Practical approach towards teaching a content intensive subject in higher education

Prof. James Lambrechts P.E., Wentworth Institute of Technology

James Lambrechts received a B.S. from the University of Maryland and an M.S. from Purdue University, both in civil engineering. He was a geotechnical engineer for 27 years with Haley & Aldrich, Inc. in Boston before taking a position at Wentworth in 2005.

Dr. Anuja Kamat, Wentworth Institute of Technology

Anuja Kamat is an Associate Professor in the Civil Engineering Department at Wentworth Institute of Technology, Boston. Prof. Kamat received her Ph.D. in Civil Engineering from the University of Arizona, Tucson and MS in Civil Engineering from the University of Illinois, Urbana - Champaign . She also has a BE in Construction Engineering from University of Mumbai and Diploma in Civil Engineering from Government Polytechnic, Mumbai. Prof. Kamat's research is in the areas of reinforced and prestressed concrete, concrete blocks and engineering education.

Ron Frattura

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Abstract

While teaching a largely content intensive course in an engineering school, it is often a challenge to achieve student learning and retention of the course material. The students tend to be overwhelmed with the large quantity of the technical content that they need to read and remember. To facilitate student learning in such courses, a strategy using several methods has been used. Methodologies used for teaching one such course are presented in this paper. To encourage student notetaking, a study guide sheet to follow along with the PowerPoint is provided. This sheet is made such that it had enough missing information to encourage student filling in the notes. At the same time the size of the sheet was kept to one page for every week to make sure that it is not overwhelming to the students. The slides were made available at the start of each class. The learning system also uses available, applicable technical videos (information and case histories). Homework was built to serve as a study aid and graded mostly for completion. Answering homework questions necessarily leads the student through the slides, the text and study guide sheet. A number of the homework questions require students to delve into the textbook which is hoped to increase student curiosity, and perhaps to encourage them to read the entire chapter. A quiz every week, based on the study guide sheet and homework is intended to encourage timely study patterns. To do well on these rather low stakes quizzes did need a little more preparation than attending classes and doing the homework. A comprehensive final exam and a research paper concluded the course. At the end of the course, the students were given a survey to evaluate the effectiveness of these methodologies. What worked, what did not work and why, is then discussed in this paper, along with suggestions for improvement.

Course Overview:

Civil Engineering Materials is a largely content intensive course. This course involves study of elemental and behavioral properties of iron, steel, aluminum, aggregate, cement, concrete, asphalt, plastics, and polymer composites, and fiber reinforced concrete. This includes describing the molecular composition of each material studied and relating its composition to the material's behavior in civil engineering structures. It also includes describing the stress-strain behavior of each material studied and learning the important aspects of their behavior in their common applications in civil engineering structures. The strength and composition properties of the materials studied., and their expected deformation responses to applied loadings is also an important part of this course. Additionally, the detrimental aspects of long-term use of each civil engineering material studied, which can occur by environmental chemicals and/or climatic effects, or by repeated loading, or combinations and methods commonly applied to mitigate the various detrimental effects of environmental factors and repeated loadings on civil engineering materials used in structures are studied. Finally, the effects that methods of materials production have on material properties are studied. The primary reference used in this course was by Domone and Illston [1], with supplements from Mamlouk and Zaniewski [2], and Callister [3].

In recognition of the content intensiveness of our C.E.Materials course, the instructional process was developed to have students "learn" information while answering homework questions. This process was useful 7 or 8 years ago when it seemed that students did not mind digging into their text books and the provided extra reference materials (via class handouts). Many students complained that homework alone was not focused enough, or that there was too much information to know for them to do well on the weekly quizzes. Therefore, the weekly study guide sheet was developed in 2014-5 to provide a list of better focused topics that could be on the weekly quiz. Information presented in lecture was then primarily via lecture and board writing, progressing through the study guide list. Through 2017, 2018 and 2019, all of the information presented in lectures was converted into PowerPoint slides, some of which were simply highlighted parts of the text or other references. The slides are made available to students through Blackboard. Also posted on Blackboard are listed of "Helpful Videos", usually 4 or 5 per week that have been 'discovered' on YouTube, which present portions of the week's content. When appropriate, the students are asked to view a video prior to class, but only a few ever seem to have the time to view these before class. Many do comment that they often view some of the videos while writing their homework answers for the week.

