Using Start-Up Questions to Effectively Prepare Engineers for the Fundamentals of Engineering Exam

Dr. Matthew K Swenty P.E., Virginia Military Institute

Matthew (Matt) Swenty obtained his bachelor's and master's degrees in Civil Engineering from Missouri S&T and then worked as a bridge designer at the Missouri Department of Transportation. He then went to obtain his Ph.D. in Civil Engineering at Virginia Tech followed by research work at the Turner-Fairbank Highway Research Center on concrete bridges. He is currently a professor of civil engineering and the Jackson-Hope Chair in Engineering at VMI. He teaches engineering mechanics, structural engineering, and introduction to engineering courses and enjoys working with his students on bridge related research projects and the ASCE student chapter. His research interests include engineering licensure policies, civil engineering curriculum development, and the use of innovative materials on concrete bridges.

Dr. Benjamin Z. Dymond, Northern Arizona University

Ben Dymond obtained his B.S. and M.S. degrees in Civil Engineering at Virginia Tech before obtaining his Ph.D. in Civil Engineering at the University of Minnesota Twin Cities. Ben is currently an associate professor of structural engineering at Northern Arizona University.

Dr. Kacie Caple D'Alessandro, Virginia Military Institute
Dr. Joshua T. Hewes P.E., Northern Arizona University
Dr. Robin Tuchscherer, Northern Arizona University

Dr. Tuchscherer is a Professor of Structural Engineering and has served at Northern Arizona University since 2011. His teaching and research interests focus on structural engineering, structural concrete, infrastructure, and educational reform.

Dr. Rebekah Martin, Virginia Military Institute
Dr. Charles D Newhouse P.E., Virginia Military Institute

Charles D. "Chuck" Newhouse received his Ph.D. in Civil Engineering at Virginia Tech after working nine years as a consulting structural engineer for MMM Design Group in Norfolk, Virginia. He spent three years teaching at Texas Tech University before joining the faculty at the Virginia Military Institute in 2008 where he is now the Charles S. Luck, Jr. '20 Institute Professor in Engineering. He is also currently serving as the department head of the Civil and Environmental Engineering department.

©American Society for Engineering Education, 2024

Using Start-Up Questions to Effectively Prepare Engineers for the Fundamentals of Engineering Exam

Abstract

The National Council of Examiners for Engineering and Surveying (NCEES) Fundamentals of Engineering (FE) exam is important to university students who plan to pursue a professional engineering license, and civil engineering has the highest proportion of graduates that eventually become licensed. An important step in this process is to prepare university students to take and pass the FE exam prior to graduation. Many different methods have been implemented to prepare students for the exam. The study described herein sought to prepare students for the FE exam while they were enrolled in required undergraduate courses that cover core civil engineering topics on the FE exam.

Students at two different universities were tasked with completing FE-style questions on quizzes to prepare for the FE exam while enrolled in the following courses: dynamics, statics, fluid mechanics, structural analysis, and reinforced concrete design. In each course, the FE-style questions were based on questions published in FE review manuals, textbooks, or a NCEES practice exam. Each question was focused on a single topic, normally administered as multiple choice, presented at the beginning of a class period to review material (i.e., start-up, concept check, review quiz, etc.), and required to be solved by students within a short amount of time (e.g., 5 minutes) to simulate the FE exam. Approximately 10 FE-style questions were presented to students in each class over the term. After completing the quiz questions, class time was dedicated to discussing the solution and approaches to solving these types of problems. Later in the term, students were presented with similar FE-style questions a second time on an assessment. Both attempts were part of the grade in the courses.

To assess if the objectives of this study had been achieved, individual quiz question scores from the first and final assessments were compared to determine if student performance improved throughout the course. Furthermore, a student perception survey was administered before and after implementing the FE-style questions to determine how this review method affected students' familiarity with the FE exam, their confidence in passing the FE exam, and their preferred FE preparation method. Results from the study indicated that students were significantly more familiar with the FE exam, FE-style questions, and FE exam expectations. By the end of the study, 57% of students were confident that they would pass the exam and only 6% were not confident. Students appreciated the opportunity to review more questions in class and thought using the transition time at the beginning of class to review the material with FE-style questions was a good use of time. Furthermore, student performance on the FE-style quiz questions significantly increased; students correctly answered 73% of the FE-style questions presented on their second attempt near the end of the semester. FE-style start-up quiz questions were a good use of time and provided significant benefits to the students throughout this study.

Introduction

In addition to receiving an ABET-accredited undergraduate engineering degree, passing the National Council of Examiners for Engineering and Surveying (NCEES) Fundamentals of Engineering (FE) exam is the first step toward professional engineer (PE) licensure in most states. Civil engineering has the highest proportion of graduates that eventually take the Professional Engineers (PE) exam and become licensed [1]. To this end, it is important that university students who plan to pursue professional licensure be aware of the FE exam. The FE exam plays a crucial role in gauging the readiness of aspiring civil engineers for the challenges of practical engineering work. Success on the FE exam establishes professional credibility within the field, and the exam functions as a practical benchmark for evaluating the foundational knowledge and competence of engineering graduates.

Preparing students to take and pass the FE exam prior to graduation is a crucial step. This preparation occurs naturally through the ABET-accredited degree as students take their required courses. In addition, being aware of the exam and understanding the importance of the exam early in their academic journey empowers students to make informed decisions about their career paths and coursework. Encouraging students to take the exam prior to graduation not only aligns with licensure requirements but also fosters a sense of professional responsibility. By emphasizing the practical relevance of the FE exam, educators can inspire students to proactively prepare for the test. Different methods have been implemented to prepare students for the FE exam, including credit-based courses dedicated to reviewing material, online review courses, commercial for-profit review programs, informal review courses hosted by student groups, or a program requirement to take the exam prior to graduation. The study described herein sought to achieve the objective of preparing students for the FE exam while they were enrolled in required undergraduate courses that cover core topics on the civil engineering portion of the FE exam. Integrating exam preparation into an existing curriculum can ensure that students acquire the necessary knowledge and skills, bridging the gap between academic learning and practical application.

In this study, FE-style start-up quiz questions were implemented at the beginning of class periods throughout the term. FE-style questions refer to those that are multiple choice, are scored correct or incorrect, and are taken from published FE review manuals, textbooks, or a NCEES FE practice exam. A start-up style question is defined as one that is given at the beginning of a class to help review past topics and reinforce foundational concepts to students. The start-up questions in this study were brief, presented at the beginning of a class period as a quiz, and served to both review previous material and provide immediate student feedback related to their performance. This type of FE-style start-up quiz review was incorporated in classes that occurred earlier in a students' career, typically prior to their senior year. Furthermore, this style of review incorporated FE topics continuously throughout the term, rather than solely at the end of the course. The goal was to help students become accustomed to the style, difficulty, and time limit associated with FE-style questions. Finally, discussing the solutions to each FE-style question and how to solve problems related to each topic allowed the students to gather immediate feedback about both their performance in the context of the future exam and about their grasp of the technical content in the course.

Background

FE Exam

Taking the FE exam is a crucial step for engineering graduates on their path toward professional licensure in the United States. The FE exam serves as a foundational assessment method, ensuring that engineers possess the essential knowledge and skills needed for entry-level professional practice. Designed to assess minimum competency, the FE exam covers a broad spectrum of topics relevant to seven engineering disciplines, including chemical, civil, electrical and computer, environmental, industrial and systems, mechanical, and "other" engineering disciplines. The civil engineering FE exam questions are categorized into 14 different subjects, including mathematics and statistics, ethics and professional practice, engineering economics, statics, dynamics, mechanics of materials, materials, fluid mechanics, surveying, water resources and environmental, structural, geotechnical, transportation, and construction. Most questions on the FE exam are multiple-choice format, with a single correct answer. All questions are scored as either correct or incorrect; no partial credit is given. The exam is computer-based and administered during testing windows, year-round at NCEES-approved test centers. Results are based on the total number of correct answers, which is converted to a scaled score that adjusts for any minor differences in difficulty across the different versions of the discipline specific exams. This scaled score represents an examinee's ability level and is compared to the minimum ability level for that exam, which is determined by subject-matter experts through psychometric statistical methods [2].

