Applying the ExCEEEd Teaching Model in a Flipped Classroom Environment

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Introduction/Motivation
As a student, the author was a product of the ExCEEd Teaching Model from long before it had that name: five colors of chalk, red clouds, lesson objectives, demonstrations, enthusiastic instructors, hot dogs, and RAFA tabs were all practiced by the West Point Department of Mechanics as far back as at least 1985. Because of this inspiration, the author returned and practiced this teaching model as faculty member at West Point for eight years, thoroughly enjoyed its application, and was recognized as an effective teacher. During his latter years at West Point, he found, along with many of his colleagues that even though the students always rated classes and instructors employing the ExCEEd Teaching Model highly, many, if not most, of them were not retaining essential information from one course to the next. The best explanation for the students’ lack of retention was that they were only minimally engaged with the material. Analysis of student time survey data consistently showed that students spent large amounts of time cramming for tests and major projects immediately before the event, smaller amounts of time completing homework the night before it was due, and almost no time in daily preparation.

To rectify this issue various instructors developed a variety of different initiatives. Problem Set Zero (1) experimented with making the first homework assignment in a given class a review of the materials from the previous class. Students were told to expect this assignment, that grading would be binary, and that they would continue to work on the problem set until all questions were answered correctly. The approach, though very time and resource intensive for the instructors, led to an increase in performance in the subsequent course for students who earned a B or C in the prerequisite course. A flipped classroom approach was tried an evaluated by three mechanical engineering instructors (2). Later, the Problem Set Zero concept was modified to a high-stakes exam testing knowledge from the prerequisite class. Evaluation of the data showed (wait for it, this is a shocker) that “hard work and or achievement in the feeder (prerequisite) course is what determined” performance in the subsequent course (3).

Moving from West Point to the Virginia Military Institute in 2014 presented the author with an opportunity to teach Statics and Solid Mechanics in a new school with new students where he hoped to pair effective teaching with engagement and hard work by students to produce better outcomes for students and a more enjoyable experience for the instructor. As the first is epitomized by the ExCEEd Teaching Model and the second is the goal of the flipped classroom, these two courses were restructured by combining the principles of both approaches.
Background

ExCEEd Teaching Model
The ExCEEd (Excellence in Civil Engineering Education) Teaching Workshop (ETW), sponsored by the American Society of Civil Engineers, began at the United States Military Academy at West Point in 1999 and has been offered at West Point and other universities throughout the United States for the past 16 years. The ETW seeks to improve the quality of engineering education by providing faculty members with instruction in learning styles, class and course organization, and principles of effective teaching and learning and then practice these skills in three classes which are evaluated by their fellow ETW participants and the ETW mentors (4).

Founded on the scholarship of teaching and learning, the heart of the ExCEEd workshop and approach are the “Model Instructional Strategy”, see Figure 2, and the “ExCEEd Teaching Model”, see Figure 1 (5). In spite of the many classroom icons now commonly associated with ExCEEd like five colors of chalk, board notes, structured presentations, and theater in the classroom, it is the Strategy and the Teaching Model, rather than the theatrics, which make the ExCEEd approach powerful and broadly applicable as has been shown by recent practitioners.

<table>
<thead>
<tr>
<th>Model Instructional Strategy</th>
<th>ExCEEd Teaching Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Provide an orientation:</td>
<td>• Structured organization</td>
</tr>
<tr>
<td>• Why is this important?</td>
<td>• Based on learning objectives</td>
</tr>
<tr>
<td>• How does it relate to prior knowledge?</td>
<td>• Appropriate to the subject matter</td>
</tr>
<tr>
<td>➢ Provide learning objectives.</td>
<td>• Varied, to appeal to different learning styles</td>
</tr>
<tr>
<td>➢ Provide information.</td>
<td>• Engaging presentation</td>
</tr>
<tr>
<td>➢ Stimulate critical thinking about the subject.</td>
<td>• Clear written and verbal communication</td>
</tr>
<tr>
<td>➢ Provide models.</td>
<td>• High degree of contact with students</td>
</tr>
<tr>
<td>➢ Provide opportunities to apply the knowledge:</td>
<td>• Physical models &amp; demonstrations</td>
</tr>
<tr>
<td>• In a familiar context.</td>
<td>• Enthusiasm</td>
</tr>
<tr>
<td></td>
<td>• Positive rapport with students</td>
</tr>
<tr>
<td></td>
<td>• Frequent assessment of student learning</td>
</tr>
</tbody>
</table>

The versatility and flexibility of these idea has been demonstrated by ExCEEd participants who have used them to improve engineering education under a variety of circumstances. Geiger and O’Neillll applied the ExCEEd principles to a junior level biomaterials course in a bioengineering
program (6). Morse applied the ExCEEEd concepts to develop a special topics course for graduate students to prepare them as teaching assistants and future professors (7). Welch and Farnsworth use the ExCEEEd model as an evaluation standard for assessing and then improving the quality of distance education courses. Their goal was to produce instruction consistent with the ExCEEEd concepts regardless of the medium used (8). As these outstanding educators have demonstrated, the operative part of ExCEEEd is excellence.

