Generation-Z Learning Approaches to Improve Performance on the Fundamentals of Engineering Exam

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Abstract

The Fundamentals of Engineering (FE) exam is now computer-based, allowing examinees to schedule the test more conveniently. The FE is also discipline-specific, so students can focus more on areas related to their course of study. Traditional university FE review courses cover material throughout a semester, eliminating a part of the year where students would take the exam. By developing online learning modules, including short video reviews of particular topics, videos of worked sample problems, and a bank of FE-like problems, students can better prepare for the exam on a just-in-time basis. Redesigning the course to include 5-7 minute topic-specific video reviews, in-class mentoring, application, assessment strategies and more interactive exercises better engages current students, sometimes called Generation Z (GenZ), who are familiar with *YouTube*, *Khan Academy*, and other topic-targeted websites. Rather than longer classes with little interaction, students can focus on areas where their knowledge needs improving, view (and re-view) the topic-related videos, and explore example problems on their own, in conjunction with interactive in-class activities. In parallel with subject assessments delivered through our learning management system, we were able to correlate frequency of student viewings of related video reviews to evaluate the overall impact on student performance. This feedback helped the design/development team identify subject areas that students were struggling in. Post-course surveys indicated that students found using the videos and online example problems to be both motivating and instructionally effective. This redesigned approach to the FE review course has been used in consecutive semesters, with encouraging results, and is currently being incorporated in other engineering and computer science courses.

1. Introduction

The administration of the Fundamentals of Engineering exam transitioned from paper-based to computer-based testing (CBT) in January 2014. In the Department of Mechanical Engineering at the University of Idaho, previous to the transition to CBT, we offered an FE review course geared towards the paper-based exam, which finished the week before the exam was offered. After the switch to the CBT, we continued to offer the FE review course in this format. We found that the student pass rate fell over 20 percentage points and that the student participation rate declined significantly. This indicated to us that the FE Review course was no longer adequately preparing the students to pass the FE exam. In the original format, students were ideally prepared to take the exam immediately following the end of the course, but under the CBT format the exam can be taken almost any time throughout the year. With this in mind, we decided to revamp the course to make it more flexible, allowing students to review material in areas where they need help and do so closer to the time when they would take the exam.

There are a number of commercial FE review courses available, but our engineering GenZ design team chose to develop a course for our students where not only would the relevant technical material be covered and receive university credit, but students could review the material on an as-needed or just-in-time basis. Review problems would be available for students

to go over and a bank of FE-like problems would be developed so that students could simulate taking the FE exam on a computer. Muqri, et al.[1] developed learning and teaching modules to reinforce fundamentals for electrical engineering technology students to perform well on the FE exam. Falconer, et al. [2] provided online teaching/learning resources for Chemical Engineering students. They developed screencasts, with narration by instructors, of relevant material. These screencasts were organized as an FE exam playlist which was created on *YouTube*. The results of the FE exams can be used as assessment data for ABET student outcomes [3,4].

The change in course structure allowed the College of Engineering design team to incorporate teaching strategies that are geared to the learning styles of GenZ students, i.e., those born between 1995 and 2005. Many commentators have described the learning style of these students. They grew up in a technological era where information is available at their fingertips. Because of this easy access to information, learning styles have changed dramatically [5]. Cilliers [6] has discussed the challenge of teaching GenZ students. She found that these learners are more equipped with technology than the typical lecturers, which increases the complexity of the educational processes involving instruction, guidance and supervision. In a survey she performed, 71% of the GenZ students indicated that they wanted more technology as part of their courses; this correlates with results from other studies. Wondergem [7] states that GenZ students don't see technology as a tool but a normal part of daily life. They have a very short attention span filter and a need for immediate response. To help engage GenZ learners, she suggests incorporating technological devices into educational activities and that students be allowed to use their devices, instead of taking away their devices in the classroom.

A recent LinkedIn study [8] showed that 43% of GenZ learners are self-directed or independent learners, yet only 20% of teachers plan on offering self-directed learning experiences and that instructors should focus on engagement tactics to encourage GenZ students to be active participants in learning. Pearson [9] showed that 67% of GenZ students consider college to be an important stepping stone for future success. The study also showed that 82% of the students use *YouTube* and that 59% prefer *YouTube* or apps to printed books for learning. Although GenZ students are digital natives, 78% consider teachers to be very important to learning and development, but that 71% were more likely to figure out problems on their own first. Engineering educators are beginning to adapt to learning strategies of GenZ students. Moore, et al. [10] discuss five areas for successfully working with GenZ students. Included among these areas is the use of online learning to augment classroom instruction, which aligns with students' desire to learn independently and on their own pace. They also discuss the importance of assessing student work and providing effective feedback.

