Student performance in an online chemical engineering thermodynamics course on a summer schedule

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Abstract

The authors have individually taught a course in chemical engineering thermodynamics at the University of Kentucky for many years, but starting in 2017 brought the course into an entirely online format for the summer term. The course coverage includes 1st and 2nd law (building off a pre-requisite material and energy balances course), equations of state, phase equilibrium, mixtures, and ideal/non-ideal VLE. Through three summer offerings, the authors have compared student performance as measured through a common final exam and entering class average GPA at time of enrollment with that of students taking the traditional offering. Performance in both the traditional face-to-face spring term offering (over 16 weeks) and the summer offerings (over 6 or 8 weeks) with small sample sizes (n<20 for each section) were compared without finding apparently significant differences. Details on course structure and other lessons learned regarding teaching foundational courses like this one online are offered.

Background

Online learning is an increasingly common methodology for teaching University courses, building on the distance learning pedagogies of previous decades. In engineering, the concept of online learning is not new [1] , but there is little work specifically examining the effectiveness of online chemical engineering courses. Additionally, the complexity of courses offered on an accelerated timeline as in the case of a summer course schedule compared to “traditional” offerings over a full term with face-to-face class meetings has not been significantly studied.

Thermodynamics courses are common in chemical engineering curriculum [2], though some argue that they can be amongst the most challenging courses to teach. Some work has compared online summer thermodynamics courses to traditional sections during the summer [3], while others have compared regular term traditional and online sections of the thermodynamics course and detailed development of online sections [4, 5]. Work to date consistently indicates comparable outcomes between online course offerings and traditional in-person instruction when each method applies a deliberate, pedagogically sound approach to teaching the course.

In this paper, in-class and summer offerings of thermodynamics will be compared and differences in student performance will be discussed. Additionally, recommendations for future offerings and for faculty developing their own online courses will be provided.

Course Description

Chemical Engineering Thermodynamics (course number to be added after review) at the University of Kentucky is a second semester sophomore year course with a course in material and energy balances as its primary prerequisite. Calculus 3 and Physics I are also pre-requisite courses. The catalog course summary describes the course as:

Fundamentals of thermodynamics, review of first law, second and third laws, VL, LL, and SL equilibria, homogeneous and heterogeneous chemical reaction equilibria.

The course outcomes are that students should be able to:

1) Demonstrate conceptual understanding of the 1st and 2nd Laws of thermodynamics
2) Carry our energy balances on material and power systems
3) Conduct 2nd Law analyses on systems
4) Thermodynamically design expanders, compressors, pumps, reactors, and separators.
5) Develop, analyze, and interpret thermodynamic property and physical and chemical equilibrium evaluations on non-ideal flash devices
6) Carry out material and equilibrium evaluations on non-ideal flash devices
7) Demonstrate an elementary understanding of molecular thermodynamics
8) Successfully formulate and solve problems using computer software

To accomplish these objectives, the course topics can be summarized as 1^{st} and 2^{nd} Laws of Thermodynamics, cycles, equations of state, thermodynamic modeling, phase equilibrium, mixtures, and ideal/non-ideal VLE. An introduction to other phase equilibria and reaction equilibria is included but has not been a required part of the course for the past year due to a change in credit hours for the course from 4 to 3. During the terms considered in this paper, the text by Dahm and Visco was used without the online publisher learning platform[6].

The online and traditional implementations of the course were very similar. Outcomes remained constant and lecture topical coverage was identical to the regular term face-to-face course. All assignments were also essentially the same with small modifications to account for differences in timescale.

To develop the online course, lectures with active learning elements (both group and individual) during the live meetings were captured at the instructor's desktop through video lectures. Active learning was incorporated through encouraging "pause and consider/calculate" during a given question or problem. A limitation of prior offerings of the online course was being unable to enforce active engagement through integration of questions that require student action before they can proceed in the video. Moving forward, these types of questions will be integrated to encourage active participation in the lecture videos. For the online course, a chapter-centric organization was chosen, with students progressing through modules such as the one below in Figure 1.