FE Exam Preparation Methods

Preparing for the FE exam can involve a diverse range of review methods tailored to suit individual learning preferences. Many candidates opt for traditional study materials such as review books, practice problems, and reference manuals that comprehensively cover the exam syllabus. There are many FE review books available, such as those published by Goswami [3] and Lindeburg [4]. Furthermore, the NCEES provides content for use when preparing for the FE exam, including YouTube videos describing the types of questions and other exam functions, pdfs of practice exams available for purchase [5], and free access to a pdf of the reference handbook [6] that is available for use during the exam.

Online web-based platforms and review courses offered by professional organizations have gained popularity, providing interactive learning experiences, practice exams, and real-time feedback to participants. These collaborative learning environments allow candidates to benefit from shared insights and diverse perspectives through structured guidance and expert-led instruction. Two common examples of companies providing services in this realm are PPI and Udemy. PPI [7] offers several FE exam preparation bundles that include various levels of support, ranging from live online courses with structured guidance and instruction from professional engineers to online self-learning bundles where candidates pay for access to curated materials to prepare on their own timeline. Udemy [8] also offers FE review content in an online setting, with pre-recorded videos and downloadable resources; some universities pay for a subscription to Udemy, and students can access the FE review course and content for free.

Academic institutions are also heavily involved with preparing students for the FE exam. For example, students may elect to depend solely on the material they learn through an undergraduate curriculum to prepare them for passing the FE exam. Historically, a thorough civil engineering curriculum would provide a course in every area on the FE exam, but that is no longer the case because the breadth of material on the exam requires more courses than most programs have time to offer [9]. Alternatively, informal review sessions are frequently organized by formal undergraduate student groups, such as those under the umbrella of the American Society of Civil Engineers (ASCE); some informal review sessions may include faculty who volunteer to re-review course material outside of the related credit-bearing courses.

A significant amount of literature has documented other learning strategies that professors and universities have implemented to help students prepare for the FE exam:

- Formal credit-bearing review courses are available at many universities, with the sole objective of reviewing FE material [10]-[20].
- Some university engineering programs have made taking the FE exam a degree program requirement before graduation [16], [18], [21]-[23].
- In addition to commercial online resources available for student purchase, some universities have implemented their own online learning management system modules for self-paced student review [24]-[26].
- Several universities have set up a mock FE exam, where students complete an exam with FE-style questions during an extended time [11], [16], [19], [27]-[29].
- Some groups have implemented FE-style questions on quizzes and tests in undergraduate classes, in lieu of traditional assessment questions [11], [13], [21], [30].
- A strategy to increase familiarity with the FE exam requirements is to only allow students use of the FE handbook, or a similar replica of the equation-based reference manual, during in-class assessment, rather than homemade reference sheets or equations sheets made by the professor [31].

Review Quizzes

Start-up style review questions are like other warm-up, introductory, or reading quizzes that are common in higher education. In-class review questions are a form of ensuring students have done readings for a class and retained knowledge from previous classes. Such quizzes have been shown to improve students' scores on future assessments of the same material when the quizzes were administered a few days after reading the material [32]-[34]. This continual retrieval of course material helps with long term retention [35], and these types of quizzes can also help review previous material while providing guidance for a student if they have not mastered a topic and need additional help [36]. Another common use of in-class pre- and post-quizzes throughout a semester is to strategically measure gains in knowledge in the class. This helps determine the efficacy of the course when considering what materials to cover [37]. Using short in-class assessments or quizzes is a common and effective way to review prior material, prepare for upcoming tests, and review for final exams.

Summary

Ultimately, the effectiveness of FE exam preparation lies in finding a combination of review methods that align with individual learning styles, ensuring a comprehensive and tailored approach to mastering the exam content. Regardless of the method or methods selected, part of the objective is to make students aware of the test, the style of questions, and the time limitations they will face on the test.

With all the strategies that can be implemented for student success, there are also some concerns that arise with exposure to FE-style assessment methods. Significant implementation of FE-style assessment or a degree program requirement of taking the FE exam prior to graduation may push a curriculum to "teach to a test" rather than allow a curriculum with the freedom to focus student learning on the fundamental principles of engineering education [38]. Implementing a significant amount of FE-style content could skew the assessment methods to include an excessive number of multiple-choice questions, which are often graded as either correct or incorrect. While this type of assessment is representative of the FE exam, it may have a significant deleterious impact on assessment of student learning in a university setting. Significant implementation of FE-style material and assessment, which can be considered too basic or too easy, may take away from the educational depth that students can learn in upper-division undergraduate courses, especially as they enter courses in their senior year. In addition, use of class time on basic FE-style material and questions may detract from other successful learning strategies associated with the upper tiers of Bloom's Taxonomy [39]. Exposing students to the logistics, style, and knowledge related to the FE exam can become a burden, both within individual class periods and within a student's time during the later part of their collegiate career. For example, requiring students to enroll in a FE exam review class or take a mock FE exam may tax their limited amount of free time.

In this study, FE-style start-up questions were implemented as additional quizzes at the beginning of class, rather than replacing existing assessment throughout the entire class curriculum. Furthermore, a significant amount of time was not taken away from classic instructional topics/methods. These start-up questions served as a transition time between the start of class, review of prior material, and presentation of future material. Students were able to evaluate their knowledge in a short but relevant way. These start-up quizzes served as concept checks, where immediate discussion of the answer/method after completion of the quiz allowed students to scaffold a review of the material on top of their baseline knowledge [40]. Not only was the objective to review for the FE exam, but the questions forced the students to review key concepts in the current class and continue to review for future assessments within their class.

Research Objectives and Questions

This study had two primary objectives: (i) document changes in student awareness and perceptions of the FE exam, and (ii) gauge student confidence and ability to correctly answer FE-style technical questions associated with the class in which they were enrolled. The following three research questions (RQ) were answered to accomplish these objectives:

RQ1) Can student awareness and confidence in passing the FE exam be improved through repeatedly experiencing FE-style questions in a standard class?

RQ2) Does asking FE-style questions in a required undergraduate course help students prepare for the FE exam?
RQ3) Did student performance on FE-style questions improve by the end of the semester-long course?

Research Methods

The research objectives of this study were addressed in required undergraduate civil engineering classes through implementation of the following:

- perception surveys administered at the beginning and end of the term that gauged student awareness of the FE exam, familiarity with technical topics on the FE exam, and confidence in passing the FE exam;
- FE-style start-up questions given throughout the semester that made students aware of question type, time limitations, and the testing situation. In this study all FE-style questions were initially administered as start-up questions and then presented a second time on a future assessment.

These research methods were implemented in six different civil engineering classes at two universities, as shown in Table 1. In all cases, data were only collected from students who agreed to let their data be used, based on the Institution Review Board (IRB) agreement. Every class had at least 90% participation. There were 200 unique individuals who participated.

Table 1—Classes in which the perception surveys and start-up quiz questions were implemented.

Class	University (A or B)	Program year in which the class is taught	Course enrollment
Dynamics	A	3	33
Structural Theory	A	3	33
Fluid Mechanics	A	3	28
Statics	B	2	101
Structural Analysis	B	3	45
Reinforced Concrete	B	4	21

Students in their second, third, or fourth year of study in an engineering program were enrolled in the classes listed in Table 1, as documented in the third column. Most students were civil engineering majors, but some other engineering majors (i.e. mechanical engineers) were enrolled in some classes at University B. A different professor taught each course but had previously taught the same course without implementation of the FE-style start-up quiz questions. University A is a small, public, undergraduate-focused university that requires all engineering students to take the FE exam prior to graduation. While some students may know about the FE exam from discussions with other faculty or students, most of the instruction and preparation in the program at University A comes during the last (4^{th}) year of study in the program, when a FE review technical elective class is taken by most students. University B is a large, public, doctoral university that does not require students to take the FE exam prior to graduation; however, the Civil Engineering program at University B is mid-sized and does not offer a Ph.D. degree.