With as much content as the C.E.Materials course contains, it has been considered essential to use weekly quizzes to measure student learning/retention on a week to week basis. Each quiz contains 20 to 25 questions, most of which require brief explanations or are fill-in-blank. Retention at the end of the semester is gauged by a comprehensive final exam, which contains 10 questions from each of the 12 semester quizzes.

Learning Models:

While there are a number of learning models widely discussed and applied, such as project-based learning, online learning, personalized learning, and so on. Three that appear to be more popular among engineering educators are the active learning model, the flipped classroom model, and the ExCEEd model. Our opinions of the usefulness of these three in the CE Material course are as follows with brief description of each.

Active learning model: [4] In this model, students are "active" participants in learning. This is the model we have utilized most extensively. Our use of this model had students participate in the learning by writing on the study guide sheets. We observed that many students would write notes in the provided blank spaces, but others would just sit and listen to the lecture and watch the PowerPoint slides. There might be too much information for the students to fully comprehend and digest during the lecture presentations, so the active students would not fill in all the answers during lecture. However, even a partially filled-in study guide sheet would provide a strong basis for the students to complete each week's homework assignments and study for the weekly quiz. It has been reported that active writing by hand helps in retention of information [5].

Flipped classroom model: [6] This model encourages the student to learn the content before coming to class, and then to use the class time for deeper understanding and assisting retention. While this pre-lecture viewing of videos or other content was tried only on limited basis, most students complained that they needed to be guided through the extensive technical material. We have had success with providing videos for student viewing and study after class as a way to

reinforce lecture materials and provide a second format for *active learning*. While it would be nice for the students to watch key videos and do some of the week's reading before coming to class, once the students fall behind in a semester, as many of ours invariably do, it is nearly impossible for them to get caught up and "move ahead of the time curve".

ExCEEd model:[7] This model discourages the use of PowerPoint presentations in class and encourages the use of the instructor writing on the whiteboard. The model also encourages the use of in-class demonstrations. The author used this model in Statics 1 class after attending the ExCEEd workshop. It worked well for an analytical-mathematics-based class. Study of this model led to a realization that this model was largely applicable for use in an analytical-mathematical course. However, this model had been used in the first three years of this course in 2012 through 2017. The first two years were presented without the Study Guide sheets, and students complained heavily about the great volume of content they were expected to acquire and retain. The students were then expected to take extensive notes, read and study the textbook, and learn when answering the homework questions. But two years, it became obvious that the study guide sheets were needed to give the students specifics on content they could be quizzed on. The ExCEEd model is used in part to supplement information transmitted via the PowerPoint slides.

Instructional methodology:
While the course presentation would hope that the students would prepare for each class by reading the assigned textbook materials and by viewing recommended videos to be ready to participate in discussions during lecture, the reality is that the students are fairly passive receptors. While presenting the lecture's materials via the day's PowerPoint slides, questions are occasionally posed by the instructor to initiate and foster discussion, and to make the students try to remember information from prior lectures that also apply to the current topic.

To facilitate ongoing learning, weekly homework sets and quizzes are given throughout the semester. Usually there were 11 to 12 quizzes based on 11 to 12 homework sets. Quizzes are based on the material covered in lecture the preceding week and are given in the first 25 minutes of lecture, typically on Wednesday. The quiz questions are largely simply restatements of the questions on the week's study guides. Make-up quizzes are not given in this course, except as may be warranted for very extraordinary illness circumstances. Homework Assignment Sets in the form of questions and problems, given weekly do provide exercise on each topic, and are due the Wednesday of each quiz. All homework assignments must be hand-written (which is noted to aid in learning and retention of information, and of course done individually. All assigned work must be handed in on time. Late work is not accepted.

