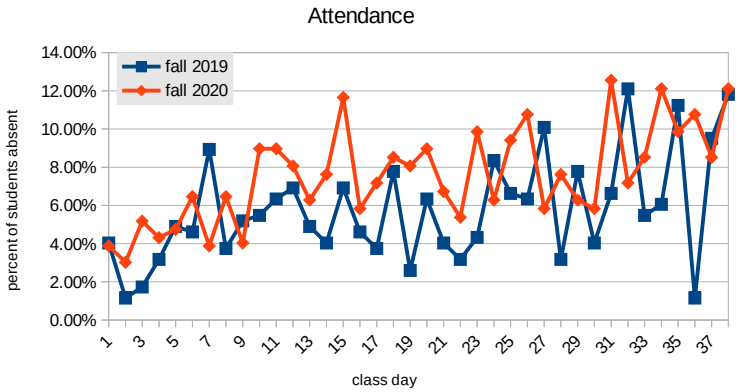
In 2019, the assessment plan for this project was to compare the success rate of students in fall 2019 to fall 2020 to determine whether the gamification of this course had any effect. And then we had a pandemic. What comparisons were reasonable are shown here. The population has been restricted to the students who took the final exam: 347 in fall 2019 and 333 in fall 2020.

Attendance:

During Fall 2019 attendance was required. 10% of the semester grade came from class participation which was measured with Top Hat. Attendance was measured on 38 class days.

During Fall 2020 students were able to choose to attend a synchronous class or complete the work on their own asynchronously. Students could make this choice after each midterm but were not allowed to switch from synchronous to synchronous between exams. Attendance for synchronous students in each phase was mandatory with 5% of their grade coming from attendance. The four phases had between 223 and 233 students attending synchronously. Attendance was measured on 38 class days.

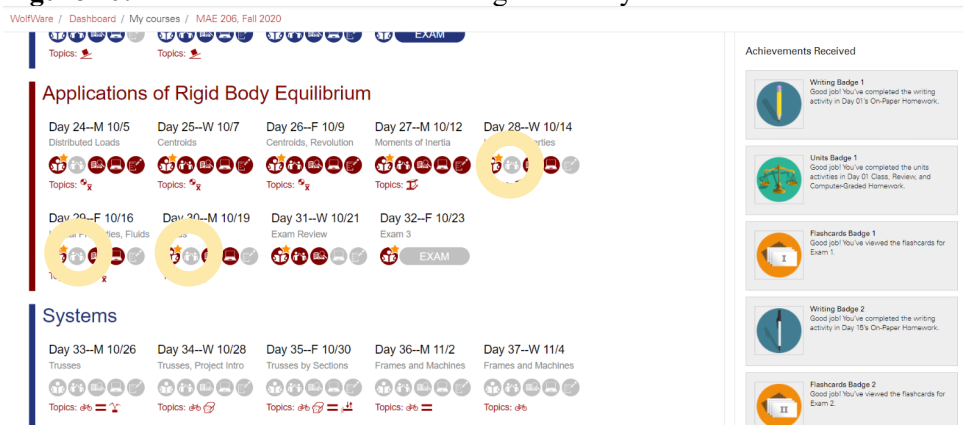
Figure 9. Attendance in Fall 2019 and Fall 2020 for Synchronous Students



By and large, attendance was worse during fall 2020 than in fall 2019. Anecdotal evidence suggests that students were quite aware of missing class. For example, on days 28-30 I neglected to upload the grades due to technical issues. When I uploaded the grades for class on day 31,

multiple students emailed me within the next 24 hours to ask about their missing daily grades. One student sent me a screen shot of what he was seeing:

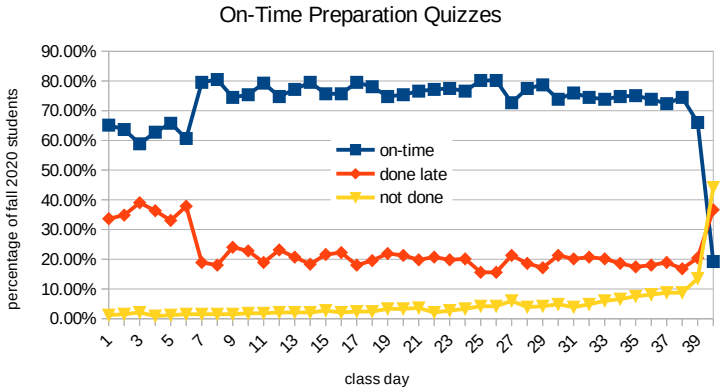
Figure 10: Student Submission of Missing Class Days



For some students, watching the bubbles fill in clearly helps them keep track of their grades even if it might not motivate them to come to class in a pandemic.

The preparation quizzes were new in fall 2020. Students were awarded a star for finishing the prep quizzes before they came to class as an incentive to coming to a flipped class having done the work. Prep quizzes also had a 25% penalty for not completing them before class.

Figure 11: Preparation Quizzes Completed

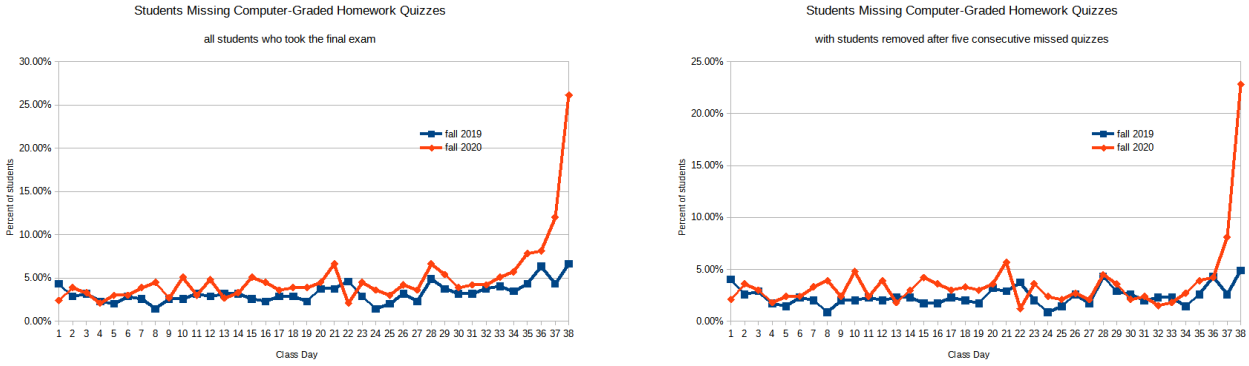


The preparation for class was better this year despite the pandemic than in prior years; I have observed in the past that only about half to two-thirds of students were prepared for class. The number of students completing the quizzes on-time was significantly higher than late or not at all. The data from days 1-7 were inconsistent with the days after that: I did not make it sufficiently clear to asynchronous students that they were being held to the same deadline for completing the preparation quizzes as everyone else.

The road map has the potential to encourage students not to miss assignments. A comparison was made between the number of students missing computer-graded homework quizzes in Fall 2019 and Fall 2020. These quizzes cannot be made up and there are no drops. Either the road map did

not have this effect or the effects of the pandemic were larger than whatever advantage was gained. Note: the semester was shorter for Fall 2020 by one class day though the quiz was still assigned. Many students missed the extra assignment because there was no class that day.

Figure 12: Students Missing Computer-Graded Homework Quizzes



A second analysis removed student grades after five consecutive zeros: The rationale here is that the a road map reminder probably wouldn't help a student who has decided not to do the homework. With these zeros removed, the number of students missing computer-graded homework quizzes is essentially the same until the last two quizzes of the semester.

Overall student evaluation: Students were surveyed three-quarters of the way through the semester. Two percentages are given for Fall 2020 (N=339) and Spring 2021 (N=141).