**Flipped Classroom Concept**

When the author was first exposed to the concept of the ‘flipped classroom’, his response was, “Oh, this is the Thayer Method; it’s been around since 1820!” As the Superintendent of the United States Military Academy in the early 1800s, Colonel Sylvanus Thayer built the Academy’s educational approach around the idea that “every cadet recites every day.” Cadets were required to read the course textbook, often in French, and then class time was spend answering questions or working problems based on the reading. Professors provided little direct instruction. Though there are certainly common points, the advance of technology has moved the flipped classroom far beyond the original “Thayer Method.”

A growing body of literature exists on the flipped classroom. For those unfamiliar with it, the *Flipped Classroom Field Guide*, available at [http://www.cvm.umn.edu/facstaff/resources/active-learning-classroom-resources/index.htm](http://www.cvm.umn.edu/facstaff/resources/active-learning-classroom-resources/index.htm), provides an excellent primer and is summarized here. The general concept of the ‘flipped classroom’ is that instruction is moved from the classroom to outside of class in various media. The intent is to make class time more available for student centered and lead discussion, active learning activities, practice problems, and instructor mentoring. Figure 3 shows an activity comparison of the traditional and flipped classrooms.

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1 While the author did not hear this personally from Colonel Thayer, he did hear it from several instructors whom he secretly suspected got it directly from Sylvanus himself.
Though it may initially appear so, the flipped classroom is not a ‘throw the kids in the water and then they’ll learn to swim’ approach. The before, during, and after class activities are structured to lead and guide as well as promote student engagement. In class activities are varied to support different learning styles and tailored to the material in individual lessons. Feedback to students is immediate and student misconceptions and misunderstandings are corrected, hopefully, before the student attempts the homework.

Though flipped approaches may vary, successful approaches are reported to share these characteristics.

1. Learning environments are highly structured, often planned to the minute.
2. In class activities involve significant quizzing, problem solving, and other active learning activities to increase student engagement with the material
3. Students are incentivized through grading and instructor expectations to complete out of class work and participate in class activities.

In 2014, Faculty Focus, a publisher of articles and materials for effective college teaching, conducted a survey of its readership on their experiences with the flipped classroom and received 1,084 responses. The first question asked respondents to indicate which of several provided definitions aligned with their interpretations of the flipped class. The top three responses were:

- Students complete pre-class work individually before class and engage in team work and collaborative learning activities during class. 67.80%
• Lectures are recorded as videos for students to view outside of class time freeing up time in class to engage in discussions and problem solving. 59.23%
• The learning environment is designed to switch the focus away from the instructor and toward the students. 58.49%

Five percent of the respondents had never heard of the flipped classroom.

Seventy percent of respondents reported that they had flipped a class and would do so again, with an additional fourteen percent planning to do so in the next year. On the other hand 16% either had tried to flip and would not do so again or had no intention of flipping their classrooms. The survey also asked professor to rate both their experiences and their students’ experiences. The results were interesting.

<table>
<thead>
<tr>
<th></th>
<th>Positive</th>
<th>Neutral</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professors</td>
<td>70.34 %</td>
<td>22.40 %</td>
<td>7.26 %</td>
</tr>
<tr>
<td>Students</td>
<td>64.83 %</td>
<td>25.78 %</td>
<td>9.39 %</td>
</tr>
</tbody>
</table>

These responses confirm what many of us have experienced in many facets of life: the attitude and experiences of the led are shaped by the attitude and experiences of the leader.

Respondents also reported that the biggest benefits observed from moving to a flipped format were:

• Increased student engagement 74.90%
• More learner-centered teaching 66.62%
• Improved student learning 54.66%

For this question eight percent of respondents reported not realizing any benefits. It is interesting to note that across all questions, strongly negative experiences and feelings were consistently reported at about eight percent (9).