A research project was also assigned during the middle of the semester on steel materials engineering topics. Each student prepared a concise report on an assigned topic, which they each selected from a list provided by the professor. Generally, three typed, single-spaced pages in length were required. The topic was on specific material aspect of steel.

Final Exam is given during the assigned final exam period. It was cumulative for all material covered during the semester, and contains questions only from weekly quizzes. in preparation for the final. 10 questions of the 22-25 on each weekly quiz are used. The students were told several days ahead of final exam day which 6 to 8 questions from each quiz will not

appear on the final. Also, minor changes to quiz questions are always needed to make fill-in-blank and explanation answers from the quizzes apply to multiple choice (or true/false) questions on the final.

Topics covered in the class:

This course covers various C.E. Materials topics including metals, concrete, asphalt and polymer. The order and grouping of presentation are:

1. Basics of Materials, Atomic Structure, Properties, Behavior
2. Properties and Behavior of Metals: Iron, Steel, Aluminum
3. Composition, Properties, Behavior, Deterioration of Concrete
4. Composition, Properties, Behavior, Deterioration of Bituminous Material
5. Types of Composites, Properties, Durability of Polymers, Fiber Reinforced Polymer, Fiber Reinforced Concrete

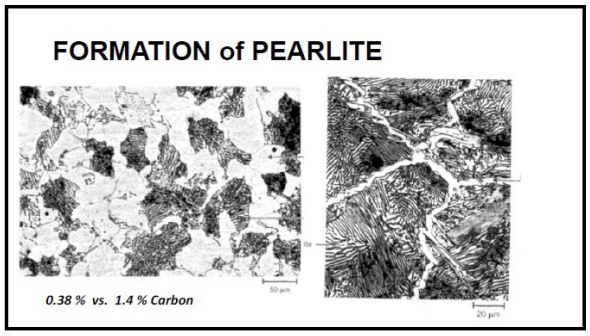
Sample of Student's Weekly Course Activities:

A week in the Civil Engineering Materials class should include the following elements: viewing of specific recommended videos prior to class; lecture presentation based on PowerPoint slides compiled to explain each key topics on the weekly study guide; filling in the study guide during lecture and afterward while writing answers to questions on homework assignments; studying for weekly quiz, based on study guide.

Attached below are four examples of the content taught in Week 5 (excluding reading and videos). In each of the Figures (1-4), four components of the class are shown which include the PowerPoint slides, the study guide accompaniment, the relevant homework question and the quiz question based on this topic. The students are given a copy of the slides, study-guide and the homework set every week. In addition, the same content is also made available on Blackboard.

Example 1 is shown in Figure 1a-1d with, Figure 1a showing PowerPoint slide, Figure 1b. showing the Study Sheet, Figure 1c. showing the Homework and Figure 1d. showing the Quiz question for Example 1. All four figures show how the topic "Pearlite", is taught in Week 5. Similarly, Example 2, 3 and 4 are shown for the topics Embrittlement, Rebar and Fire.

Example 1



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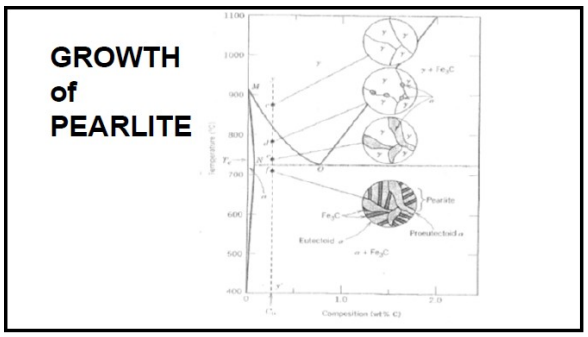