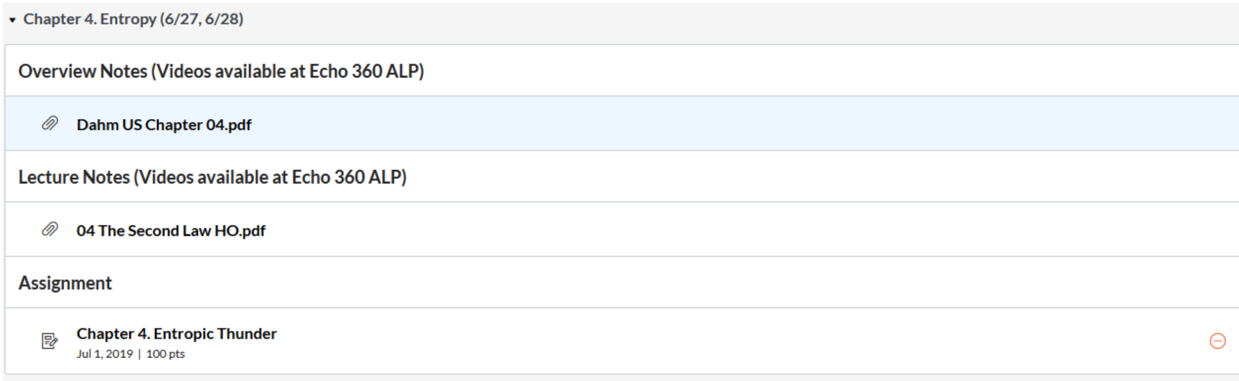

Figure 1. Module for Chapter 4 materials which shows lecture notes associated with a specific course video and links students to assignments associated with that specific chapter.

The notes in the module were the slides with gaps that were filled during the lectures with students strongly encouraged to complete the gaps for problems prior to watching the solutions. There were two complete, parallel video sets available to students for the course: a chapter overview built using slides provided by the publisher and authored by the textbook authors, and a set of problem-solving lectures with punctuated pauses to involve students in the video. The videos were broken into short segments of 5-15 minutes, such that the video content for the two note sets shown in Figure 1 would correspond to about 16 separate videos as shown in Figure 2.