We shall end this brief discussion of flipped classroom back where we started at West Point where three junior faculty members updated Colonel Thayer’s educational approach to take advantage of 21st century technology. Dubbed “Thayer 2.0”, the approach included short individual preparatory work, lesson videos for out-of-class viewing, in-class self-paced problem solving, mandatory milestone testing, in-class demonstrations, and in-class time allocated for homework, and was evaluated in the Thermal Fluid Systems course. The authors’ perceptions and experiences are illustrative of the challenges of flipping a classroom. First, students who expect to be lectured in class have to be re-socialized into taking responsibility for learning and preparing before class. Students initially refused to watch the pre-class videos hoping their recalcitrance would spur the instructor into resuming the lecturers. When the instructors did not, video observations increased and peaked before the final exam. Second, as suggested by the first, instructors must not lecture. Third, incentives are valuable and must carry sufficient
weight. In the experiment, quizzes based on pre-class preparation accounted for 30% of the course grade (2).

**Combination Principles**
These principles guided the development of the two new course structures. Some were intended beforehand and some developed as the courses were developed, taught, and modified.

1. **Develop the courses together.** Solid Mechanics follows Statics so linking the two courses in concept, teaching format, structure, and texture should assist in student learning.

2. **Deliberate socialization.** One, often unstated, affective domain objective of Statics is to ‘socialize’ students on how one studies engineering and what it means to be an engineer. We have a certain vocabulary, a way to approach problems, a diligent work ethic (if we want to make it as engineers), and, of course, cool green engineering paper! Students learn to appreciate each of these through contact and engagement with them. For this project, the learning framework in Statics should prepare the student to be a more engaged, deliberate, and responsible student in Solid Mechanics.

3. **Build on successful practice.** Both the ExCEEd Teaching Model and the flipped classroom have been shown to work. Deliberately combine both so that the offspring is more than the sum of the parents.

4. **Structure for student engagement.** The original driver of the work was the observation and sense that students were simply not doing very much work. While the students cannot be compelled to work, the courses should be structured to give students multiple opportunities to engage in work, receive feedback, and attempt again.

5. **Apply Motivation 3.0.** In *Drive*, Daniel Pink (10) analyzes what motivates us and different forms of motivation. Motivation 1.0 describes motivations driven by physiological needs: food, water, shelter, companionship. Motivation 2.0 achieves outcomes through the use of rewards and punishments. Pink describes research that demonstrate that while this approach can work well for routine tasks, it actually harms performance on higher-order, creative, cognitive tasks. For these we need Motivation 3.0 which taps into the human desire for creativity and both self and societal growth and development. To apply Motivation 3.0 in a classroom, one needs to provide for:

   - **Purpose:** Why, beyond the course requirement, is the student doing the work?
   - **Autonomy:** The student must have some control over what is learned, how it is learned, when it is learned, and the work schedule.
   - **Mastery:** The student must have time and opportunity to achieve mastery of tasks.
Clearly this relates to the socialization principle above, and in the long run is essential to student success. Both Pink and Friedman (11) suggest that the vast majority of job growth in the foreseeable future requires the critical and creative thinking fostered and encouraged by Motivation 3.0 yet inhibited and retarded by Motivation 2.0.

6. Acknowledge the realities of the internet. All solutions to all published problems can be found on-line, often for free. Additional and alternative explanations for everything in a Statics or Solid Mechanics course are available on line for the low, low price of absolutely free.

**Course Structure**

At the Virginia Military Institute, Statics and Solid Mechanics are both 3.0 credit hour courses with 42 attendances meeting 3 times per week for 50 minutes. Class sizes typically range from 8 to 20 students with sufficient chalk board space for eight groups of two students to work at the chalk boards. Wireless internet connections are available in the classrooms along with a computer work station and projector for faculty. This section explains the course components that support both the application of the ExCEED principles and the flipped classroom environment.

**Course Notebook**

A principal tool for learning, socialization, and course structure for the classes are the course notebooks. For each class, at the beginning of the semester, students are given 42 tabs, and 42 advanced sheets, one for each lesson, and told to buy a 3 ring binder for the purpose of keeping everything associated with each lesson in that lesson tab. The table of contents for the notebook is the course schedule which lists the topics for each of the 42 lessons. Each advanced sheet contains the lesson title, lesson learning objectives, and questions or practice problems related to that lesson. Before class, students are expected to review the lesson objectives, read the assignment, answer the assigned questions, and work the pre-class problems. Questions are all based on the reading assignment and are focused on definitions, formulas, and fundamental concepts. For example, in Solid Mechanics, students might be asked to define prismatic, homogeneous, and isotropic. Pre-class problems are fundamental in nature requiring use of particular concepts, but not extensive in calculations. For example, in Statics a student might be asked to find the internal force in a single member of a simple truss using the method of sections. Pre-class work is peer-evaluated at the start of each lesson. The top header of the advanced sheet contains the words “GO  NO GO.” If the peer-evaluator feels that the student made a good faith effort to prepare for class, then on it which the evaluator circles GO, otherwise NO GO. Good faith does not mean the work has to be completely correct; simply that the student tried to prepare for class, usually evidenced simply by lots of pencil marks. Prior to each exam, the instructor evaluates student portfolios and typically checks class preparation from two lessons, class notes from two lessons, and the presence of homework for two lessons. If the material are present, then points are awarded. From a pedagogical perspective the intent of the notebook is to
cause students to take responsibility for learning the material; from a socialization perspective, the intent is to demonstrate and practice organizational techniques and deliberate preparation so students experience the value of both.