Student Perception Survey

Student perception data were collected from surveys administered in the first ("initial") and last ("final") week of the semester to track changes in student responses. The initial and final points in the semester were chosen because they occurred before the first FE-style start-up review questions were implemented in class and after the last FE-style quiz was given. The survey questions are shown in Table 2 and aligned with two research objectives, RQ1, and RQ2. Questions 1 and 6 provided information on each participant. Responses from Questions 2, 3, 4, and 7 were used to determine student awareness of the FE exam (RQ1). Answers to Question 5 were used to gauge students' confidence in passing the FE exam (RQ1), and responses to Questions 8 and 9 were used to categorize students' preferred methods of review for the FE exam (RQ2). Question 10 was open-ended and used to gather any additional student feedback.

FE-style Start-up Quiz Questions

Students were presented with a series of FE-style start-up quiz questions during the semester, that aligned with the topics taught in the course. The exact same (or nearly identical) quiz questions were presented to students a second time in the semester to gauge students' change in ability to answer technical FE-style questions correctly, which helped answer the third research question (RQ3). The students were tasked with answering these quiz questions as part of a formal assessment in their class. During the FE exam, students are allowed to access the NCEES electronic reference handbook, which is a searchable pdf [6]; however, use of the reference handbook was not implemented in this study. Approximately 10 questions were asked per class on either a quiz or test. The questions were created or taken verbatim from published FE review manuals [3]-[4], a NCEES FE practice exam [5], or textbooks in each topic area. Textbook questions often require more depth and time to solve. Using an external resource provided guidance to help ensure the problems were not overly difficult or long. Each professor selected questions relevant to their class and selected the question type (multiple choice or work-out problems). Most questions presented to students in this study were multiple choice style, but a few questions were workout problems. In each case, only student answers that were completely correct were counted as correct to mimic how the FE exam is scored. No partial credit was given regardless of the type of mistake made.

Results and Discussion

Student Perception Survey

Only data from students that completed the initial survey at the beginning of the semester and the final survey at the end of the semester were used in this study; a few students only completed the survey one time. Survey results were anonymous, but an identifier was assigned to each student to track changes on a per-student basis within the set. There were 200 unique individuals who completed the survey (there were some in multiple courses.) Most students who completed the survey were in their second or third year of study (Table 1) and had not yet taken (or thought about taking) the FE exam. This was supported by data from survey Question 6, which asked if they had taken the FE exam; only 2 of the 200 students had taken the exam by beginning of the

semester and neither passed. Only 4 of the 200 students had taken the exam by the end of the semester and 75% had passed.

Table 2—Survey questions deployed to gather student perceptions about the FE exam and answer the associated research questions (RQ).

Questions		Answer Choices	RQ
1.	What is your undergraduate major?	CE, ME, Other	—
2.	How familiar are you with the Fundamentals of Engineering (FE) exam?	1 - Not Familiar, 2 - A little Familiar, 3 - Familiar, 4 - Very Familiar, 5 - Extremely Familiar	RQ1
3.	Is the FE exam part of the professional development path in the career you are considering?	Yes, No, Don't know	RQ1
4.	Are you required to take the FE exam to graduate?	Yes, No, Don't know	RQ1
5.	What is your confidence in passing the FE exam?	1 - Not Confident, 2 - A little Confident, 3 - Confident, 4 - Very Confident, 5 - Extremely Confident	RQ1
6.	Have you already taken the FE exam?	Yes - I passed the exam, Yes - I did not pass the exam, No - I have never taken the exam	—
7.	Do you know if the material from this class is on the FE exam?	Yes, No, Don't know	RQ1
8.	What were your impressions of the FE-style questions in this class? Pick all that apply.	a. I like reviewing past concepts. b. I like gauging how well I understand the material. c. I like having extra example problems to practice in class. d. I like the transition time at the beginning of class. e. I did not like taking up class time with these problems. f. The problems did not help me learn the material. g. Practicing for the FE is not important to me. h. I did not put forth much effort on these problems. i. Other - Please explain in the open response question below.	RQ2
9.	What method of reviewing for the FE exam do you prefer? Pick all that apply.	a. Reviewing questions at the beginning of class (like we did). b. Optional review classes on my own time. c. A dedicated review course that gives me credit toward my degree. d. Test or quiz questions that simulate FE questions. e. No review - I am not concerned with the FE exam. f. No review - My coursework should be enough. g. Online - Watching videos (YouTube, professor web sites, etc.) h. Other - Please explain in the open response question below.	RQ2
10.	Do you have any additional comments about this method of reviewing for the FE exam?	Open response	—

Responses from Questions 2, 3, 4, and 7 were used to determine student awareness of the FE exam. Question 2 asked about student familiarity with the FE exam, and responses were on a 5-point scale as shown in Table 2 (a response of 1 was not familiar while a response of 5 was extremely familiar). It was assumed that, at this point in the students' education, the FE exam had not been discussed in-depth. Thus, all responses were likely based on prior knowledge from previous classes, work experience, or personal research on the profession. Results from the initial survey shown in Figure 1 indicated that 36% of students responded with a rating of 2 (a little familiar) and 24% of students responded with a rating of 1 (not familiar). Approximately 40% of students responded with a rating of 3 – 5, indicating familiar to extremely familiar. Less than 15% of students were very or extremely familiar (responses of 4 or 5) with the FE exam at the time of the initial survey. Results from the final survey shown in Figure 1 indicated that student familiarity with the FE exam increased for many students. Only 3% were not familiar with the exam (response of 1), while 46% were familiar (response of 3) and over 30% were very or extremely familiar with the exam (responses of 4 or 5). Combined, 76% of students responded with a rating of 3 – 5, indicating familiar to extremely familiar. It was clear that student familiarity with the FE exam significantly increased throughout the semester. The change in familiarity with the FE exam, which was taken as the numerical difference in response between the initial and final survey, was investigated more in-depth using student-specific response data. Results shown in Figure 2 indicated that 37% of students (the highest percentage) gained one level of familiarity with the FE exam while 34% did not change their familiarity (numerical change of 0). Very few students had a decrease in familiarity (11% decreased by a numerical value of 1), and approximately 18% of students substantially increased their familiarity (changes in numerical response of 2 or 3). A paired sample *t*-test was performed to confirm that there was a significant difference in familiarity with the FE exam before (M=2.33, SD=1.31) and after (M=3.09, SD=0.92) the interventions, t(164)=-7.97, p<0.001.

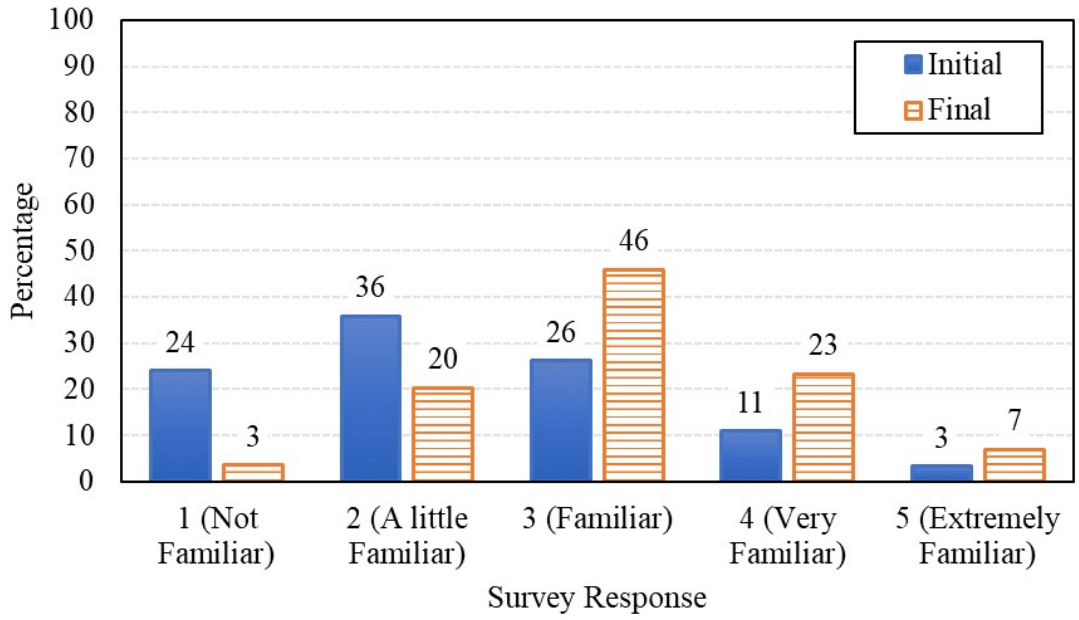

Figure 1—Results from survey Question 2: How familiar are you with the Fundamentals of Engineering (FE) exam?