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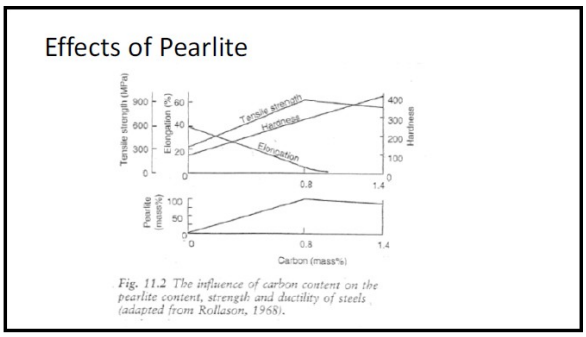

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Figure 1a. PowerPoint slide for Example 1 (Pearlite)

What is *'pearlite'*, How formed? _____

How does *pearlite* chemical composition _____

vary? Affect on hardness, strength, ductility? _____

Figure 1b. Study Sheet for Example 1 (Pearlite)

5.4 What is 'pearlite'? How does it form? What is its chemical composition? What does pearlite look like? What is the effect of the carbon content of the steel on the pearlite that forms? What are the: hardness, strength, ductility and toughness of pearlite?

Figure 1c. Homework for Example 1 (Pearlite)

5. Describe the structure of **Pearlite**? _____

Figure 1d. Quiz question for Example 1 (Pearlite)

Example 2

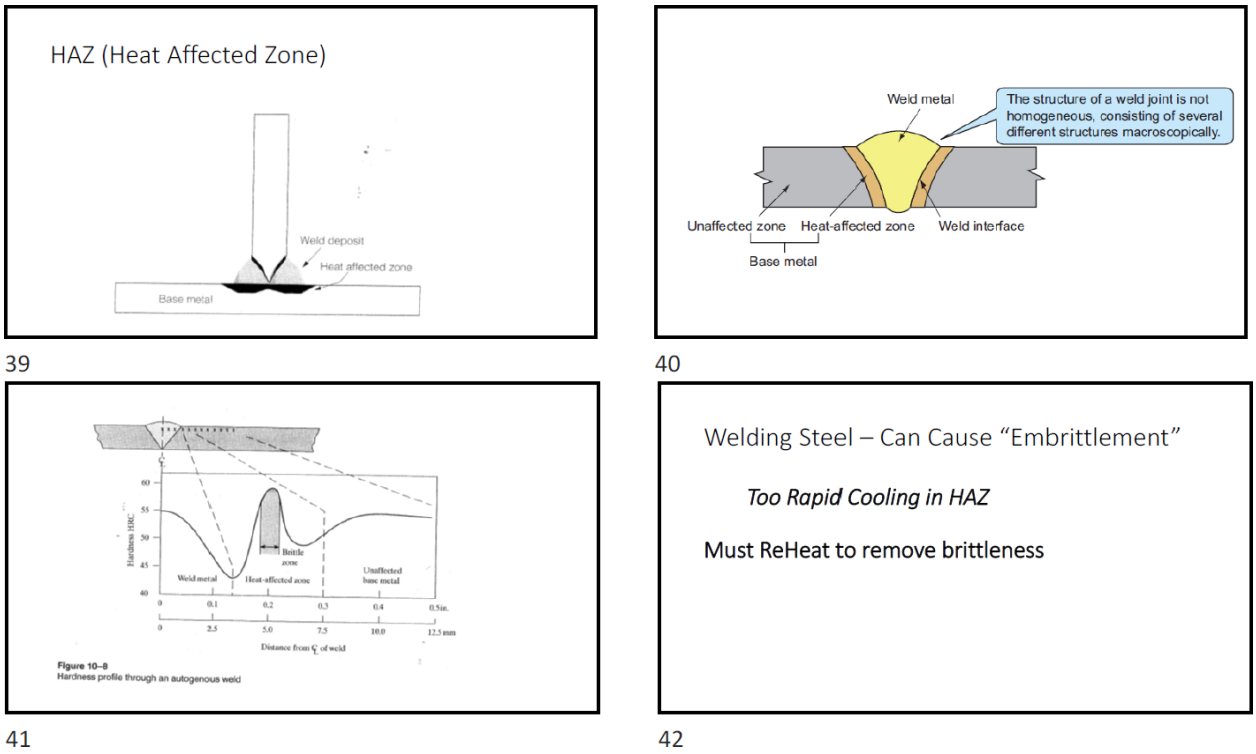


Figure 2a. PowerPoint slide for Example (Embrittlement)