Course Lesson Structure
With students expected to acquire fundamental knowledge before class, more time is made available in class for discussion, practice, and other activities. In statics, after administrative and exam lessons are discounted, there are 38 instructional lessons which cover 18 primary topics, more or less. These 38 lessons are split between theory lessons and problem solving sessions. The theory lessons look like what one would expect from any ExCEED graduate: five colors of chalk, high level of contact with students, questions, physical models, example problems hatchets, and the occasional doughnut in the trashcan. Before the problem solving lessons, the lesson advance sheet directs students to complete one basic problem for the lesson topic. During the problem solving lessons, students work at the boards or their desks in groups of two and complete one or two problems for that topic. The instructor provides guidance, focused instruction on sticking points, and correction. Students also correct and assist each other on the problems and check their work using the back of the book answers, which in the selected textbook, include partial worked out solutions. The paired lesson structure is a mechanism for socializing students to participate in directing their own education. The theory lessons presented in the traditional style are comfortable to them, provide a high degree of structure and professor-student interaction, and equip students to complete the work in the subsequent problem solving lessons. Throughout the semester, the course structure causes students to work, individually or in pairs, an average of five problems on each topic. Managing and directing their own learning in the problem solving lessons prepares them for Solid Mechanics.

Solid Mechanics is also has 38 instructional lessons which cover about 28 topics. Every instructional lesson, except one, in Solid Mechanics is flipped with students preparing for class by reading the textbook, watching recorded instructional materials, and completing either questions or fundamental problems. In class five to ten minutes are spent on demonstrations or models, a single ‘board’ reinforcing critical or confusing points, or discussing complex topics which develop from the pre-class work. For example, during the lessons on column buckling, pre class work focuses on the Euler buckling equation enabling detailed in class discussions of the collapse of the Quebec Bridge. Simpler topics like longitudinal strain are covered in one lesson while more complex topics like shear and moment functions and diagrams are allocated three lessons to provide more practice opportunities. In Solid Mechanics, students who complete all pre-, during-, and post-class problems will work almost 350 problems during the course of the semester.

Homework
Upon completion of the problem solving lessons for each topic in both courses, students are assigned two to four homework problems on the topic. In Statics there are 18 and in Solid
Mechanics 25 homework assignments of two to four problems each. Because solutions are available on the internet anyway, instructor provided solutions to all problems are provided on the university learning management system at the start of the course. Homework grades are submission grades only—points are awarded if the student did the work. Students that complete the work on their own and students that copy the solutions both receive full credit. Students are required to complete a coversheet where they report how much assistance, from doing the work themselves to copying the solution, they received. Because the solutions are detailed and include process notes, students are thus able to self-correct their own work. The learning assessment on the cover sheet allows students who have copied most solutions to own up to the fact that they have not learned the material and therefore know they will not do well on the test even before they complete it.

The homework coversheets also employ a version of the ‘muddiest point’ classroom assessment technique. At the bottom of the coversheet, students are asked to write the aspect of the problems that are causing confusion or difficulty. The instructor’s grading time is then spend writing specific comments based on each student’s points of confusion. Rather than trying to deduce student error and guess at student issues, the instructor’s time is spend directly on addressing issues and concern.

**Exam structure**

Both Statics and Solid Mechanics have three exams and a final. Each exam covers six to eight topics and has one question on each topic. The final exam for Statics has 21 and Solid Mechanics has 19 questions, which is the total number of questions asked on the exams. Students are therefore afforded two chances to answer a question on each topic with the grade for the topic being the higher of the two attempts. For example, exam 2 in Statics has a question on truss analysis as does the final. The possible outcomes for a student are:

- Student correctly completes truss question on exam and does not need to answer that question on the final. Student receives grade earned on the exam for this topic.
- Student does not attempt truss question on exam and attempts it on the final. Student receives grade earned on the final for this topic.
- Student does poorly on truss question on exam and elects to complete the truss question on the final. Student receives the higher of the two grades.

By having one question for each major topic of the course, students end the course with an assessment of the degree to which they have mastered the essential knowledge. In other words, they know what is required to master the course and they know what they know and what they do not (12).