- Over the last 15 months I have worked with a team of developers to redesign the course interface for Statics. The goal of the road map and the learning progress bar was two-fold: 1) to increase student awareness of both what you were learning and what you had completed in the course, and 2) to increase student motivation to complete all the tasks.
- Do you feel that the road map (the part with the bubbles) has helped you know what you were supposed to do next?
  - Helped a lot 60% 55%
  - Helped a little 31% 35%
  - Didn't help much 6% 5%
  - No help at all 2% 5%
- Do you feel that the learning progress bar helped you notice what you were working on?
  - Helped a lot 12% 18%
  - Helped a little 35% 36%
  - Didn't help much 34% 31%
  - No help at all 18% 15%
- Did seeing the bubbles fill in motivate you?
  - Helped a lot 32% 39%
  - Helped a little 47% 34%
  - Didn't help much 14% 17%
  - No help at all 7% 10%
- Did you ever go back to take a preparation quiz just to see a bubble fill in?
  - Never. I did them on time. 60% 47%
  - Never. I don't care if the bubbles fill in. 5% 6%

◦ Maybe once or twice.	31%	32%
◦ I will by the end of the semester	4%	14%

- For the parts of the semester when you were synchronous, did having the bubbles for class fill in help you track your absences?

◦ Helped a lot	16%	17%
◦ Helped a little	22%	26%
◦ Didn't help much	8%	8%
◦ None at all	4%	4%
◦ Not applicable--I didn't miss any class.	50%	45%

About 90% of my students felt that the roadmap helped them know what they were supposed to do next. Half of my students felt that the learning progress bar helped them keep track of what they were working on. (Note: any increase in helping students connect their work with a topic is considered a plus!) Three quarters of my students felt like the bubbles were motivating. And at least a third admitted to going back to take a quiz just to see the bubbles fill in. Of the students who missed class, three-quarters felt like the bubbles helped them track their absences. These numbers were enormously encouraging that the redesign had helped the students.

NC State University allowed Enhanced Pass-Fail Grading during the period from Spring 2020 through Summer 2021. Students were allowed to drop the class or switch to pass-fail grading up to a week after the semester grades were finalized. Normally students who take the class pass-fail cannot go on to take the next courses in their majors, but during the pandemic students who earned a pass were allowed to go on to Dynamics and Solid Mechanics. One unintended effect of this is to remove some of the incentive to struggle for an A since a pass is sufficient and doesn't hurt the GPA like a C- might. Because this decision could be made even after the semester, some students quit doing the homework and simply took the final. While there are always some students who make this choice, the number of students choosing to slip by has been increased during remote learning.

Three Small Lessons Learned

1) There is a *huge* value in having someone else look over all your materials, especially someone who is not an engineer. Being forced to justify the design decisions for a course that I've taught for almost fifteen years solidified which ones were important.

2) It was interesting how resistant I was to the scroll of death. Reflection has shown that my experience with dial-up internet has lingered in how I see web design. Working with younger people led to a course design that was closer to what my students needed.

3) Having a common lexicon with young graphic designers needed intentional communication. We were six weeks into design before we settled on what load, phase, and cycle would mean. (It was also very entertaining to try to describe a free-body diagram to the team!)

In conclusion, the gamification seems to be going strong but solid results will need to wait until the pandemic is behind us all.

Future Work

The team identified six next tasks which would have fit into our goals but which we were unable to complete in the time available:

1. Adopt an open-source textbook. This will consolidate where students can go for information to the course pack and the Moodle site.

2. Allow student peer evaluation for classwork. A student who comes to a class and does not participate should not get participation credit. We would need the gamification module to have a third color: absent, present, and present but not helpful.

3. A third stage could also be used for quizzes which are accessed but not submitted. Or perhaps submitted but not with a sufficient score. These bubbles which are colored differently than simply "complete" could indicate to students visually where they need extra work.