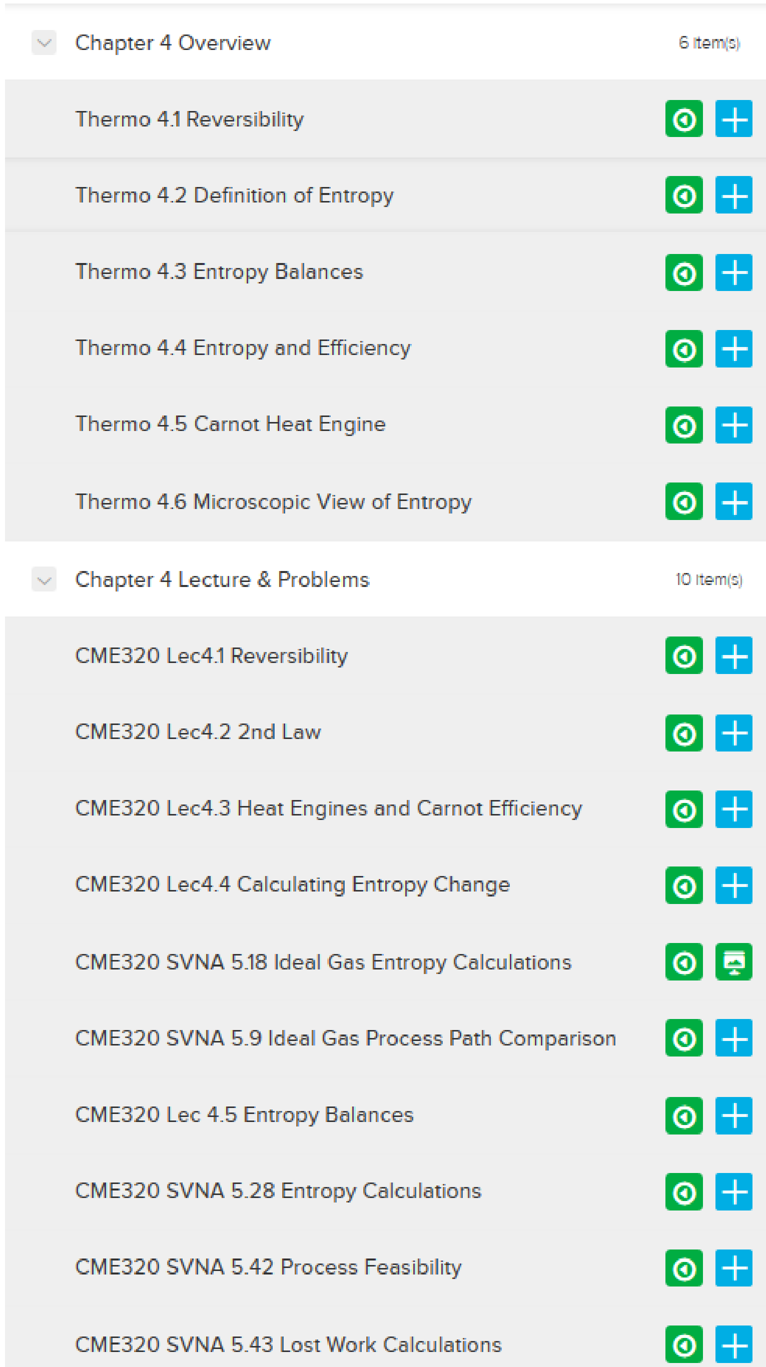

Figure 2. Videos on Echo360 Platform corresponding to the 2nd Law chapter modules shown in Figure 1. Most videos were 5-15 minutes in length, with longer videos consisting of single example problems.

In addition to the two sets of online "lectures", there were addition example videos recorded from both the Dahm and Visco textbook, as well as the thermodynamics textbook authored by Smith, Van Ness, Abbott, and Swihart [7].

With only six weeks to cover the course, the pace was very rapid with no more than one or two days dedicated to a chapter. As a result, students were given guidelines for when they should be completing course content. Homework deadlines were typically twice per week, with each homework covering a single chapter. By setting required homework deadlines for the course, students were required to keep up with course content and complete each chapter with sufficient time to prepare for each exam. This also allowed instructors to hold multiple online meetings per week to go over homework solutions and clarify any confusion with the students that were in attendance. These homework review sessions were recorded with the live interaction with students and made available to those students who were unable to attend. Students were also exhorted to email and schedule individual video conferences with the instructors to resolve questions, and to use discussion boards to ask questions that would be answered by the instructors and viewable for the entire class.

Hour exams for the course were newly developed for each section. For the summer course, proctoring was managed at testing centers or at universities in the region where the students were located. Graded hour exams were returned to students electronically for their review. An identical final exam was used in all sections, with tweaks made to remediate possible sources of confusion along with changes to correspond to course content.

Performance Analysis

From a wholistic subjective perspective, the summer course offerings were comparably successful to the regular term offerings. In both cases, there were students that failed but most students were successful in completing the course with a ‘C’ or better. For face-to face sections, class rosters for sections considered here peaked at 17 for a regular term offering and at 15 for a summer section. Consequently, there is limited potential for statistically meaningful evaluation. Given the small populations, perhaps the most meaningful evidence of comparable outcomes between sections can be obtained from looking at the course final exam grades across both traditional term and summer online offerings.

Figure 3 shows plots across sections of both course formats the average grade point average of students in the term prior to taking the online course (as a potential proxy of student “quality”), and the average final exam grades of the same students in the course. While there is not significance asserted for the comparison, the consistency in the final exam scores across all sections even when average cumulative GPAs of students entering the course are lower suggests that the course may have been comparably effective. It is acknowledged that the final exam instrument has not been validated.

Qualitative instructor assessment has been that students who were successful in the course are well-prepared to continue in the chemical engineering curriculum. Student surveys convey the impression that the course is well-designed, well-executed, and that the structure and online content contributed to their learning.