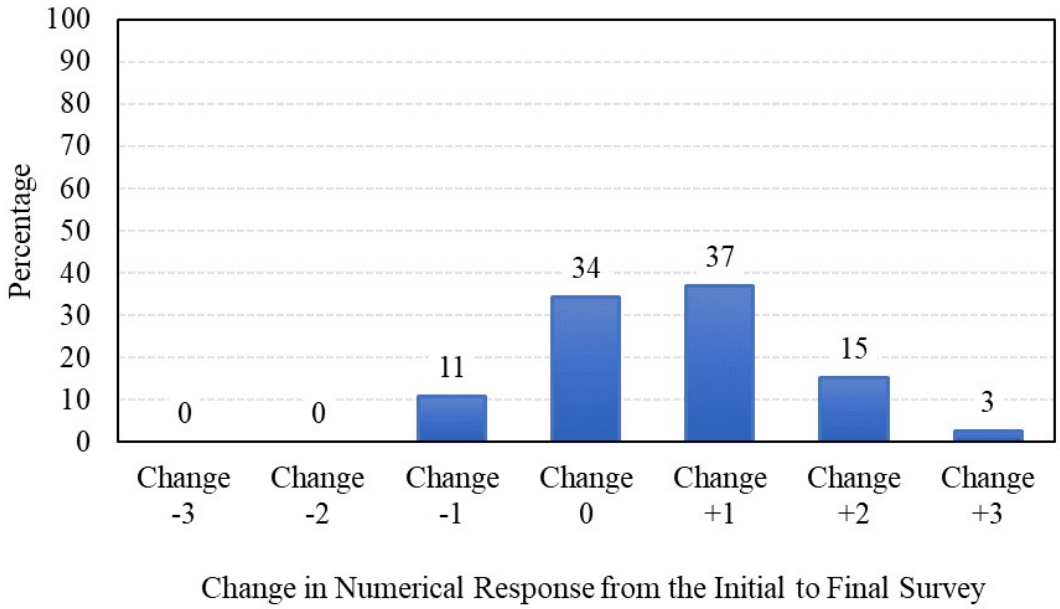

Figure 2—Change in response to Question 2 (familiarity with the FE Exam).

Question 3 asked if the FE was part of the professional development necessary for a student's career path. Not all engineering career paths require a professional license, so it would be likely that some students would answer no. The response results in Figure 3 did not change much between the initial and final survey, but the "Don't Know" and "Yes" responses went down and up, respectively, by 18%. The FE exam review implemented throughout this study helped students become more aware of their need to take the FE exam.

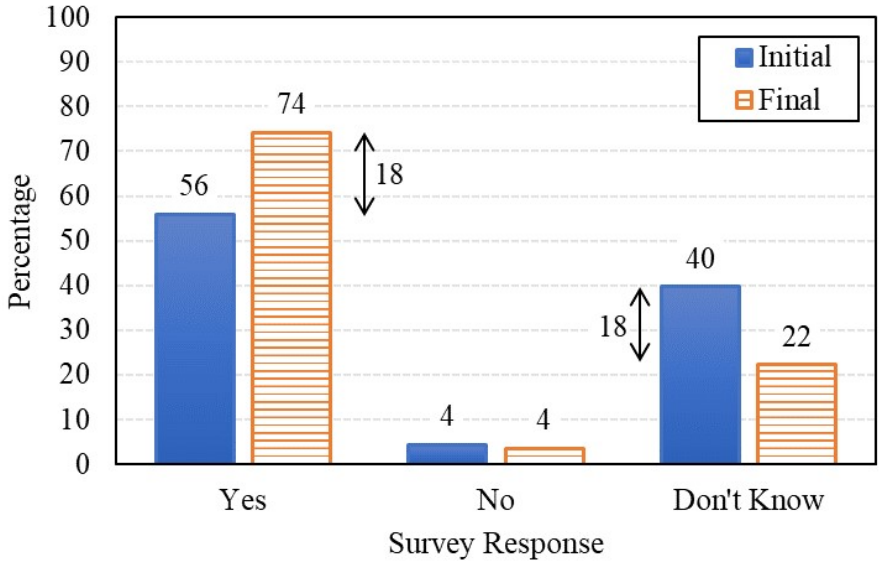

Figure 3—Results from survey Question 3: Is the FE Exam part of the professional development path for the career you are considering?

Question 4, much like Question 3, indirectly measured students' awareness of the FE exam. In both cases the student had to not only be aware of the exam but be aware of how it affected their education and career path. In this study, students at University A were required to take the FE exam to graduate while those at University B were not, and neither university requires students to pass the FE to graduate. Initial survey results in Figure 4 indicated that 45% of the students did not know if they were required to take the exam, but most of those students attended University B. In the final survey, the percentage of students answering Don't Know dropped to 28%, which were mostly responses from students at University B. Over the course of the semester, the results from this question indirectly indicated that students became more aware of graduation requirements and how the FE exam might affect their plans.

Question 7 asked if content from the students' course was on the FE exam. This helped confirm the responses from Question 2 and indicated the depth of awareness of the FE exam. Every class in this study covered a major topic on the Civil Engineering FE exam, so the correct answer throughout should have been Yes. Initial and final survey results in Figure 5 indicated that the percentage of students who knew that their course content was on the FE exam increased from 46% to 89% throughout the semester. On the final survey, less than 10% didn't know and less than 2% answered incorrectly. Student awareness of at least part of the content on the FE exam went up substantially.

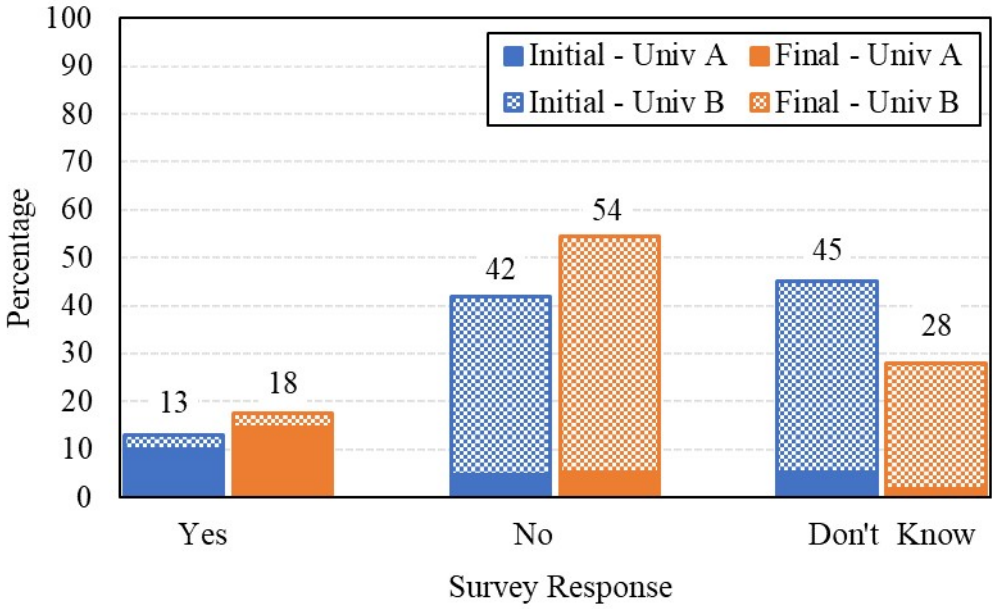

Figure 4—Results from survey Question 4: Are you required to take the exam to graduate?