**Grading**

Exam problems are graded on a 0 to 4 scale which can be viewed two ways. The obvious one is each letter corresponds to the standard letter grades F to A. The other is a professional
performance standard developed by the author that related grades to office work. It is related to
students as, “If you worked form me in an office I would give you a

4 if the work is right and ready to go to the client.
3 if the work requires some correction, but once the corrections are made, send it to the
client without further review.
2 if the work is going to require a couple of revisions and checks by the boss before it is
ready to send to the client
1 if the work on the page could be developed into something useful
0 if the work is wrong or blank.

This is a more honest grading scale with the students. Under the traditional scale, if a student
gets a 0 on a 100 point problem, then it requires perfect scores on the next seven 100 point
problems to get back to a B average. Using the 4 point scale, a zero on the first problem can be
redeemed to a B by only three additional problems with perfect scores; a condition which still
required effort but is more achievable.

Evaluation by the Principles
The basic principle of the flipped classroom is that instruction is moved out of class and practice
and assessment are moved into class. This is clearly achieved in both courses where half of the
lessons in Statics and almost all lessons in Solid Mechanics are ‘flipped’. The learning
environment remains structured through the course notebook and in in class practice problems
which are designed to build the student’s understanding of each topic. Student engagement is
further maintained by discussion, demonstrations, and physical models.

In the ExCEEd teaching workshop, the teaching model and instructional strategy are used for
class and course evaluation and will be used here to see if the course structures comply with the
models. The Model Instructional Strategy bullets from Figure 2 are shown below with
assessment comments in the sub-bullets

➢ Provide an orientation:
   • Orientations are provided through stories, discussions, articles, and direct
     instructor references to past and future lessons.
➢ Provide learning objectives.
   • Provided in course notebooks in both courses and discussed in class.
➢ Provide information.
   • In Statics, basic information is provided in reading assignments and during the
     theory lessons and supplemented with a few videos.
   • In Solid Mechanics, information is provided in reading assignments and mainly
     through recorded video lessons.
➢ Stimulate critical thinking about the subject.
• With more time available in class, more discussion requiring critical thinking are possible (provided the students come prepared).

➤ Provide models.
  • Physical models remain an extensive part of in class demonstrations.

➤ Provide opportunities to apply the knowledge:
  • Students have about five opportunities to encounter and apply knowledge as they typically engage with one pre-class problem, two in-class problems (with peer and instructor feedback), and two homework problems (with instructor feedback) per key topic prior to having two opportunities to demonstrate performance on this topic on exams.

➤ Assess the learners’ performance and provide feedback.
  • Student performance is assessed and feedback provided during in-class work and with the ‘muddiest point’ comments on assigned homework.

➤ Provide opportunities for self-assessment.
  • All problems assigned have some form of textbook or instructor solution provided so students are able to assess their own work on practice problems and homework problems. Through the use of the homework coversheet, students assess their ability to complete problems without assistance and determine if they need more practice on a given problem type.

The ExCEEd Teaching Model bullets from Figure 1 are shown below with an assessment against each.

• Structured organization
  o The focus on learning objectives is maintained in the course notebook and structure. Problems are appropriate for the course and student knowledge levels. With about five problems worked for each concept, student engage with problems of increasing difficulty. Varying the approach to appeal to different learning styles is the most difficult part. Students that cannot be self-motivated and self-directed really struggle in this environment

• Engaging presentation
  o Clear communication, both written and verbal, on recorded videos is essential and is more difficult than in the classroom. Because students will not watch videos longer than about 8 minutes and there is no opportunity to offer alternative explanations in response to verbal and non-verbal cues, the instructional videos must be clearly understood.
  o Within the classroom, student contact is increased during working sessions and is more personal. Physical models & demonstrations remain and are conducted in class.

• Enthusiasm
Beyond enthusiasm for the subject matter, instructors in a flipped classroom must also be enthusiastic about the course structure. If the instructor does not like it, the students will not like it.

- Positive rapport with students
  - No change from a standard structure
- Frequent assessment of student learning
  - Students get more personal assessment through in-class interactions in working sessions than they would otherwise. By providing homework solutions and using the ‘muddiest point’ on homework coversheets, students receive specific feedback on problem areas.
  - The exam structure provides students an overall assessment of how well they know each of the course’s major concepts.
- Appropriate use of technology
  - Though flipping is possible, without current technology, it is less effective. This approach relies on the technology.
- Teacher as a positive role model
  - No change from standard structure.

Though at first glance, these two courses may not look like ExCEEd based courses, evaluation by these principles demonstrates that they are.

