Improving our approach towards teaching a content intensive subject in higher education - An on-line variant

Abstract:

The authors carried out a study and published the results on teaching a largely content intensive course in an engineering school, where it is often a challenge to achieve student learning and retention of the course material. Methodologies involved encouraging student notetaking, a study guide sheet to follow along with the PowerPoint, homework built to serve as a study aid, weekly quiz, and a comprehensive final exam, as well as a research paper. An additional challenge in last year's course was added when the course went on-line in the middle of the semester. To accommodate this on-line crisis, recordings of each lecture were added. At the end of the course, the students were given a survey to evaluate the effectiveness of these methodologies. Based on the survey results and student performance, the text for the course was changed which then required significant modification our course materials. This year the course is only on-line for the entire semester. With the textbook changed, study guide sheet was made more focused, homework was revised and shortened somewhat, quizzes were modified to comply with on-line testing available, recorded lectures were uploaded onto the Brightspace, and an additional project was added. The students were given a mid-semester survey to evaluate the effectiveness of these modifications to that point, and some course tweaks have been instituted. We are sharing with reader what we have been able to do and how our students have reacted. What worked well, what could be improved further, and why, are then discussed in this paper.

Introduction:

Civil Engineering Materials (C.E.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. The primary reference used in this course was by Mamlouk and Zaniewski [1] with supplements from Domone and Illston [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. A 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 generally through the study guide list. Through the years 2017, 2018 and 2019, all of the information presented in lectures was converted into PowerPoint slides. 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. Retention at the end of the semester is gauged by a comprehensive final exam, which contains 10 questions from each of the 11 semester quizzes. Individual student research project during the semester is used to encourage in-depth learning and emphasize technical writing skills. More information on this

methodology can be found in our previous paper (Reference will be added to final paper).

In Spring 2020, when the course went on-line in the middle of the semester, a significant modification was made to the course with the posting of pre-recorded narration of lecture slides on each week's principal topic(s), in addition to in-person lecture during the regular course meeting times. Further improvements were subsequently made to additional parts of the course for the current Spring term. These improvements are based on the student comments of the end of semester survey in Spring 2020 in which 48.4% students responded to the survey and the mid-semester Spring 2021 survey in which 66.7% students responded. The changes are presented in the next sections.

Recorded Lectures:

In Spring 2020, the class was taught with many PowerPoint slides each week and a study-guide which helped the students to take notes during the lectures. Sample of slides on the topic of HCP transition zone around the coarse aggregate is given in figure 1a below. When the course went on-line in mid-semester, we asked the students via an on-line questionnaire about their thoughts and concerns during the transition. The students appreciated that we contacted them and asked their input. They also gave some helpful feedback. Several students were concerned about their wi-fi and worried about being able to listen to the material. They asked if the professors could record the lecture themselves with notes/images and post it for students to see and go through all at their own pace. Others were concerned that they would not be able to meet the professors if the class was with self-paced videos. Some other students had confidence in the instructors' decisions, "I think this class will be my most prepared class to transition to on-line learning. We have had access to PowerPoints and videos unlike many of my other classes."

We recorded some videos on topics and posted them a couple days before the class. An example of this video can be found on an unlisted YouTube video here (XXXXX—to be listed in the final paper). Our initial plan was to discuss the content using a flipped-classroom concept. However, only a few students pre-watched the videos for the first class and others did not seem interested. With so many things changing all at once with the on-line format, we decided not to use the flipped classroom as it would be yet another change, and we were concerned the students would find that much change to be too daunting. The pre-recorded videos were posted on blackboard and the students could watch them at their own time. We taught the class using Zoom at regular class times. Most students liked the narrated slides videos of lectures that were posted in addition to the live lectures. They said that they really liked that they could go back over material. Students appreciated the various sources of information. Several student comments received are listed below:

1. I like the recorded lectures, I think that should be something to consider doing for when we are on campus as well. I like the fact that I could go back and listen to see what the professor(s) are finding important on the topic.
2. The videos were good. Easy to follow and was a good refreshing lecture outside of class.
3. Narrated slides were a huge plus
4. The narrated slides were super helpful; life at home is more crazy than school and there are a lot more responsibilities I have so time can be constrained and my mind would be

thinking about all I had to do that day instead of focusing on the zoom meeting, so it was nice to have those to re-watch.
5. We didn't stray too far from how we would conduct the class in an in-person manner and I think that's was a key component in successfully conducting the class virtually
6. Keep all of the videos and study guides they were the most helpful things for the course after in class sessions ended.
7. The narrated slides were very helpful. For on-line, I think the best approach was the one taken.