4. If the skeleton notes could be collected and graded, even if only optionally, the team discussed allowing students to earn "bones" to complete a picture of a skeleton by the semester end.

5. Each day could use an extra bubble for "Why should I care?" with real-life applications and information about where the material will be needed later in the curriculum. This bubble could include alumni testimonials, extra derivations underlying the topics of the day, or even professional skills required.

6. And finally, the team would like to develop a way for students to "buy a hint." We envisioned some sort of opportunity for students to decide whether or not a small grade reduction on an assignment or test question was worth it.

References

1 "Gamification In eLearning: What Is It + 6 Killer Examples (2020 Update)," eLearning Industry, Oct. 06, 2015. https://elearningindustry.com/6-killer-examples-gamification-in-elearning.

2 I. Caponetto, J. Earp, and M. Ott, "Gamification and Education: A Literature Review," in European Conference on Games Based Learning, Reading, United Kingdom, Oct. 2014, vol. 1, pp. 50–57. http://www.proquest.com/docview/1674172795/abstract/CF9865415CA4BD1PQ/1.

3 J. Majuri, J. Koivisto, and J. Hamari, "Gamification of education and learning: A review of empirical literature," p. 9, 2018.

4 T. D. Indriasari, A. Luxton-Reilly, and P. Denny, "Gamification of student peer review in education: A systematic literature review," Educ Inf Technol, vol. 25, no. 6, pp. 5205–5234, Nov. 2020, doi: 10.1007/s10639-020-10228-x.

5 M. Milosz and E. Milosz, "Gamification in Engineering Education – a Preliminary Literature Review," in 2020 IEEE Global Engineering Education Conference (EDUCON), Apr. 2020, pp. 1975–1979, doi: 10.1109/EDUCON45650.2020.9125108.

Appendix A: Site Comparison between Fall 2019 and Fall 2020

Fall 2019 and Fall 2020 Navigation Comparison:

Before the current course redesign, students logged into the LMS to find a calendar:

Schedule

Mondays		Wednesdays		Fridays	
Aug 19: Day 00	Class Setup	Aug 21: Day 01	Prerequisites Review	Aug 23: Day 02	Vectors
Aug 26: Day 03	Forces	Aug 28: Day 04	FBDs in 2D	Aug 30: Day 05	Particle Equilib 2D
Sep 3: Labor Day-- no class		Sep 4: Day 06	Particle Equilib 3D	Sep 6: Day 07	Particle Equilib 3D

Consider one specific day as an example. For Day 38, the Fall 2019 Home Page Link looked like this:

Nov 20: Day 38	Internal Loads

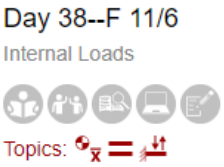
If you clicked on that day's link, before the gamification you would see a table as shown below:

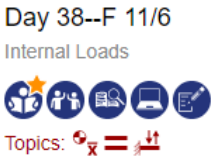
Day 38: Internal Forces, Shear and Bending-Moment Diagrams by Definition

Internal Forces • What is an Engineer? • Internal Loads • Sign Conventions, Two-Dimensions • Example: Internal Loads for Cantilevered Beam with Tip Load • Example: Internal Loads for Simply Supported Beam with Point Load in Middle • Example: Internal Loads for Cantilevered Beam with Multiple Loads • Straight Two-force Members • Curved Two-force Members • Vertical Beams • Sign Conventions, Three-Dimensions Shear and Bending-Moment Diagrams by Definition • Introduction • Shear and Bending Moment Diagrams for Beams by Definition • Example: Simply Supported Beam with One Force • topic continued on Day 39 Back to Day 37 Ahead to Day 39 Complete Course Index	Between Day 38 and Day 39 you should: a. Review: ◦ Review the class notes for Day 38. Take your own notes. ◦ Take the checkpoint quiz for Day 38. b. Practice: ◦ Take the computer-graded homework quiz for Day 38. ◦ Work the on-paper homework problems for Day 38. c. Prepare: ◦ Watch the YouTube video for Day 39: Shear and Bending-Moment Diagrams by Definition ◦ There is no additional reading for Day 39. ◦ Make sure you bring your course pack to class for Day 39. ◦ Optional: read through the problem statements for Day 39. Other items that might help: • Watch the 2010 Lecture. • Suggested problems in the book: 7.3, 7.9, 7.17 (solutions) • Extra examples • Slides for Day 38