What is '*embrittlement*'? *a*s might develop _____

from *welding* hot-rolled steel? _____

What *factors /conditions* make hot-rolled steel OK _____

to be *welded?* What *precautions* needed to weld? _____

What types of welding hot-rolled steel _____

must be done in a shop, and then how treated? _____

Figure 2b. Study Sheet for Example 2 (Embrittlement)

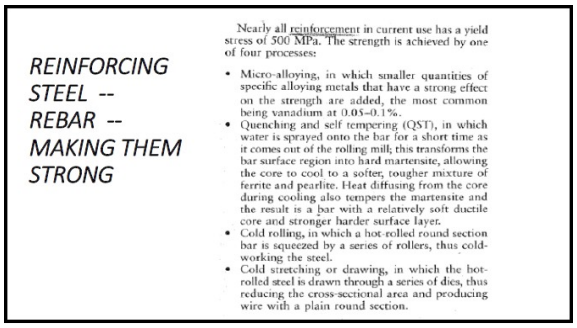
5.7 Weldability of hot-rolled steel is an important factor, particularly in regards to embrittlement. Describe how the embrittlement could occur (see Ch. 9) and the various factors that are considered in the different hot-rolled steels that make each suitable for welding (or not).

Figure 2c. Homework for Example 2 (Embrittlement)

9. Why does embrittlement frequently occur when welding? _____

Figure 2d. Quiz question for Example 2 (Embrittlement)

Example 3



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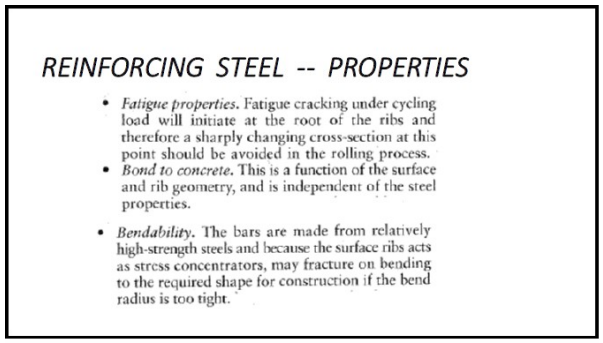

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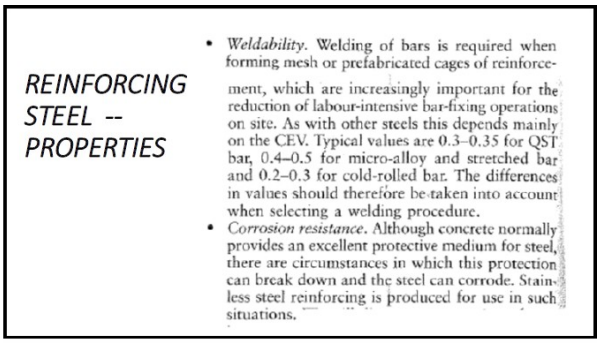

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Figure 3a. PowerPoint slide for Example 3 (Rebar)

How are steel ***bars*** for concrete *re-bars* produced? _____

What alloys used? _____ What source of *Martensite?* _____

How does *rebar perform* in terms of: welding, bendability, _____

bond to concrete, fatigue and corrosion resistance? _____

What are 4 ways very high strength *rebars* are produced ? _____

What is metallurgy of steel in the four process? _____

Figure 3b. Study Sheet for Example 3 (Rebar)

5.11 Describe the basic process by which steel for reinforcement of concrete is produced. What alloys (and amounts) are commonly used in reinforcement steel.
Explain the four different ways by which high strengths are achieved in reinforcing steels, and the metallurgy that results in each.
Explain the atomic structure and properties of martensite that occur due to quenching and how the brittle martensite is dealt with in the production process.