Sabag and Kosolapov [11] have discussed the importance of providing instant feedback to enhance learning. They stated that providing rapid feedback helps keep students engaged and participatory in the material presentation. Waldorf and Schlemer [12] describe an "Inside-Out" model where ten to fifteen minute video snippets of pertinent course material is pre-recorded, then class time is reserved for practice problems or hands-on learning. They discuss the importance of students' staying on task and of having face-to-face working sessions for collaborative problem solving. Robledo-Rella, et al.[13] studied the use of mobile devices in educating engineering students and found that effective use of these devices can significantly

improve student learning. These studies show that it is imperative that engineering faculty adapt their teaching strategies to better meet the learning styles of GenZ students.

2. Project Description

The aim of this project was to incorporate prerecorded videos, problem reviews, and online assessments with face-to-face interaction to help students prepare to take and pass the FE exam. The National Council of Examiners for Engineering and Surveying (NCEES) offers six discipline-specific exams and one Other Disciplines exam. The NCEES has guides listing knowledge areas related to each discipline and a range of the number of questions that each knowledge area may have on the exam. We developed this review course for the Mechanical exam, although the structure is easily applicable to the other discipline-specific or Other Discipline exams. The knowledge areas for the Mechanical exam include Mathematics; Probability and Statistics; Computational Tools; Ethics and Professional Practice; Engineering Economics; Electricity and Magnetism; Statics; Dynamics, Kinematics and Vibrations; Mechanics of Materials; Material Properties and Processing; Fluid Mechanics; Thermodynamics; Heat Transfer; Measurements, Instrumentation and Controls; and Mechanical Design and Analysis.

The course was structured so that students met face-to-face with the instructor once a week to review a knowledge area. These sessions were then supplemented with recorded review segments and recorded problem reviews. Each week, a new knowledge area was reviewed. The idea of the quiz was to help students get a feel for taking the actual FE exam on a computer.

To facilitate preparation for this project our Engineering Outreach (EO) program, the online/distance education unit of the College of Engineering, developed a faculty-controlled video recording studio. A video switcher, built-in audio mixer, and related technology was used to create an easy-to-use, one-button recording studio with technical support and oversight provided by EO. A document camera, a laptop computer to support visual content, an instructor camera, and a microphone were connected to the video switcher. The output of the video switcher fed into a small video recorder which saved the data to an SD card. Ceiling and wall baffles were installed to help correct poor acoustics in the room. Lighting was added to improve the instructor appearance on camera and a backdrop was added for professional appearance. In the studio, faculty members could record short video segments covering their material. Operating the video switcher themselves, instructors were able to easily change from the instructor camera to the document camera or laptop, depending on the visuals they wished to present. The video switcher and associated equipment were placed on an adjustable lectern for ease of access. The raw video was post-processed for quality control and an introductory segment and copyright notices were added. The file size was then reduced for ease of download and viewing.

We then assigned various faculty members to prepare three or four brief (5-7 minutes) presentations for each of the knowledge areas. Since this project was to help prepare students to take the FE exam, each of the recorded segments reviewed material which was taught in previous courses. For example, in the heat transfer knowledge area, a brief review of conduction, convection and radiation heat transfer were recorded, along with a segment on heat exchangers. The choice of knowledge areas closely followed the NCEES exam specifications [14]. The

nomenclature in these review sessions matched the nomenclature given in the FE Reference Handbook that each student is allowed to use during the exam.

In addition, faculty members recorded problem reviews covering the knowledge areas. These problems were structured to be similar to what a student would likely see on the FE exam. The problem reviews typically lasted 3-5 minutes. This allowed the student to apply the information covered in the review session and get a feel for FE-like problems. The instructor then helped develop a bank of FE-like problems. These problems simulated the various types of problems a student might see on the FE exam. Some of the problems were programmed such that the same problem could be given to different students, but the values used in the problem were changed.

The video review modules were used to supplement face-to-face classroom time. The lead instructor for the course organized the approximately 10 review sessions and determined which knowledge area(s) would be covered that particular week. Students met once a week for two hours to go over the assigned knowledge area(s). Ideally, the faculty member who recorded the video segments came to the class that week and reviewed areas that students struggled with and answered questions. This pairing of self-directed video study with face-to-face classroom time allowed the student to fully review the knowledge area and have any concerns resolved.