Scrolling down on this page included all the lecture notes for that day with embedded concept videos and example videos. The table included information about how to Review, Practice, and Prepare. This information was only available at a depth of one-click into the site.

After gamification, the homepage looked very different. The calendar was replaced by a road map:

Fall 2020 Home Page Links: before completion 

and after 

Each bubble in the road map is a link from the home page to five separate pages per class day, one each for Preparation, Class, Review, Computer-Graded Homework, and On-Paper Homework. Hover-over text identifies exactly what bubble refers to what learning object. Bubbles turn from grey to red or blue when completed: The review must only be accessed to be colored in while the remaining four bubbles must have grades assigned to turn from grey to blue.

These links take students to pages as shown on the next pages.

Fall 2020 Bubble #1 Preparation:

Day 38 Prepare

1. Prepare for Day 38.

   Lecture Videos

   - Internal Loads
   - Shear and Bending-Moment Diagrams by Definition

   Readings Materials

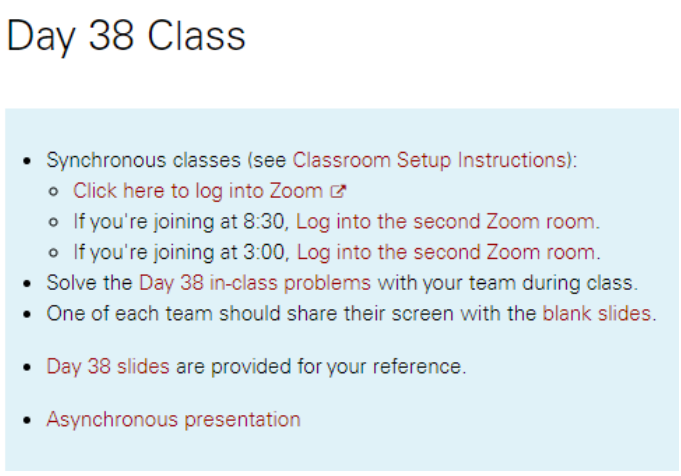
   - Supplementary material on Shear and Bending-Moment Diagrams by Definition (also found in the course pack.)
   - Textbook. Fill out the Day 38 skeleton notes as you read.
     - 8th-10th editions: Review Section 5.8, Read Sections 7.1 – 7.2 and 7.4 – 7.5
     - 11th-13th editions: Review Section 5.3A, Read Sections Introduction to Chapter 7, 7.1, 7.2B – 7.2C.
   - Overview of Day 38 definitions, calculations, and concepts