For Spring 2021 the instructors had planned on pre-recording the videos and adopting the flipped classroom model in a face-to-face class. However, the course was moved to the on-line format, making the flipped classroom model too difficult to adopt. So, the instructors decided to teach the class live on zoom and post the recordings of each of our lectures on-line instead.

In the mid-semester Spring 2021 survey the 63% of the students who responded found the recorded lectures extremely useful or very useful. Students have indicated that they watch a particular lecture up to 6 times. Other students mentioned that they pay attention in class and take good notes and so have not needed to watch the videos very often. Overall, the recorded lectures seem to be very useful to the current generation of undergraduate students. The authors plan to continue to post videos of class even after moving to face-to-face classroom next Spring.

Textbook :

The textbook that we used prior to Spring 2020 was Domone and Illston [2]. This is a thorough book, however it is written in England with UK standards and needed supplements. This made it perhaps not the most appropriate book for the introductory course. While looking at other books, we came across Mamlouk and Zaniewski [1]. This text covers the material in a less rigorous fashion than the Domone and Illston [2] book, which we considered a drawback. However, Mamlouk and Zaniewski [1] book also contains many lab exercises compiled at the end of the text.

In the end of year survey for the Spring 2020 semester, students overwhelmingly stated that they would like to have had a lab component in the class. Some of the student comments are given below:

1. I would perhaps add a lab to the class, to let students have a hands-on approach to what we are learning.
2. I would like there to be a lab part added onto the course because it was very intense on reading, lecture, and writing.
3. I am most motivated by lab work because there is actually something to do so I can't get interested by class.
4. I'd like to see a lab component to this class. Getting hands on experience with steel, concrete, asphalt, and polymers would be extremely helpful for this class and for the field.
5. I would prefer the Lab section for statics 2 to be part of materials instead, I believe in materials everything we did on statics 2 could be expanded.

We had been thinking of adding a lab component to this class from a few years and after seeing the survey responses decided to add the lab component for Spring 2021 semester. Unfortunately, since we are on-line this semester, we had to postpone starting the lab component to next Spring. We have still changed the textbook in anticipation of the future lab, but we have retained some of the more rigorous information from the Domone and Illston text through our slides and lecture presentations.

Study guide:

A study guide was prepared by the instructors and given to the students before the weekly topic was started. Each contains short questions or topics statements and provides some space to write notes. The study guide was made in the same order as the lecture slides. The students were expected to follow the lectures using the study guide. Sample of study guide topic questions on the topic of HCP transition zone around the coarse aggregate is given in figure 1b below. In Spring 2020, the students who used the study guide said that it helped them. Some of their comments are given below.

1. Doing the study guide really helped me understand the topics for the quizzes. Studying the study guide after doing homework for 1-3 hours was sufficient to do well on the weekly quizzes.
2. I spent around a half hour before each Wednesday class studying for the quiz. I found the completion of the homework to be a great mode of studying for the quizzes and merely reviewed the study guide before class.

However, a portion of the students said that they did not do the study guide because it was long. This year we made the study guide more focused. It is still one page (front and back) long, but the questions/topic statement are more direct.

In the mid semester Spring 2021 survey 58% of the students who responded said that the study guide was extremely useful or very useful. Another 33% said that the study guide was moderately useful. Some of the student comments are listed below:

1. Most of the time the study guides prepare me for weekly quizzes. I think as the year is progressing the study guides are helping more with the content on the quizzes.
2. The weekly study guides are packed full of questions; I regard them nearly as a second homework assignment that I can simply write abbreviated answers on. They are useful.
3. Combined with the homework it is very helpful in preparing for the quiz
4. Yes, it is like you know what you are going to see. You are prepared.

Homework:

Homework is 20% of the final grade. There are 11 homework sets and each homework has 17-20 questions. It contains mostly theory questions and sometimes problems, where applicable. Homework is weekly to provide exercise on each topic, and to force students to dig into these facts/topics. These completed homework assignments are to be handed in just prior to the beginning of the following week's quiz. All homework assignments must be hand-written and done individually (no type-written work is accepted). Sample of homework questions on the topic of HCP transition zone around the coarse aggregate is given in figure 1c below.