**Assessment by Students**

The real test of this approach is how well it works with the students. A survey was conducted of the students in Statics in Fall, 2015 with 34 of 61 students responding. Survey questions and answers are presented. Based on the responses, it appears that the course structure and organization function as intended, although the true level motivation is difficult to assess. What one student might consider highly motivated, the instructor might view as only slightly interested. These responses seem consistent with instructor-student conversations outside of class, particularly for exam motivation. Students actually wanted to take the final exam because of the strong potential for improving their grade with little risk of damaging it.

What is the impact of the homework grading scheme on your MOTIVATION to complete the homework?

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>% Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>It really kills my motivation. I don't see the point in doing it this way.</td>
<td>0</td>
</tr>
<tr>
<td>Without the pressure to earn a grade, I'm a little less motivated</td>
<td>21%</td>
</tr>
<tr>
<td>I'm a little more motivated because I know I can get help if I'm stuck on a few points.</td>
<td>29%</td>
</tr>
<tr>
<td>It really improves my motivation because I can focus on learning without worrying about blowing my grades.</td>
<td>50%</td>
</tr>
</tbody>
</table>
The readings and pre-class work are designed to get you ready for class—to prepare you with fundamental information or allow practice of basic skills. Please evaluate the pre-class work on how it affected your learning:

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>% Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>It was just busy work that I did not put much effort into</td>
<td>12%</td>
</tr>
<tr>
<td>I did it, but I didn’t really get much out of it.</td>
<td>9%</td>
</tr>
<tr>
<td>I found it slightly helpful, but I have trouble learning from the book or working new problems on my own.</td>
<td>56%</td>
</tr>
<tr>
<td>I found it very helpful in learning the material, and came to class prepared for the lectures or practice problems.</td>
<td>23%</td>
</tr>
</tbody>
</table>

In this class I asked you to write your most confusing issues with each homework on the cover sheet. How often did you do this?

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>% Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>9%</td>
</tr>
<tr>
<td>1-2 times per semester</td>
<td>29%</td>
</tr>
<tr>
<td>3 or 4 times per semester</td>
<td>50%</td>
</tr>
<tr>
<td>5 or more times per semester</td>
<td>12%</td>
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</table>

For the times you included questions on your homework, please evaluate my responses as:

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>% Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>I never asked questions.</td>
<td>9%</td>
</tr>
<tr>
<td>not really helpful</td>
<td>0%</td>
</tr>
<tr>
<td>somewhat helpful, but I was still confused</td>
<td>3%</td>
</tr>
<tr>
<td>slightly helpful, but I still had to figure some stuff out</td>
<td>50%</td>
</tr>
<tr>
<td>the responses fully answered my questions</td>
<td>38%</td>
</tr>
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I found the course notebook with tabs:

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>% Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Just a haze. Don’t like it and will never do it this way again</td>
<td>0</td>
</tr>
<tr>
<td>Not a problem, but not really useful to me either</td>
<td>6%</td>
</tr>
<tr>
<td>Slightly helpful in organizing the material and helping me learn.</td>
<td>6%</td>
</tr>
<tr>
<td>Extremely helpful in organizing the material and helping me learn.</td>
<td>88%</td>
</tr>
</tbody>
</table>
The in class working sessions are designed to allow you practice key concepts and get help with points of confusion. Please evaluate the working sessions by checking all that apply:

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>% Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>I did not get much out of them because I did not put much effort into them.</td>
<td>0%</td>
</tr>
<tr>
<td>I really tried to do the work, but I did not find it helpful.</td>
<td>0%</td>
</tr>
<tr>
<td>The instructor was able to answer my questions and it helped me understand the concepts.</td>
<td>65%</td>
</tr>
<tr>
<td>I needed more help from the instructor than he had time to give.</td>
<td>15%</td>
</tr>
<tr>
<td>I found that answering my classmates’ questions helped me to learn and understand the material.</td>
<td>50%</td>
</tr>
<tr>
<td>When I asked questions of my classmates, their answers helped me understand the material.</td>
<td>56%</td>
</tr>
<tr>
<td>Overall, I liked the working sessions and the helped me master the material.</td>
<td>79%</td>
</tr>
<tr>
<td>Overall, I did not like the working sessions and they did not help me master the material.</td>
<td>6%</td>
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Given the exam structure for the course, my MOTIVATION to take exams in this format is

<table>
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<tr>
<th>Answer Choices</th>
<th>% Responding</th>
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<tr>
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<tr>
<td>Slightly higher than the ‘normal’ way</td>
<td>26%</td>
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<tr>
<td>Much higher than the ‘normal’ way</td>
<td>74%</td>
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**Conclusion**

The author has long suspected that every advance in pedagogical theory has been just another attempt to get the students to do the work; the same is true of the approach presented here. This approach does not make the instructor less engaged in the classroom or with students, but it does provide an opportunity for students to be more engaged. If it works, it works for the simple reason that it presents students with the opportunity to work LOTS of problems with a course and grading structure that encourages them to do so. Thus, it hopes to build in them the habit of working diligently to acquire knowledge and master skills. Hallway conversations with former students indicate that this does happen, but, as always, it is only for those who want it.