2. Complete the quiz below.

3. Read through the Day 38 in-class problems. (optional)

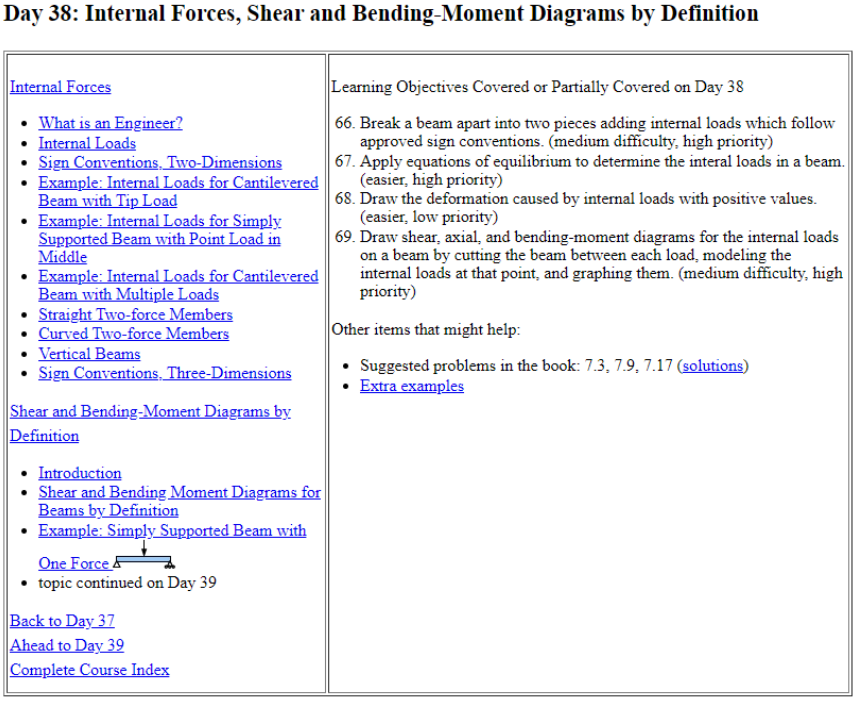
Lecture Videos average 5.5 minutes long and are hosted at YouTube. Some days have supplementary learning materials available here. The textbook readings are listed along with a PDF of the skeleton notes for the readings.

Fall 2020 Bubble #2 Class:



The pandemic required Zoom instructions. But even without that the Class Bubble is a place to post the problem statements for the class. (As a flipped class, students are working problems and answering questions during class.) My PowerPoint slides are provided as a reference. A prior year's recorded lecture is available for students taking the course asynchronously which will likely continue into next year. I created a set of blank slides with all the figures and problem statements but no solutions or steps. Students are provided with a link that copies this blank slides file into their own Google drive. Student teams can share their screen in Zoom with that blank slide file and work it together in Zoom using the annotate tools.

Fall 2020 Bubble #3 Review:



Day 38: Internal Forces, Shear and Bending-Moment Diagrams by Definition

Internal Forces

- What is an Engineer?
- Internal Loads
- Sign Conventions, Two-Dimensions
- Example: Internal Loads for Cantilevered Beam with Tip Load
- Example: Internal Loads for Simply Supported Beam with Point Load in Middle
- Example: Internal Loads for Cantilevered Beam with Multiple Loads
- Straight Two-force Members
- Curved Two-force Members
- Vertical Beams
- Sign Conventions, Three-Dimensions

Shear and Bending-Moment Diagrams by Definition

- Introduction
- Shear and Bending Moment Diagrams for Beams by Definition
- Example: Simply Supported Beam with One Force
- topic continued on Day 39

Back to Day 37
Ahead to Day 39
Complete Course Index

Learning Objectives Covered or Partially Covered on Day 38

66. Break a beam apart into two pieces adding internal loads which follow approved sign conventions. (medium difficulty, high priority)
67. Apply equations of equilibrium to determine the interal loads in a beam. (easier, high priority)
68. Draw the deformation caused by internal loads with positive values. (easier, low priority)
69. Draw shear, axial, and bending-moment diagrams for the internal loads on a beam by cutting the beam between each load, modeling the internal loads at that point, and graphing them. (medium difficulty, high priority)

Other items that might help:

- Suggested problems in the book: 7.3, 7.9, 7.17 (solutions)
- Extra examples

Much of the prior day material is available here. But since much of the direction to Review-Practice-Prepare has been moved to the main page, the space left over has been used to showcase the specific learning objectives covered with that day's material. As in prior semesters, this Review page includes recorded solutions for all the students' in-class problems. Also included here are the YouTube concept videos from the preparation: These are repeated here to provide a complete linear path through the material. One review page leads into the next.