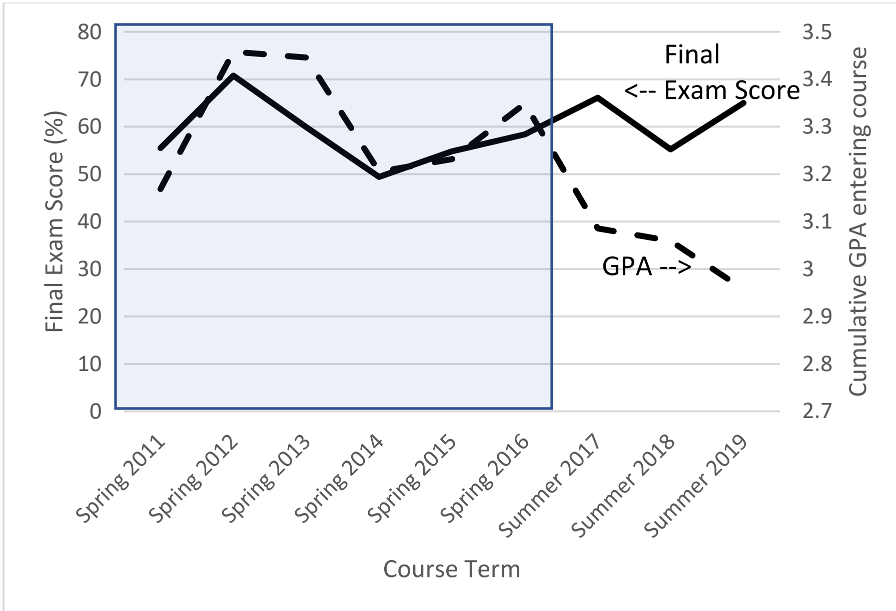

Figure 3. Plot of student final exam performance (left axis, solid line) and grade point average entering the course (4 point scale, right axis, dashed line). N varied from 4 (Spring 2011) to 17 (Spring 2015). Summer section enrollments ranged from 8-15 but have incomplete data for GPA due to inclusion of transient students in the study. The shaded region highlights the regular term face-to-face offerings, and the unshaded region the online 6- or 8-week sections.

Recommendations for Online Core Course Instruction

From our collective experiences in teaching this course and others online, we have established a series of recommendations for online course development.

1. **Communication**. Make certain students are made aware of course expectations, opportunities to ask questions, where to find resources, and what they should be doing at all points along the course timeline. As you are ensuring you communicate well with students, ensure students have effective paths to communicate with you as well.
2. **Structure**. Consider where your students are in their curriculum. If they are taking one of their first disciplinary courses where standards are distinct from those of other courses, it is important that students clearly understand expectations of workload, preparation, and performance. For an online course offered on an abbreviated schedule, a detailed structure and schedule seems critical with appropriate enforcement of deadlines.
3. **Availability**. In general, students taking online courses are likely to have external commitments that drove them to take the online course with its flexible schedule. An instructor needs to be flexible in meeting with students and consider how to communicate effectively with students in a timely manner. Additional flexibility in the timeline for watching videos can also allow accommodate student schedules.
4. **Archiving**. For the same reasons, making group sessions available by recording is recommended to prevent students with inflexible schedules from being at a disadvantage in the course. While synchronous and asynchronous course offerings can both be effective, it is important that any synchronous sessions are recorded for students to watch at alternative times.

5. **Segmentation**. Shorter videos better align with student attention spans. Consider how your lectures will proceed before recording or transmitting them in order to optimize their length. Are there images or equations that would be just as effective if presented in their final form, or should you plan to develop those as you might in a face-to-face course?. Remember students have a pause button they do not have in a live class where writing and reflective time is important. Shorter videos also ease your burden as there is less cost associated with technical glitches or individual errors that can wipe out a recording in process.
6. **Accountability and Engagement**. Consider how you can incorporate low-stakes assessments or other activities into your instructional materials to keep students on track, allow for formative assessment of learning (for you and for the student), and encourage reflection on the concepts presented.
7. **Rigor**. The online courses should be compared to regular course offerings to benchmark student performance and ensure both the instructor and the students are meeting course outcomes at an acceptable level. Learning objectives can also be used to regulate content and assessment. For core courses, it is important not to compromise student preparation for their future courses and careers, but it is important to refine you're the focus and emphasis of the course given the time constraints.
8. **Adapt**. Take advantage of the wide range of resources available to chemical engineering instructors from sites such as http://www.cache.org/teaching-resources, https://cw.edudiv.org, and https://www.learncheme.com.

We believe the essential learning outcomes were achieved in the summer online course to a similar extent as they were in the traditional term face-to-face course. The biggest shortcoming is a sense of detachment from the students both corporately and individually in many cases. For the instructors, the relationship with the students is a motivating factor, and there were fewer individual connections made with the online format.

Conclusions

The authors have successfully converted a traditional face-to-face chemical engineering thermodynamics course into an online format that appears to have achieved intended student outcomes on a compressed summer schedule. Performance in the class as measured by a common final exam was comparable across sections, and there was no discernable impact of the GPA of student entering the course on the final exam score. While the lack of a validated assessment instrument and small populations preclude firm conclusions, there is a suggestion that the practices implemented for this course resulted in desired outcomes for the summer online offering at a level comparable to that of the traditional face-to-face course.

The authors are willing to share more detail regarding course structure and contest upon request.

Acknowledgements

Data analysis for this project was conducted under protocols approved by the Internal Review Board as an Exempt Project, IRB#56753.

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