Although this project was geared towards the Mechanical exam, many of the knowledge areas, like Mathematics, Probability and Statistics, Ethics and Professional Practice, Engineering Economics, etc., are shared with other disciplines. This means that the segments, once recorded, can be used by students taking the exam in other disciplines.

3. Results

In all, 185 modules, including knowledge areas and problems reviews, were recorded. Fourteen faculty members recorded the modules, including faculty from the University's Departments of Civil and Environmental Engineering and Computer Science. Besides the faculty presenters, the Executive Director of the Idaho State Board of Professional Engineers recorded modules on the importance of professional registration for engineers and ethical engineering practice. Table 1 shows the distribution and number of video modules and review problems for each of the knowledge areas.

This hybrid course structure began in the Fall 2018 semester, and has been offered every academic semester and one summer semester since then. During that span, 124 students were enrolled in the course and, of those, 118 students watched knowledge area modules or the problem reviews. The total number of modules viewed was 8,644, for an average of 73.25 views per student, with a standard deviation of 81.9. While the standard deviation was quite high, one student had 454 module views and another watched one. The number of median views was 41.

Table 2 shows the number of students taking the Mechanical FE exam and the corresponding pass rates from a few years before the start of the CBT period to the present date. Before the first testing period of 2014, the pass rates ranged from the low 80% to low 90% and the number of participating students ranged from 25 to 39. Historically, more students took the FE exam during the spring testing period when the exam was offered only twice a year.

Table 1. Number of video modules and example problems recorded for each knowledge area

Knowledge Area	# Video Modules	# Example Problems
Mathematics	6	16
Probability and Statistics	2	5
Statics	4	5
Dynamics	8	9
Mechanics of Materials	10	10
Thermodynamics	10	17
Heat Transfer	8	8
Fluid Mechanics	10	17
Material Properties	6	5
Mechanical Design	4	2
Electricity and Magnetism	2	5
Measurement/Controls	2	1
Computers	4	0
Economics	5	14
Ethics	4	0

There was a surge in students taking the exam during the Fall 2013 testing period to avoid having to take the computer-based test. After the computer-based testing period began both the pass rates and the number of students taking the exam began to decline. The decline in both of these metrics indicated to our faculty that the review course needed to be changed. The revised FE review course discussed herein began in the Fall 2018 semester and pass rates have improved, although the number of students taking the exam has not increased to previous levels.

Table 2. Number of students taking the FE exam and corresponding pass rates. S represents the testing period from January to June, and F represents the period from July to December.

Date of Exam	S12	F12	S13	F13	S14	F14	S15	F15	S16	F16	S17	F17	S18	F18	S19	F19
#Taking Exam	39	25	28	36	31	20	21	7	17	14	24	8	28	16	10	8
%Pass Rate	92	92	82	89	87	90	90	71	88	71	67	63	68	75	80	77

Observations

Several of the students who took the review class requested access to the review modules and practice problems in subsequent semesters so that they could prepare to take the exam. We found that 13 students (11%) watched the modules after the course completion date so as to better prepare for taking the FE exam. Those students accounted for 674 of the 8644 (7.8%) total views. Figure 1 below shows the number of views in each knowledge area for the four semesters in which the course was taught.