The author will make available all course materials from Statics and Solid Mechanics to anyone who wants them.
Appendix: Sample Lessons
This appendix contains sample lessons from both Statics and Solid Mechanics. For Statics, the course schedule along with a lesson sample for the Truss Analysis Theory and Problem Solving lessons are shown. The lesson samples show the advanced sheet from the student notebook, board notes, and instructor provided solutions. For Solid Mechanics, the course schedule and the two advanced sheets for the Statically Indeterminate Systems are shown.
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<th>Homework</th>
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Lesson 24: Truss Analysis—Theory

Lesson Objectives
1. State the assumptions for truss analysis.
2. Determine forces in a truss member using the Method of Joints.
3. Determine the forces in a truss member using the Method of Sections.
4. Identify zero force members in a truss.

Reading Assignment: Hibbeler, 6.1 to 6.4.

Notes from the reading assignment:
1. Define a truss.

2. State the truss assumptions.

3. What is the difference between the method of sections and method of joints? (make the explanation simple)

4. What are the rules for identifying zero force members?
TRUSSES
- SLENDER MEMBERS
- PIN CONNECTED [FIG 6-3]
- LOADS @ JOINTS
- ALL 2 FORCE MEMBERS
- LONG SPANS w/ LIGHT WEIGHT

GIVEN
- \( F_{10}, F_{20}, F_{30}, \) \( \text{Ans} \)
- \( F_{10}, F_{20}, F_{30} \)

FIND: \( F_{10}, F_{20}, F_{30}, \) \( \text{Ans} \)

6.2 METHOD OF JOINTS

FREE BODY DIAGRAM

- \( F_{10}, F_{20}, F_{30} \)
- \( F_{10}, F_{20}, F_{30} \)
- \( F_{10}, F_{20}, F_{30} \)

2 UNIQUE: \( zF_k, zF_{k+2} = 0 \), 2 UNKN (??)

\( 4E+10 = 0 \) \( +15k + 10 \) \( F_{10} \)
\( F_{10} = -33.54k \)

\( 4E+10 = 0 \) \( +15k + 10 \) \( F_{10} \)
\( F_{10} = 33.54k \) \( \text{Ans} \)

\( 2F_k + 20 \) \( F_{10} + 10 \) \( F_{10} \)
\( F_{10} = -20 \) \( -33.54 \)

\( F_{10} = 29.56 \) \( \text{Ans} \)

6.4 METHOD OF SECTION

- NON-COMPL. FORCE SYS.
- 3 UNKN: 2 UNKN (??)

\( \Sigma M_c = 0 \)
\(-15k(40) + 10k(20) - F_{10k}(10) = 0 \)
\( F_{10k} = -40k \)

\( F_{40k} = 40k \) \( \text{Ans} \)

\( \Sigma F_y = F_{10k} \)
\( \Sigma F_x = F_{10k} \)

\( \text{Ans} \)
6.3 Zero Force Members

- Z MBRZ: 3 UNKS...
- \( F_{hL} \Rightarrow F_{hL} \Rightarrow F_{hL} \) (Indicate, 2 Load)

\[ F_{cL} = 0 \]
\[ F_{cL} = F_{cL} \]
\[ F_{cL} = 0 \] (Indicate)

**Why:** Stability

- Other Loadings

**Rules**

- MBRS W/O LOADS
- Z Non-Linear W/O LOAD
- Z Linear
  +1 W/O LOAD

Finding ZFM Can Speed Solution
Lesson 25: Truss Analysis—Problem Solving Session

Lesson Objectives
1. State the assumptions for truss analysis.
2. Determine forces in a truss member using the Method of Joints.
3. Determine the forces in a truss member using the Method of Sections.
4. Identify zero force members in a truss.

Reading Assignment: Review Hibbeler, 6.1 to 6.4.