In the end-of-semester Spring 2020 survey, students indicated that they spent "too much time on homework". Some reported 3 to 5 hours while others reported spending 5-7 hours on homework. A few others reported spending less than 3 hours were on homework. Several said the homework cut into their expected outside activities time. Several complained about the requirement for all the homework to be handwritten, particularly since they were compiling the answers by computer cut and paste. Several indicated the homework took so much time they could not fill in the study guide. Others said doing the homework was their way to study for weekly quiz.

This year, we shortened the homework by about 20%. In the mid-semester Spring 2021 survey, students indicated that they spend an average of 4.2 hours on homework (range is 3-6 hours, standard deviation was 1.0 hr.). Students recognize the value of the homework even when some of them thought it was time consuming. Two-thirds of the students who responded to the survey found the homework extremely useful or very useful while the other third found it moderately useful. Only one student complained that the homework had to be handwritten. However, the complex task of writing results in better memory, and a comparison of recall and recognition for common words demonstrates that memory is better for words when they have been written down rather than when they are typed [4]. Also, when writing on paper, the rates of information recall have been found to be significantly higher with handwritten exercises[5],[6]. Therefore, in this course we have continued to require all homework assignments to be handwritten, because as many students note, the questions asked in homework require the students find and write information that are important topics in the course.

Some of the student comments from the mid-semester Spring 2021 survey are included below:

1. A lot of time is spent on the homework, but the topics in the homework are usually very indicative of what will be on the weekly quiz.
2. Most of the time is spent on the homework which usually prepares me for the quiz the following day.
3. The homework, while extensive, ultimately solidifies my understanding of the content.
4. I usually do not spend time studying for the quizzes because the homework takes too long.
5. To be quite honest, the physical process of handwriting the assignments takes a disproportional amount of time (hours of writing by hand).

The reason for the requirement for handwriting homework assignments needs to be made clear to the students at the start of the semester along with providing background information such as the references cited above. new plan to provide these references to the students at the start of the semester next spring, and add a few slides to show them why we require handwritten answers to homework questions.