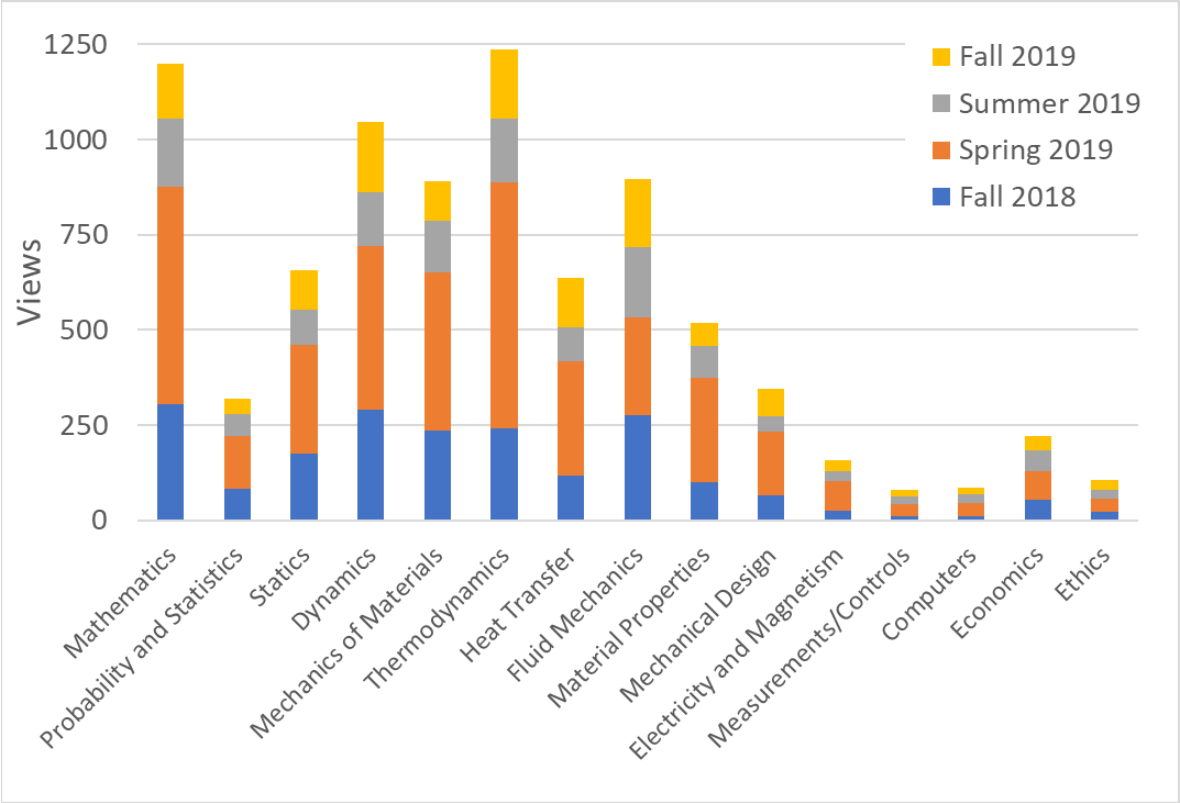

Figure 1. Number of module views in each knowledge area for each of the four semesters in which the review class was taught.

The new review course structure generated greater discussion between the students and the department chair regarding the status of signing up to take the FE exam and reporting of the results in the previous semesters. Students valued having multiple instructors for the knowledge areas. The instructors brought unique perspectives to the content and problem solving styles. Many students stated that the course provided a good practice environment for the FE exam, and appreciated the self-paced participation. They also stated that they wanted to see more example problems worked out and recorded. Students also mentioned that it was very helpful to solve problems during the live session. It enabled them to go through the steps and have questions answered by the instructor. If a particular topic was difficult, students were able to watch the modules covering that particular knowledge area more frequently. Students felt that the modules were well-made and were very valuable as they prepared to take the FE exam. Often, small groups of students watched the modules together. Students also appreciated having lots of resources available to practice for the exam.

Students agreed that this was a great structure for FE exam preparation. Several students mentioned that they wished every class had online competency modules to help in classes. Working through these on the students' own time was beneficial. One student stated that this teaching approach elevated his confidence in his knowledge of the course content. During the first semester that this approach was tried, word got out to the students about the structure of the class, and other students in the program asked when their classes would be structured in this fashion.

Figure 2 shows the distribution of when the video modules were watched. The review course was offered on Tuesday nights. Students tended to watch the videos immediately before class. Unfortunately, this did not allow time for reflection between watching the videos, taking the knowledge area assessment and asking a question in class. Because of this, questions tended to be more coarse, e.g., "How do I solve this exact problem?" versus "How should I view this topic or set of problems?"