Before Class Practice: Work Problem F6-3

Given:

Find:

Solution:

In class exercises: Exercise #1: F6-7
Exercise #2: F6-12
Homework 13: Problems 6-15, 6-41
Given: Truss W/ loads shown

Find: Forces in all members & state T or C

Solution:

1. Reactions

\[ \text{Free Body Diagram (FBD)} \]

Equilibrium:

\( \Sigma M_D = 0 \):

\[ 400 \text{lb}(30') + 400 \text{lb}(20') - A_Y(30') = 0 \]

\[ A_Y = 66.7 \text{ lbs} \]

\( \Sigma F_Y = 0 \):

\[ -400 + A_Y - 400 + D \sin 60 = 0 \]

\[ D \sin 60 = 133 \]

\[ D = 154 \text{ lbs} \]

\( \Sigma F_X = 0 \):

\[ A_X - 400 \cos 60 = 0 \]

\[ A_X = 154 \cos 60 = 76.8 \text{ lbs} \]

2. To determine zero force members

CE: No load \( @ \) E, \( \perp \) members

\( CE = 0 \)
2. Method of Joints

\[ \Sigma F_y = 0 \]
\[-400 + 667 + \frac{3}{2}AB = 0 \]
\[ AB = -378 \text{ lbs} \]
\[ AF = 190 \text{ lbs} \]

3. Method of Sections

\[ \Sigma F_y = 0 \]
\[ + \frac{3}{2}DC + 153 = 0 \]
\[ DC = -188 \text{ lbs} \]
\[ EO = 56.1 \text{ lbs} \]

Always assume tension matches assumption at joint A. Sub in the -378 to correct direction.

\[ \Sigma F_x = 0 \]
\[ -400 + \frac{3}{2}AB + BF = 0 \]
\[ BF = 261 \text{ lbs} \]
\[ F_x = 0 \]

\[-BC - \frac{1}{2} CF + \frac{1}{2} 96 = 0\]

\[-267 - \frac{1}{2} 188 = \frac{1}{2} CF\]

CF = 190 lbs = 190 kips (T)

All units LBS

Check: \[ F_y = 0 = -400 - 400 + 667 + 133 = 0 \]
**GIVEN**

TIES SHOWN w/ WIND LOAD

**END**

FORCE IN

\( FG, F_G, CB \)

\( 3 \text{ m} \)

\( F_G, \text{ etc.} \)

\( 3 \text{ m} \)

\( \text{STATE force} \)

\( 3 \text{ m} \)

\( \text{A} \)

\( \text{P} \)

\( \text{D} \)

\( \text{E} \)

\( \text{B} \)

\( \text{C} \)

\( \text{H} \)

\( \text{M} \)

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\( 900 \text{ N} \)

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Final Exam
Lesson 9 Statically Indeterminate Systems I

Objectives:
1. Explain, in your own words, the concept of compatibility and how it can be used to solve statically indeterminate problems.
2. Use compatibility conditions and the load-displacement relationship to solve statically indeterminate problems (axially loaded members only…beams come later 😎)

Before:
Read: Section 4.4
Study: Examples 4.4, 4.5, 4.6 and 4.7
Pre-Class work:
1. How do you know if a structure is statically indeterminate?

2. Compatibility requires that the _________ at a point on one section of a structure is __________ as the _________ of that point when it is considered on a different section. (I’m not sure I have written this well. Can you help me right a better one?)

3. On page 139, is there another way, perhaps easier, to arrive at the expression $F_4L_{AC}/AE - F_3L_{AC}/AE = 0$? Hint: Draw member ABC of FIG 4-10(a) and then displace point C downward. Label the displacements ($\delta_{AC}$ and $\delta_{BC}$) and see if you can relate them.
4. Study example 4.5 and write out the solution in your own and make notes on the steps.

In class questions:

1. How do you get from the equation listed in question 3 (it’s the 3rd equation down on page 139) to the fourth equation down on page 139?

2. In example 4.5, why can we not divide the 9 kip load to the brass and aluminum based on their areas?

3. What is your preferred method for solving a system of 3 simultaneous equations? (Bonus question: How do you know if you did it right?)

4. Using equilibrium, how many unknowns can we solve for? How about with equilibrium, compatibility, and load-displacement relationships?

Preliminary Problems and Fundamental Problems are not provide for this section. Instead, we will work the following problems in class: 4-31, 4-33

Homework: See Lesson 10. We will do one set of problems for Lessons 10 and 11.
Lesson 10 Statically Indeterminate Systems II

Objectives:
1. Explain, in your own words, the flexibility (also called force) method for analyzing statically indeterminate axially loaded members.
2. Use the flexibility (also called force) method to analyze statically indeterminate axially loaded members.

Before:
Read: Section 4.5
Study: Example 4.8
Pre Class Work:
1. What is the difference in the methods explained in section 4.4 and 4.5?

2. Work Problem 4-37.
In class questions:

1. When would you choose to use the flexibility method and when would you choose to use the compatibility method? In other words, how do you tell which method will make solving the problem easier?

Preliminary Problems and Fundamental Problems are not provide for this section. Instead, we will work the following problems in class: 4-37 and 4-63

Homework: 4-35, 4-39, 4-47 (this problem is tricky—make the right checks... the first question is does the gap close under the load or not? How do you know if it does or does not?)
Bibliography