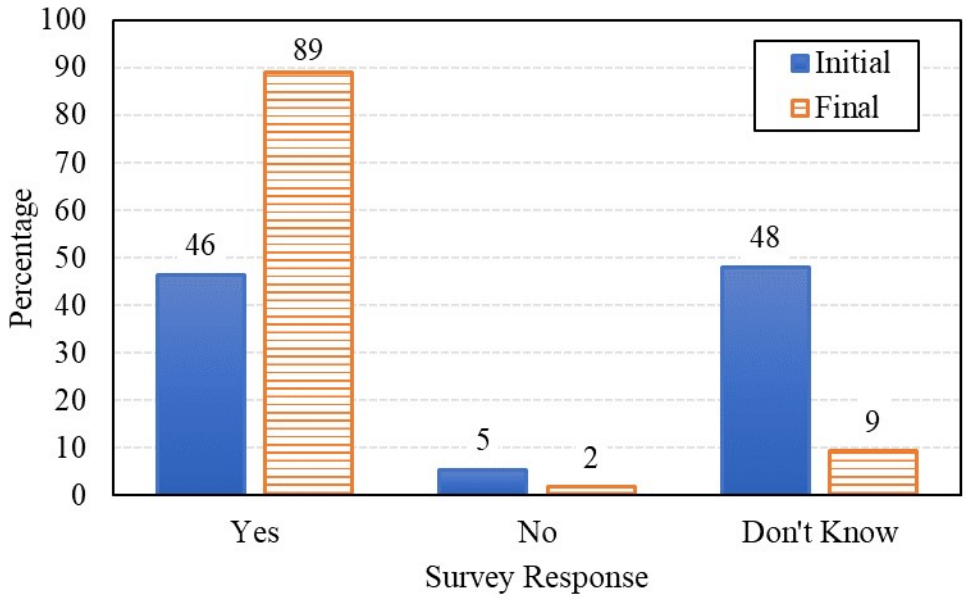

Figure 5—Results from survey Question 7: Do you know if the material from this class is on the FE exam?

Question 5 quantified student confidence related to passing the FE exam, and responses were on a 5-point scale as shown in Table 2 (a response of 1 was not confident while a response of 5 was extremely confident). Results shown in Figure 6 indicated that changes in confidence level in most categories varied by 5% or less, with the exception of response 1 (not confident). The percentage of students who were not confident decreased from 17% to 6% from the initial to final survey, respectively. The change in confidence related to passing the FE exam, which was taken as the numerical difference in response between the initial and final survey, was investigated more in-depth using student-specific response data. Results shown in Figure 7 indicated that most students did not change confidence levels (change of 0). While 31% of students did increase in confidence by 1 level, almost 18% lost confidence by 1 or 2 levels. A paired sample *t*-test was performed to confirm that there was a significant difference in confidence level related to passing the FE exam before (M=2.37, SD=1.07) and after (M=2.64, SD=0.84) the interventions, t(164)=-3.10, p=0.001.

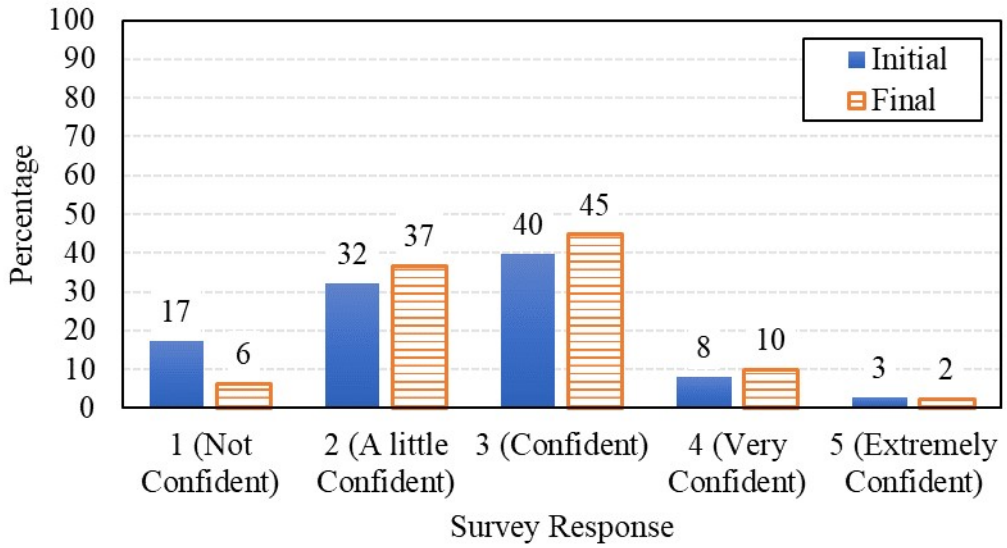

Figure 6—Results from survey Question 5: What is your confidence in passing the FE exam?

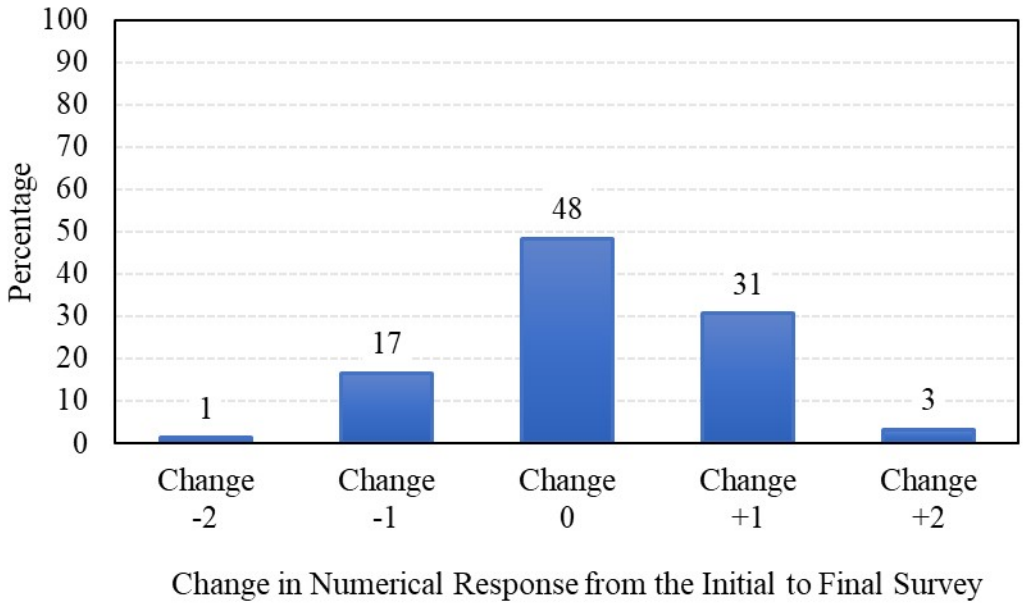

Figure 7—Change in response to Question 5 (confidence passing the FE Exam).