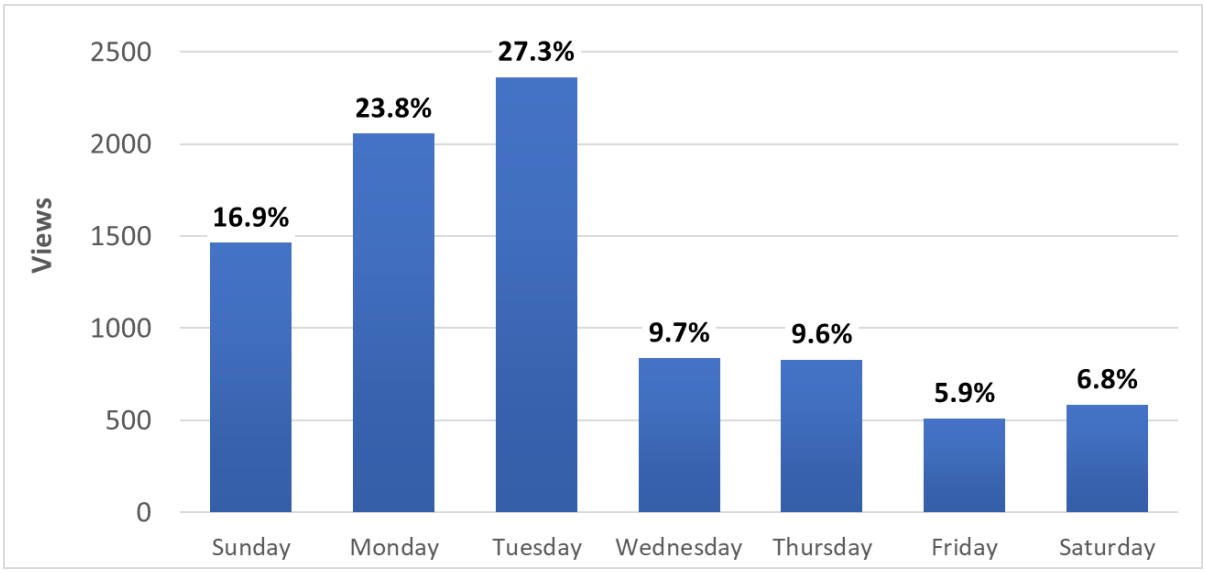

Figure 2. Histogram showing when the video modules were viewed. The review classes were taught on Tuesday nights.

Some viewing trends were noted. There tended to be a burst of video watching just prior to the class, indicating that the students were either too busy with other courses or not sufficiently motivated to come prepared to class. There was also a burst of video watching immediately before the final grades were due. We also observed that there was a lull period between the last class session and a few days before the final grades were due.

Figure 3 shows the cumulative number of modules views per week of the semester. In this plot, the data for the summer term is not included since there are fewer weeks in the semester. There is a clear increase in the number of views at the beginning of the semester, an increase in week 13 when the course ends and another increase towards the end of the semester as they prepare to take the FE exam.

Lessons Learned

Students were as positive about our willingness to change the course structure as they were about the actual implementation. GenZ students live in a modular, rapidly evolving world where change is expected. They reject many forms of the status quo, including lecture-based university courses. Merely showing interest in revising the educational system sparked the interest of our students, and many were genuinely interested in aiding the development of a new pedagogical system.