Fall 2020 Bubble #4 Computer-Graded Homework:

Day 38 Practice: Computer-Graded Homework

Internal Forces

Attempts allowed: 3

The quiz will not be available until Friday, April 16, 2021, 6:00 PM

This quiz will close on Friday, April 23, 2021, 6:00 PM.

Grading method: Highest grade

Each student is required to practice the lessons of the day. Some of these problems can be computer graded and others need to be graded by hand, a split that evolved many years ago. The computer-graded homework quizzes may be attempted up to three times and only the highest grade counts (though they have to wait 30 minutes between attempts to dissuade the students who guess A, then B, and then C.) These homework quizzes do not change between one semester and another.

Computer-graded homework and on-paper homework links were provided inside the Day link before Fall 2020 and have been moved to the main page with the gamification.

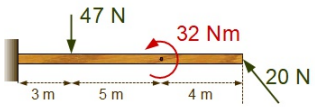
Fall 2020 Bubble #5 On-Paper Homework:

Day 38 Practice: On-Paper Homework

Reminder: Work these problems on paper and submit them to On-Paper Homework for Day 38 in Gradescope.

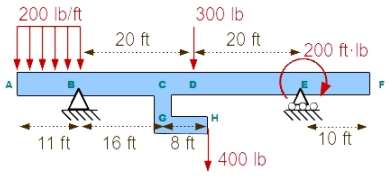
#1

Find the internal loads at 5 m and 10 m from the wall. (You should have a FBD and explicit equations of equilibrium for each.) The 20-N force acts at 55 degrees to the vertical.



#2

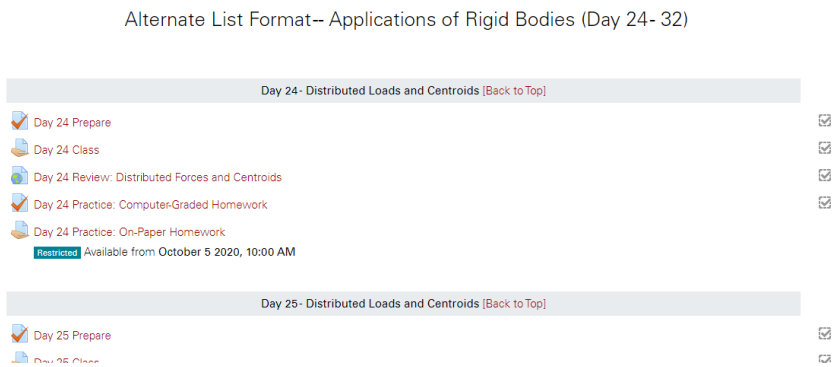
Draw the shear and bending-moment diagrams for the beam using the definitions we did in class. (That is, show your slices of beams with correct sign conventions for each slice and the equations of equilibrium to find V(x), N(x), and M(x).)



Students have one or two homework problems assigned each class day; The homework load is kept to about the same five book problems that a student might be assigned per week. These homework problems are written new each semester to limit the impact of Chegg and are supposed to be individual work by the students. Students upload these problems to Gradescope where undergraduate graders who took Statics with me in prior semesters grade them according to a common rubric.

Alternate List Format

Not all students appreciate a graphic-led interface. For students who preferred words, an alternate format was provided which was just a list of these links:



Check-boxes at the right were empty or checked based on the same triggers as described above. Exactly the same information was available in the road map or the Alternate List Format.

Appendix B: Early Site Design Options

An early design template showing the tasks and Moodle tools used in each day.