Questions 8 through 10 required students to have an opinion about how to review for the FE exam. The first time the survey was administered many had no response because they had no opinion or did not understand the question yet. Questions 8 and 9 were used to categorize students' preferred methods of review for the FE exam; Question 8 asked about their perception of the FE-style questions used in their class. A list of eight answer choices were prepopulated, followed by an open response option. The first four answer choices (Table 2) were all positive reactions to the FE-style quiz questions, and they were the most selected response in both the initial and final surveys, as shown in Figure 8. Initially, most students did not respond to the question (no category had more than 27% response) since the FE-style quizzes had not yet been implemented. However, the final survey results shown in Figure 8 indicated that over 65% of the

students responded that they liked how the FE-style questions helped them review past concepts, gauge their understanding of the material, and provided extra example problems. Of the final survey negative responses to Question 8, only 5% of students said they put forth little effort on the questions.

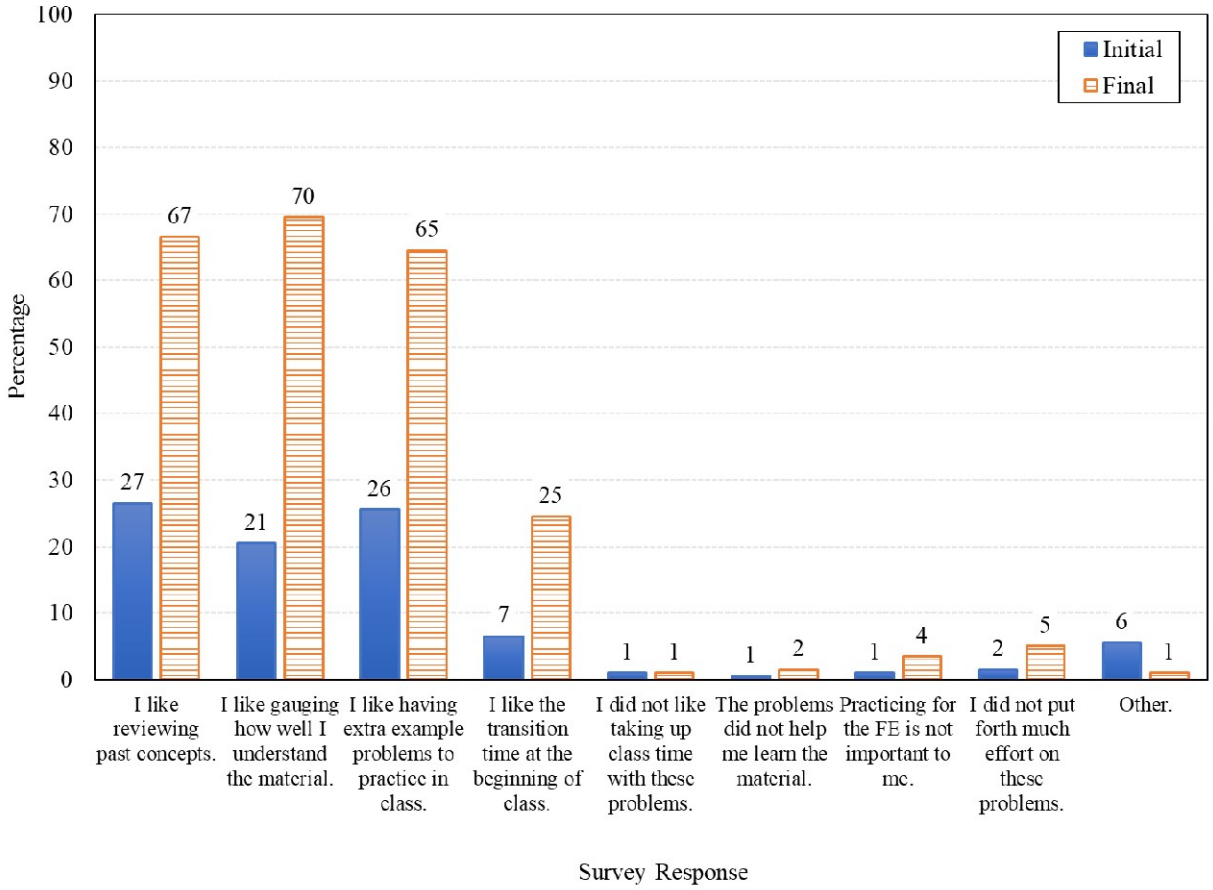

Figure 8—Results from survey Question 8: What were your impressions of the FE-style questions in this class? Pick all that apply.

Question 9 was similar to Question 8 and asked students about their preferred method of FE review. The initial and final survey results shown in Figure 9 indicated that student responses were similar for most categories before and after implementation of the FE-style quiz questions. However, in both the initial and final survey, the most common student responses were "Reviewing questions at the beginning of class (like we did)" and "Test or quiz questions that simulate FE questions." Both responses directly align with the style of FE exam review implemented throughout this study. Overall, students agree that they need additional methods to prepare and study for the FE exam; a low percentage of students don't care about studying or think their coursework is sufficient.

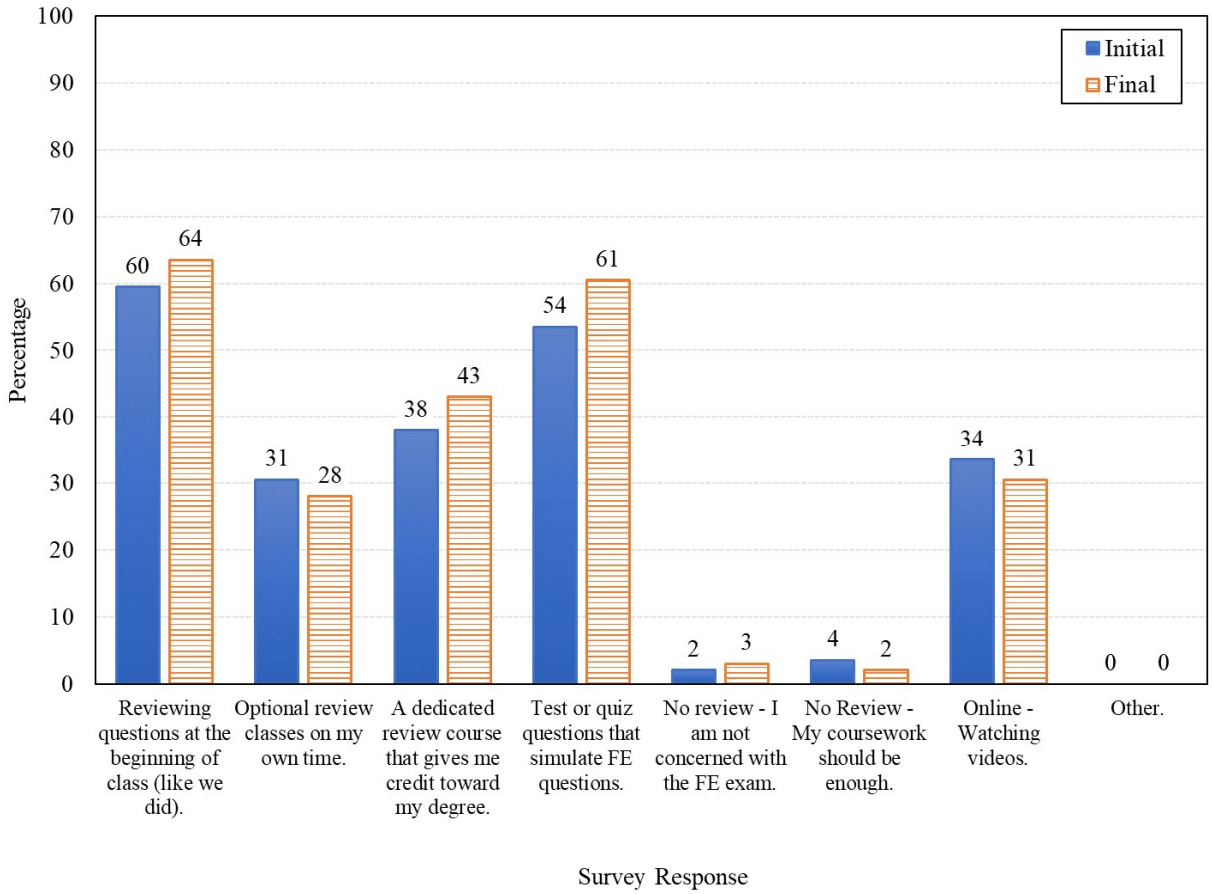

Figure 9—Results from survey Question 9: What method of reviewing for the FE exam do you prefer? Pick all that apply.