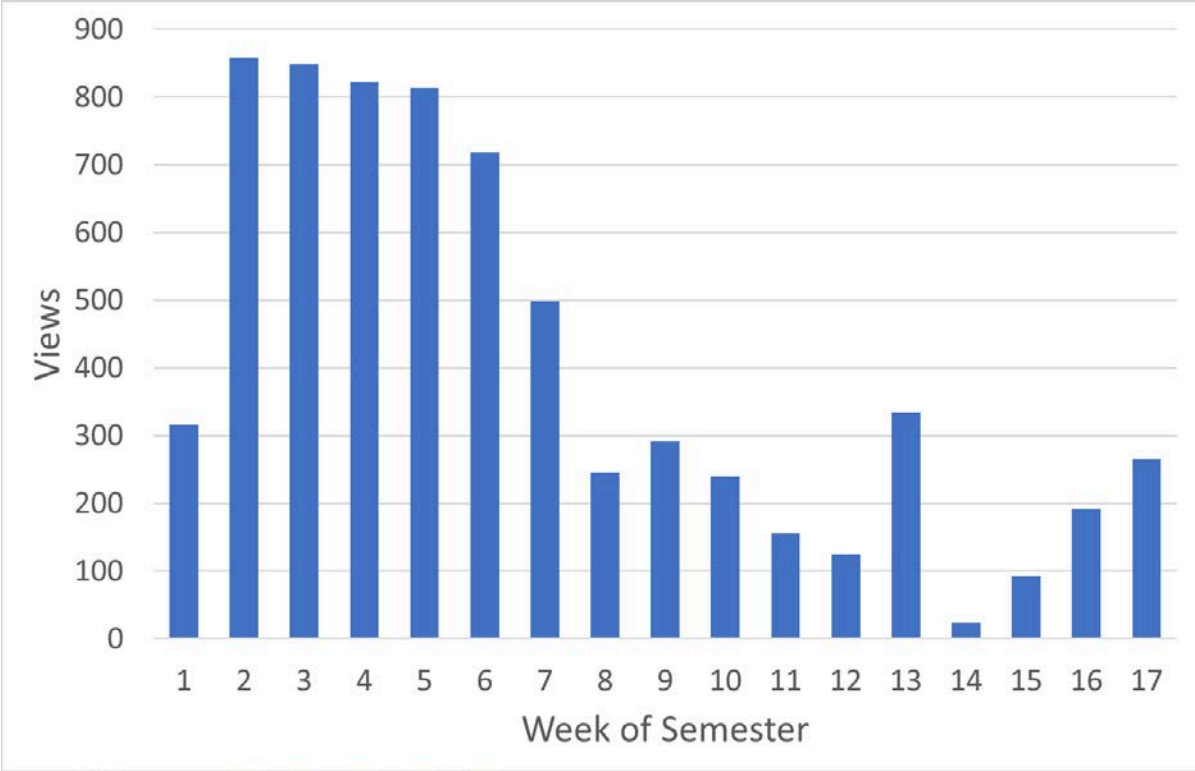

Figure 3. Number of module views by week of the semester (excluding the summer term)

Students appreciated loose deadlines. Providing opportunities for students to take assessments before and/or after reviewing the material proved very beneficial since students could study at their pace and focus on areas where they needed extra time to understand the material. Many used this as an opportunity for a self-guided improvement cycle: Test, Analyze, Review, Repeat. The students also want more resources, time, and accessibility. GenZ students are acclimated to having all of the necessary resources at their fingertips. Giving them plenty of resources, even if not completely used, gives them confidence to think, “the answer is here, somewhere…” The course management software (CMS) did not seamlessly integrate with active learning implementation. Without a standard flipped classroom model, the learning system leaned towards more traditional lecture-based classes. Development of the pre-assessment materials, reversed sequencing of activities, and other active learning tenets can be difficult to implement in many CMS packages. Many of the leading developers of CMS do not have active learning as a design criterion.

The most common positive feedback from the students was regarding the application of knowledge to the assessment questions. Students had opportunities to self-assess their comprehension of a particular topic to decide whether or not they needed to study it more.

Truly flipping the FE review course was not feasible for a number of reasons. Many students did not need as much review as others in particular topics. Mandating or expecting students to attend these review sessions may be detrimental. The FE review course in-class sessions were envisioned as an opportunity for students to access an expert in that area to ask questions.

Modifications were made to accommodate those differences and we ended up with a different model – a review course model.

Student profiles need to be identified and distinguished properly to adequately apply this review course model across a broad student grouping. We identified multiple traits shared by several students across semesters; some beneficial characteristics and some risk-factors. The Ideal Student took the pre-class assessment once or twice to prepare questions for class and used the feedback to achieve higher performance in class. Several students took the pre- and post-class assessments multiple times trying to get perfect scores and had a likelihood of burning out if perfection was not reached. Many students didn't take the pre-class assessments until the very last minute before class and did not have adequate time to articulate questions; this group of students didn't leave class with a clear understanding of the topic. A few students just clicked through the assessments, hoping to get lucky or see repeated questions. These students did not benefit from the course or the process. More characteristics, including gender, educational and cultural backgrounds, and age, should be identified and investigated to fully establish these profiles. An appropriate understanding of these different profiles should provide instructors and course developers opportunities to maximize the review potential and identify at-risk students.

On the process side, we found that quality control was necessary for the assessment and question banks. Many students pointed out errors in review question programming and general interaction with the CMS software. Students also noted that the example problems done in the review videos should not be identical to those given in the assessment questions. Most of these issues were worked out after the first semester that the class was offered.

4. Conclusions

A set of review modules reviewing knowledge areas for the Mechanical FE exam were developed. In addition, video modules covering review questions and a bank of FE-like problems were generated to help student prepare to take the FE exam under the CBT format. We found that these GenZ students enjoyed the video review modules and the flexibility afforded to them with this pedagogical method, which fit into their learning styles. We found that students did not watch as many modules in a particular knowledge area where they felt they were proficient and focused their efforts on areas where they needed improvement. Many students commented that they wished other engineering courses adopted this method course material learning. Our institution is currently piloting these teaching/learning practices for its introductory computer science and statics courses.

We found that after introducing this method of FE exam review course, that pass rates improved. Students accessed the video modules throughout the semester and after the course ended, presumably as they prepared to take the exam.

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