Topics	Steps	Tasks	Moodle Tools	Check boxes	
Prereqs Review	Prepare	Study introductory materials (intro videos, textbook readings, read problem statements).	Page (one page per topic)	☐	Before Day 01
		Complete the readiness quiz	Quiz (combined topics)	☐	
	In-Class	Work on in-class problems in groups. [Append class slides and problem solutions]	Assignment with description	☐	Day 01
	Review	Review concepts and skills (e.g. texts, link to intro materials, link to examples, link to flashcards, etc.).	Page (one page per topic)	☐	Between Day 01 and Day 02
		Complete checkpoint quiz.	Quiz (combined topics)	☐	
	Practice	Complete computer-graded homework.	Quiz (combined topics)	☐	
		Complete on-paper homework.	Assignment -- submitted in Gradescope	☐	
		Get more help or practice (other examples).	Page (one page per topic) (optional)	☐	
Vectors	Prepare	Study introductory materials (intro videos, textbook readings).	Page (one page per topic)	☐	
		Complete the readiness quiz.	Quiz (combined topics) (optional)		
	In-Class	Work on in-class problems in groups. [Append class slides and problem solutions]	Assignment with description	☐	Day 02
	Review	Review concepts and skills	Page (one page per topic) (html explanations, link to prepare page, link to flashcards).	☐	Between Day 02 and Day 03
		Check your understanding of definitions	Flashcards (optional)		
		Complete checkpoint quiz.	Quiz (combined topics) (optional)		
	Practice	Complete computer-graded homework.	Quiz (combined topics)	☐	
		Complete on-paper homework.	Assignment	☐	
		Get more help or practice (other examples).	Page (one page per topic) (optional)		
Forces	Prepare	Study introductory materials (intro videos, textbook readings).	Page (one page per topic)	☐	
		Complete the readiness quiz.	Quiz (combined topics)	☐	
	In-Class	Work on in-class problems in groups. [Append class slides and problem solutions]	Assignment with description	☐	Day 03
	Review	Review concepts and skills	Page (one page per topic) (html explanations, link to prepare page, link to flashcards).	☐	Between Day 03 and Day 04
		Complete checkpoint quiz.	Quiz (combined topics)	☐	
	Practice	Complete computer-graded homework.	Quiz (combined topics)	☐	
		Complete on-paper homework.	Assignment	☐	
		Get more help or practice (other examples).	Page (one page per topic) (optional)	☐	

Appendix C: Badges

 **Course Contributor Badge** Congratulations! Your suggested video has been approved. Thank you!	 **Proofreader Badge** Thank you for reporting the error in the course materials!	 **Flashcards Badge 1** Good job! You've viewed the flashcards for Exam 1.
 **Flashcards Badge 2** Good job! You've viewed the flashcards for Exam 2.	 **Flashcards Badge 3** Good job! You've viewed the flashcards for Exam 3.	 **Flashcards Badge 4** Good job! You've viewed the flashcards for the Final Exam.
 **Office Hours Badge Level 1** Good job. You've attended 1 office hour session.	 **Office Hours Badge Level 2** Good job. You've attended 3 office hour sessions.	 **Office hours Badge Level 3** Fantastic! You've attended 8 office hour sessions!
 **Writing Badge 1** Good job! You've completed the writing activity in Day 01's On-Paper Homework.	 **Writing Badge 2** Good job! You've completed the writing activity in Day 15's On-Paper Homework.	 **Writing Badge 3** Fantastic! You've completed writing the project.
 **Particle Modeling Badge** Good job! You've correctly modeled a three-dimensional object as a particle.	 **Rigid Body Modeling Badge** Good work! You've correctly modeled a three-dimensional object as a rigid body.	 **Slipping vs Tipping Badge** Stellar! You've correctly modeled the slipping or tipping of a rigid body.
 **Initial Design Badge** Well done! You've got a successful individual submission for the project!	 **System Modeling Badge** Gold star! You've successfully analyzed a statics system!	 **Shear and Bending-Moment Badge** Congrats! You've captured the idea that beams break when the internal loads are too big.
 **Units Badge 1** Good job! You've completed the units activities in Day 01 Class, Review, and Computer-Graded Homework.	 **Units Badge 2** Good job! You've completed the units activities in Day 27 Prepare.	 **Units Badge 3** Keep up the good work! You've completed the units activities for inertial properties!
 **Units Badge 4** Rock solid! You got the Exam 3 question involving units correct.		