Question 10 was open-ended and asked for additional thoughts, impressions, and opinions. The responses were divided into the five categories shown in Table 3. Most responses were positive; students liked the method or idea of reviewing for the FE exam, especially early in their degree. Initial confusion about the FE exam was corrected by the end of the semester. Several students desired a more comprehensive FE exam review class, whether optional, for credit, or required. Students at University A can take a technical elective course where they review for the FE exam, which may have prompted some of these responses.

Table 3—Results from open-ended survey Question 10: Do you have any additional comments about this method of reviewing for the FE exam?

Response Category	Initial	Final
Positive	22	35
Negative	0	2
Confused about the FE	13	1
Want another FE review method	7	8
Want a FE review class	5	6

FE-style Start-up Quiz Questions

Five of the classes in this study collected FE-style quiz data from the initial and final deployment of each question, as shown in Table 4. Overall, there were 1769 quiz question attempts across all the classes, students, and quiz questions. Only data from students that completed the questions twice, once during the initial deployment and once during the final assessment, were used in this study; a few students only completed quiz questions one time. Data in Table 4 indicate that only one out of the five classes had an average change in quiz question performance that decreased (Structural Theory). Changes in performance were measured by comparing how students did on each question the first time compared to the second time; students could increase their score (wrong the first time, correct the second time), decrease their score (correct the first time, wrong the second time), or maintain their score (both correct or both wrong). For example, considering the Dynamics course, the overall class average improved by 4% (all students, all quiz questions); however, the class average improved by 39% on one of the ten questions and decreased by 12% on a separate question. Results in Table 4 indicate that performance on the FE-style quiz questions varied throughout the semester in every class, even though the overall student average performance improved by 7% (all classes, all students, all quiz questions).

Results in Figure 10 indicated that students chose the right answer both times 53% of the time; 20% of students improved their performance from an incorrect answer the first time to a correct answer the second time, and 11% of students had a decline in performance from a correct answer the first time to an incorrect answer the second time. Overall, approximately 73% of students selected the correct answer on the final assessment on a per question basis. A paired samples *t*-test was performed to compare the overall quiz averages for all classes before and after the class interventions. There was a significant increase in quiz averages before (M=55.4%, SD=29.4%) and after (M=64.3%, SD=30.9%) the interventions, $t(194)=-5.69$, $p<0.001$.

Table 4—Change in FE-style quiz question performance per class.

Class	Average change per question (%)	Maximum change per question (%)	Minimum change per question (%)
Dynamics	4	39	-12
Structural Theory	-2	35	-30
Fluid Mechanics	10	61	-36
Statics	8	15	-5
Structural Analysis	14	50	-5
Average	*7*		

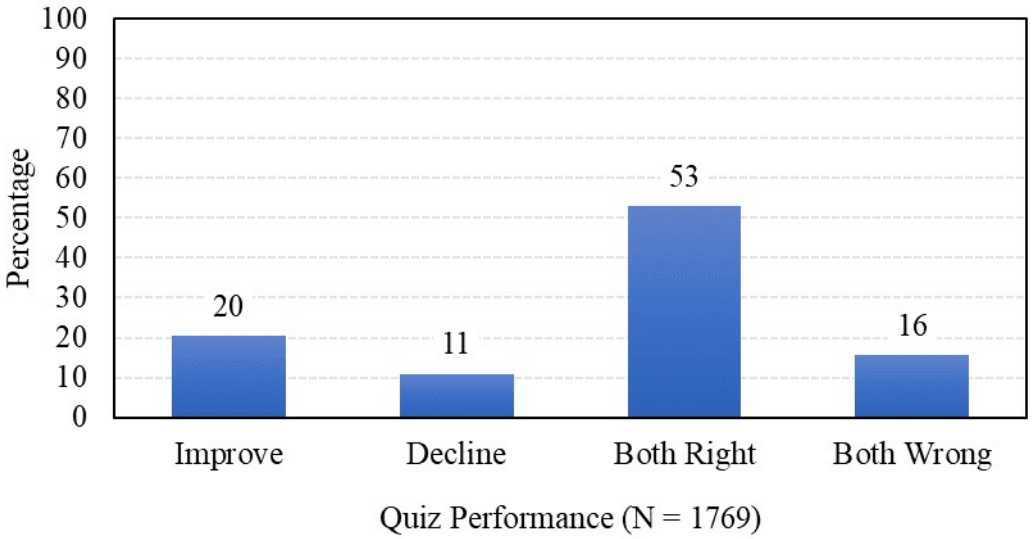

Figure 10—Change in FE-style quiz question performance from the initial attempt to the final attempt.

The FE-style quiz question results were also investigated on a per-question basis. In total, 43 questions were asked from this study for analysis. Within that set, the average score of all students who were presented with the question could improve or decline. Results in Table 5 indicate that student performance improved on 72% of the questions presented in all classes, while student performance declined for 28% of the questions presented in all classes. Every class had at least as many questions with improved scores as declined scores.

Table 5—Change in average student performance per question presented in each class.

Course	Number of FE-style questions	Improved average score (number of questions)	Declined average score (number of questions)
Dynamics	10	5	5
Structural Theory	5	3	2
Fluid Mechanics	10	7	3
Statics	10	9	1
Structural Analysis	8	7	1
Total Count	*43*	*31*	*12*
Total (%)	*100*	*72*	*28*

The FE-style quiz question data were also investigated on a per-student basis in each class. Overall, results in Figure 11 indicated that the scores improved for students in every class; student performance improved between 42% and 61% considering all classes. However, approximately 30% of the students had scores that declined in three of the classes (dynamics, structural theory, and fluid mechanics), while less than 17% of student scores declined in the other two classes. Regardless of the class, at least one third of the student performances did not improve (declined or no change). The results indicate that most students did improve on FE-style questions through repetition, but some did not.

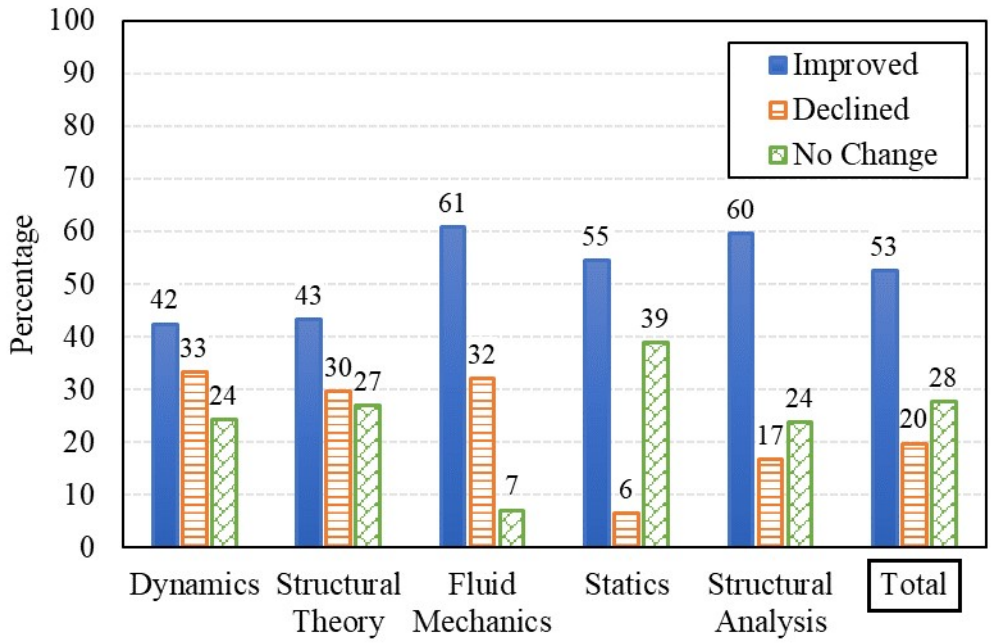

Figure 11—Change in average performance for each student in each class.