5.12 Describe the details of the five important properties of reinforcing steel; bendability, fatigue prevention, bond to concrete, weldability, and corrosion resistance.

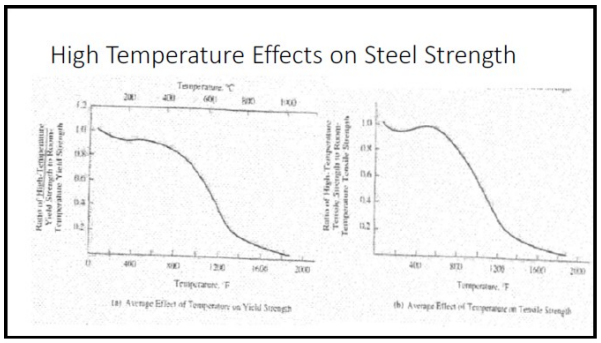
Figure 3c. Homework for Example 3 (Rebar)

17. Describe how steel bars for concrete reinforcing bars are produced? _____

19. What 5 properties must rebars have? _____

Figure 3d. Quiz questions for Example 3 (Rebar)

Example 4



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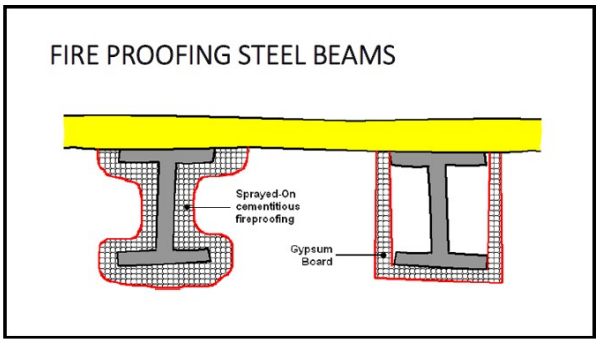

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Figure 4a. PowerPoint slide for Example 4 (Fire)

In FIRE, How and Why does steel lose strength? _____

What TEMP causes 50% loss?_____ 75% loss? _____

How is steel commonly protected from _____

fire induced strength loss? How rated? _____

Figure 4b. Study Sheet for Example 4 (Fire)

5.20 At what elevated temperature, such as occurs in an intense building fire, does steel begin to lose substantial amount (more than 10%) of its yield strength? At what temperatures has steel lost 50 % and the 75% of its yield strength? What is done in the design of a steel structure to make sure that temperature of steel does not get to such high levels?

Figure 4c. Homework for Example 4 (Fire)

23. How much is steel strength reduced when its temperature increases to 1200 deg. F? ____

Figure 4d. Quiz question for Example 4 (Fire)

Assessment of Effectiveness of the Learning Methodology:

To assess the effectiveness of the revised system used in our C.E. Materials course, we looked at overall quiz grades for two years before the change and then two years following, with particular focus on Quiz 5. The topic of Quiz 5 was the Properties of Iron and Steel. As with all 11 or 12 quizzes given throughout each semester, there were 24 to 26 questions on Quiz 5 through the four years. Data are not available to assess student performance on individual questions, and the questions are varied each year to avoid students having pre-knowledge of questions from internet searches, so direct comparisons would not be possible. Also, data are not analyzed for 2017 and 2018 because the course taught used substantially different testing methods which were not as thorough as used in 2015, 16, 19 and 2020.

Quiz 5 -- Properties of Iron and Steel

Year	2015	2016	2019*	2020**
Number of Students Taking Quiz 5	63	71	43	62
Average Score/Highest Possible	18.5/26	18/27	20.1/26	23/27
Average Percent Correct	71%	67%	77%	85%
Standard Deviation	4.9	4.5	4.0	2.3

TABLE I. Summary of Results for Quiz 5

* -- 2019 was first year using PowerPoint slides as basis for lecture presentation.