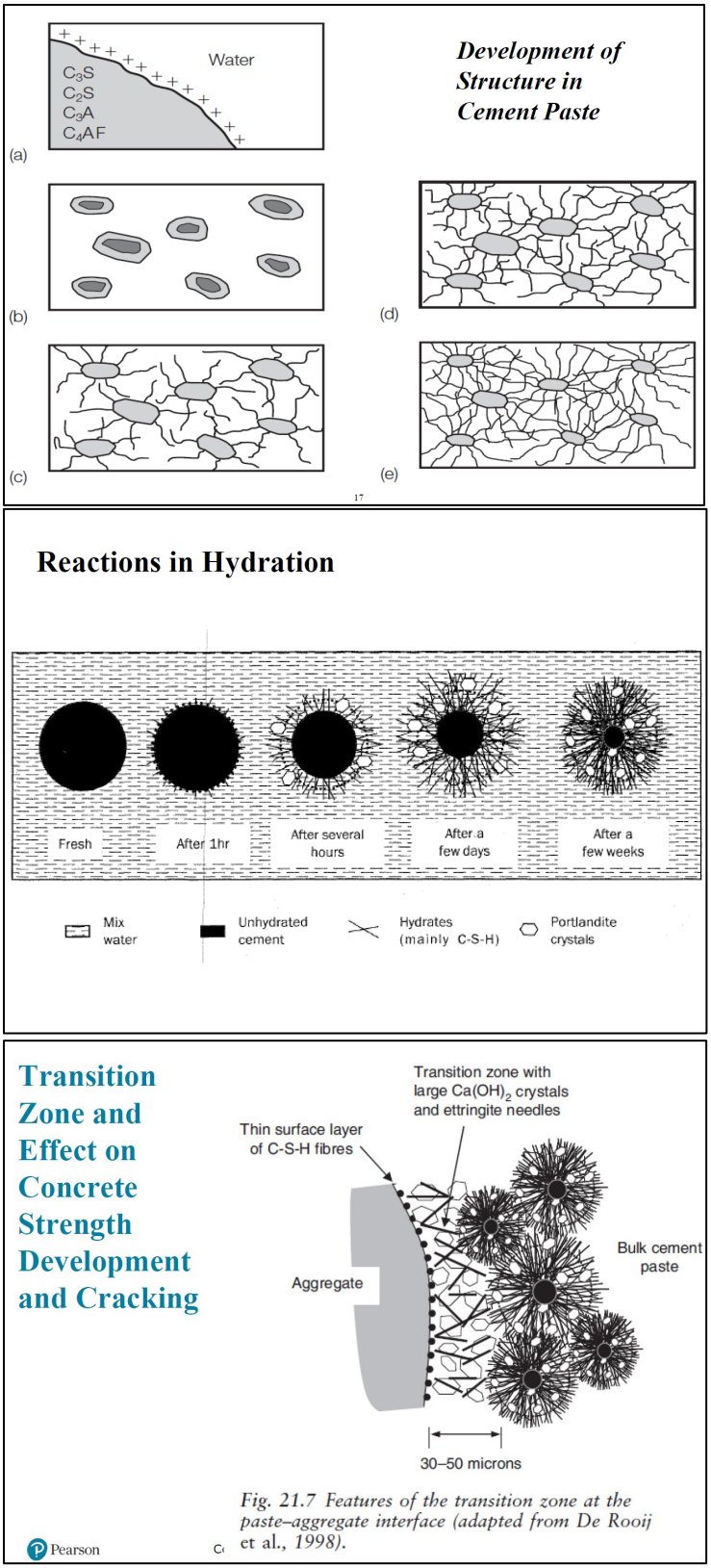

Fig. 1 a Slides from Lectures on H-C-P development and Transition Zone formation

Relevant Study Guide Topics

How does "transition zone" form? _____

What composition of HCP? Thickness and strength that develops? _____

How does the "transition zone" form ? _____

What composition of HCP, thickness, and strength ? _____

Fig. 1b Relevant study guide topics on H-C-P development and Transition Zone formation

Relevant Homework Questions

- 6.5 (T.6.5) Define what is C-S-H portion of hardened cement paste. What is C-S-H comprised of, and what form does the C-S-H take throughout the paste?
- 7.21 Describe the critical "transition" or "interface zone" as it relates to the initiation and propagation of cracks in concrete under load. What is different about the cement paste in the transition zone, and what is the structure of the HCP in this zone?
- 8.1 Describe what occurs in the 30 to 50 micron wide "transition zone" that is around coarse aggregate particles as the cement paste of a concrete takes initial and final set and then continues to harden into the full 28-day strength concrete. Be sure to include discussion on the presence of water and the different types of cement crystals that grow in this "transition zone".

Fig. 1c Relevant homework questions on H-C-P development and Transition Zone formation

Relevant quiz questions

- Explain what the "transition zone" that forms around pieces of coarse aggregate is composed of._____
- True? or False? The "transition zone" that forms around pieces of coarse aggregate is typically 15 to 25 microns thick.

Note: The first question was a possible type of question in Spring 2020 when the answers were handwritten. The second question is a True/ False question which is better suited for online quiz.

Fig. 1d Relevant quiz questions on H-C-P development and Transition Zone formation

Quizzes:

We have always had weekly quizzes based on the homework and study guides. The quizzes had 20-22 questions which were multiple choice, fill in the blanks, true/false and few open-ended questions. Usually, our quizzes were hand-written and graded. This year because of the on-line class format, all the quizzes are on Brightspace. We have eliminated open response questions (fill-in-the-blank). The student are presented one question at a time and have

approximately one minute to answer that question. They are not allowed back-tracking, to reduce academic dis-honesty issues in the quiz. A third of the students said that the quizzes were extremely helpful or very helpful, while 58% of the students who responded to the survey said that the quizzes were moderately useful for learning the content. This shows that the students are not very excited about the weekly quizzes and that most students feel okay with the quizzes. However, excitement is not the first thing that comes to mind when one thinks about taking the quiz. Therefore, these responses are comforting to the instructors. Sample of quiz questions on the topic of HCP transition zone around the coarse aggregate is given in figure 1d above.

In the end of year survey in Spring 2020, students overwhelmingly suggested that they prefer weekly quizzes, if given a choice to have them less frequently. Less than a fifth of the students would want just 2 or 3 tests each week, with each being 3 to 4 weeks of information. We continued the weekly quizzes and it still seems to work in Spring 2021

Projects:

Two projects are assigned as a part of the course. A research paper is assigned on a specific topic about Steel, such as: steel strength loss under building fire conditions, armor steel in today's army vehicles, use of high strength steel bolts and nuts, battleship steel used in WW-II, high strength steel used for prestressing wire cables, to name several of the 16 possible. There is also a project making two mix designs for specific design conditions that a concrete would be subjected to in service, and must therefore withstand for many decades.

The research paper has been a part of this course for several years. It is assigned during the middle of the semester on steel materials engineering topics. Each student prepared a concise report on a specific 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. This research paper is 10% of the final grade. No change was made to this part of the course. In the end-of-semester survey the students were either neutral or positive about the research paper and we did not see any reason to make any changes. Some of the student comments are mentioned below:

1. I found the course to be interesting in all topics. I think the most useful part were the videos and the research paper.
2. I think it's an interesting, great, and necessary course. The research paper was very interesting, and I used it to my advantage. I want to eventually go into structural engineering, specifically into bridge design. And being able to learn more about a topic I am passionate about in detail was very useful and fun for me!

The concrete mix design project is a new requirement this year. This was an extra credit project in previous years which replaced the second-lowest quiz grade (we drop the lowest quiz grade for each student). The students who have done this assignment in previous years have found the understanding helpful. So, this year it was added as a required assignment for 7% of the final grade. The students will be explained the method of designing a concrete mix in lecture and they will be assigned two exposure and strength situations to design their own mixes.

Final Exam:

Final Exam is given during the assigned final exam period. It is cumulative for all material covered during the semester and contains questions only from weekly quizzes. In preparing the final, 10 questions from each weekly quiz are used. The students are 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 made; in particular the fill-in-blank are converted to multiple-choice question on the final, and the true/false questions and multiple choice question on the quizzes might be switched in format for the final. This year, we do not plan on changing the final exam format too much, but it is rare that the exact same question will appear on the final. The students perform better during the semester than in the final exam since there is so much content to study. Last year we provided a detailed study guide specifically for the final exam. This year we will do the same but it will be more focused than last year. The final exam grade is being reduced to 20% of the final grade from 25% in the previous semester, in part because we added the concrete mix-design, as mentioned above.

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 five 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, 20 and 21.

TABLE I. Summary of Results for Quiz 5 Properties of Iron and Steel

Year	2015	2016	2019*	2020**	2021***
Number of Students Taking Quiz 5	63	71	43	62	18
Average Score/Highest Possible	8.5/26	18/27	20.1/26	23/27	26.8/32
Average Percent Correct	71	67	77	85	84
Standard Deviation	4.9	4.5	4	2.3	3.3

* -- 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.

*** -- 2021 continued using PowerPoint slides and revamped all quiz questions to remove open ended questions. Textbook was changed. Class was entirely on-line. Study guide was made more focused. Recorded lectures were provided for learning repetition. A different instructor was

assigned some sections of this course and so the number of students has reduced.

The improvement in grades shown in the data in Table I illustrates the benefit of adding the PowerPoint slides to lectures in 2019, and then the greater benefit of refining the form of quiz questions to relate to Study Guide questions more specifically in 2020, this was a quiz done before being forced to go online due to COVID crisis. The quiz grades remained about the same between 2020 and 2021. This is surprising because the 2021 has been a completely online course and to the point of the 2020 quiz that is reference in table 1, we had been completely in person. We had seen in April 2020 that quiz scores on average were substantially lower than the quiz scores earlier in the semester. However, part of this problem might have been our learning how to best utilize the learning management system and write appropriate questions and of course everyone (students and faculty) were under extreme stress in April 2020.

This year, we have utilized the substantial amount of experience in teaching and assessment in the online world. We have also had more time to plan appropriate quiz questions. Our quiz grades reflect appropriately on student's abilities and performance. The average and standard deviation this year is very similar to last year on Quiz 5 as seen in table 1.This finding is similar to the conclusion derived by Hoffman and Elmi. [7]

Conclusion:

When the material is provided in different formats, the students understand and retain the content better. As always, repetition is important in a content intensive course. In the online environment accommodations are necessary to effectively get the students to do repetitive studying. This was emphasized to us by the students' comments on how well they received the lecture videos and has convinced us to continue the practice of recording and posting lectures even after we move back to in person classroom.

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