** -- 2020 continued using PowerPoint slides, and revamped all quiz questions to more closely replicate Study Guide questions/prompts.

The improvement in grades shown in the data in Table I illustrate the benefit of adding the PowerPoint slides to lectures in 2019, and then the greater benefit of refining the form of quiz questions to more specifically relate to Study Guide questions in 2020. Also, the quiz questions followed the order in which the material was taught.

Student comments about the course:

The students were given a survey at the end of the 2019 course and had following comments *(and instructor responses)***:**

1. Add a lab section to be able to demonstrate materials behavior/properties *(a lab will be added in 2021)*
2. Reduce the number of homework questions (*18 to 21 questions asked each week*)
3. Lectures are 75 minutes, too long – break them up / induce student conversation *(short videos are being used were available)*
4. Reduce the inclusion of 'details' on a given topic and just concentrate on the major points *(an attempt is underway to remove 'unnecessary detail, but what students view as details is often necessary for understanding)*
5. Some asked for that the answers to study guide sheets be posted *(but that is part of their learning experience)*

6. Make the presented content more ‘exciting’ and include pro-active engagement with the students throughout the class period
7. T/F questions on quizzes should be eliminated because often asked with two conditions
8. Desire expressed for presentation in class of videos and more interactive approach to presentation of course materials
9. Make the otherwise ‘boring’ factual material ‘more fun’ in the instructor’s presentation
10. When asked about whether there should be Quizzes every week or just 2 or 3 examinations throughout the semester, there was overwhelming support for weekly quizzes

Some of the student comments were incorporated into this year’s course (until the virus shutdown forced strict on-line course presentation) while others are on the way to being implemented. The Civil Engineering Department has approved the laboratory component to be added to the course and the modules for the lab are being developed. This still needs to be approved by the University but is anticipated to start next year. The homework questions were further reduced by making some questions to be optional as extra credit questions. The authors agree that the 75-minute lectures are long and try to break it up with a video or conversations in the middle of the lecture. The authors do not believe that the answers to the study sheet should be posted. This attitude of ‘just give me the answers’ has become widespread in the “just Google it" world, but the instructors believe that looking up answers is fundamentally an integral part of the student higher education experience. The students are encouraged to ask questions during the class or during office hours if they are not able to fill the study sheet. The PowerPoint presentations occasionally had humor included to make the lecture more ‘exciting’ and ‘not boring’.

When we suddenly moved to the online format in mid-March, due to the COVID-19 pandemic, the students were disciplined, were used to the model and the transition to the online format was relatively easy. The students commented that this was the class they were not worried about because they knew what to expect and how to study for the course. In a predominantly theoretical course, the students usually struggle because they feel lost. It was a pleasant surprise that the students commented about the ease of transition.

Possible Application in other civil engineering courses:

After the success in the Civil engineering materials class, this method was implemented in the Soil Mechanics course. Soil Mechanics is somewhat of a hybrid between the Materials course content and a more heavily focused analysis course. The reactions from the students were similar. This class already has a lab content and the problems and theory helped to break the monotony. The authors also implemented parts of this strategy into the Statics course and Structural Analysis course. This mainly involved giving students incomplete study sheets and having complete PowerPoint lectures available. Since the two courses are mathematical courses, some aspects like weekly quizzes were not implemented.

Conclusion:

The various methodologies such as using PowerPoint and a concurrent study guide with room to fill in missing information which provide active learning, along with pre-class videos to add an element of flipped classroom (videos) , when coupled with regular homework and quizzes seems to help student learning in a theoretical content intensive subject in higher education. Adding any hands-on content, laboratory component or video seems to increase student engagement which was expected. However, helping the students stay organized and presenting the material in various ways each week, adds an element of rigor and predictability which makes the students interested and engaged which ultimately results in increased student learning.

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