The FE-style quiz question data were also analyzed to determine how many students correctly answered at least 60% of the pass/fail questions on their final attempt. The cutoff of 60% was chosen because it is the lowest score required to pass most collegiate courses, and the exact cutoff to pass the FE exam is not reported. Results in Figure 12 indicate that an average of 65% of all the students correctly answered at least 60% of the FE-style quiz questions, but results varied between 41% and 92% depending on the course.

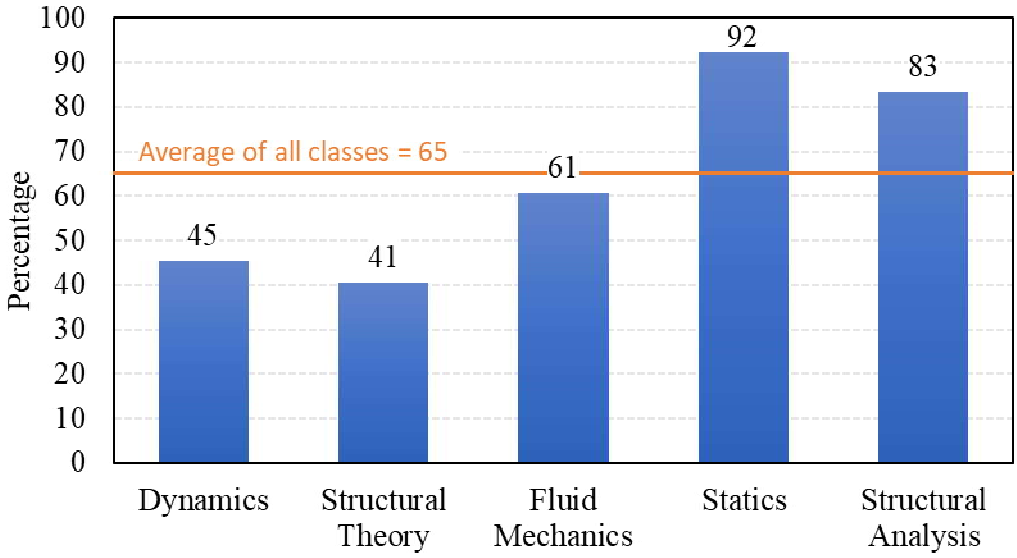

Figure 12—Percentage of students who correctly answered at least 60% of the final questions in each course.

Irregularity in question administration may have had an impact on student performance results. Some instructors administered the FE-style start up questions more regularly in class than others. In Structural Theory, fewer FE-style start-up questions were administered (5 questions) overall compared to other courses (8 or 10 questions). As a result, they were spaced two or three weeks apart in some cases. In Dynamics, questions were administered nearly every day, meaning that students were exposed to the FE-style questions at least once a week, but only about one every ten days was selected for this study. The same students were in the Structural Theory and Dynamics classes. While overall student performance in Dynamics exceeded that of Structural Theory, the difference is minimal, and more research is needed to more clearly identify how regularity affects student performance. In Fluid Mechanics, FE-style questions were administered in the online learning management system and due before class on ten out of the 14 Mondays in the semester. In Fluid Mechanics, the frequency was more similar to Dynamics, but going over the problems typically did not occur until later in the week to make sure all students had attempted the quiz before the FE-style problem was explained.

Another irregularity existed in the final administration of the questions. In most courses, the initial FE-style question was given as a start-up question at the beginning of class; however, instructors administered questions differently the second time. In Dynamics, all second iteration questions were given on tests throughout the semester. In Structural Theory and Fluid Mechanics, the questions were asked the second time on the comprehensive final exam. In these three courses, student notebooks were not allowed as a resource. In contrast, Statics and Structural Analysis students were permitted to use their notes when completing the second iteration questions, which were administered on quizzes similar to the first time the students encountered the questions.

Summary and Conclusions

This study evaluated student awareness of the FE exam, confidence in passing the FE exam, and ability to correctly answer FE-style questions. Data were collected from students enrolled in six different courses from two different universities. Student perception surveys and FE-style quiz questions were presented to students two times during the semester. The changes in the results were measured on their first and second attempt. The following conclusions and recommendations were drawn from the analysis of data obtained from this semester-long study.

- Student familiarity with the FE exam increased significantly over this semester-long study. Overall, 76% of students were familiar to extremely familiar with the FE exam by the end of the course versus only 40% feeling that way at the beginning of the course.
- Approximately 74% of the students were aware of the FE exam as it related to their career path by the end of the class compared to only 56% initially. About 45% did not know if the FE exam was a graduation requirement prior to taking the class, and this value was only 28% at the end of the class.
- Students were much more aware that the material from the course in which they were enrolled was on the FE exam by the end of the class. Awareness changed from 46% initially to 89% by the end of the class.

- Student confidence in their ability to pass the FE exam increased over the course of the semester. Initially, approximately 51% of the students were confident to extremely confident that they would pass the FE exam, and this percentage changed to 57% by the end of the semester. About 17% were not confident at the beginning of the semester, but this went down to 6% by the end of the semester. While there were changes, few students (12%) were very or extremely confident in passing by the end of the semester.
- Students generally want to study and pass the exam. They prefer a variety of methods but reviewing concepts/questions at the beginning of class and completing FE-style assessment questions were the most highly rated.
- Considering the FE-style quiz questions implemented in this class, the majority of students liked how the FE-style start-up questions helped them review past concepts, gauge their understanding of the material, and provided extra example problems.
- Students also expressed interest in a credit-based FE exam review course, whether it is required or optional. Approximately 30% of students also expressed interest in reviewing on their own with study guides or online sources such as videos.
- By the end of the semester, approximately 73% of the FE-style questions that were asked were answered correctly by students engaged in this study. The overall student performance average per question increased significantly, by 7% across all classes, even though the average change in performance varied per class.

Overall, this learning strategy implemented to help students prepare for the FE exam was beneficial because it made students more aware of the exam, how the exam was linked to their future career, and the type/style of questions on the FE exam. Student perceptions indicated that reviewing FE questions is greatly valued, whether with this method or another method. Many students commented that they were grateful to practice for and be reminded of the FE exam. Implementation of the methods described herein did not take away a significant amount of instructional time and students became more aware of the exam and need to study. Considering the methods used in this study, student familiarity with the FE exam, confidence in passing the exam, and performance on FE-style questions significantly improved over the semester.

References

[1] NCEES. "PE Exam." National Council of Examiners for Engineering and Surveying. Available: https://ncees.org/exams/pe-exam/. [Accessed February 1, 2024].

[2] NCEES. "FE Exam." National Council of Examiners for Engineering and Surveying. Available: https://ncees.org/exams/fe-exam/. [Accessed January 14, 2024].

[3] I. Goswami, *Fundamentals of Engineering FE Civil Exam Guide*, 1st Ed. McGraw Hill, 2018, pp. 656.

[4] M. R. Lindeburg, *FE Civil Review*, 3rd Ed. PPI a Kaplan Company, 2017, pp. 732.

[5] NCEES, *FE Civil Practice Exam*, NCEES, 2020.

[6] NCEES, *FE Reference Handbook 10.3*, NCEES, 2023.

[7] PPI2Pass, "FE Exam - Civil," *PPI2Pass*, Available: https://ppi2pass.com/fe-exam/civil. [Accessed January 14, 2024].

[8] Udemy, "Fundamentals of Engineering (FE) Exam Review," *Udemy*, Available: https://www.udemy.com/course/fundamentals-of-engineering-fe-exam-review. [Accessed on January 14, 2024].

[9] K. J. Fridley, W. E. Back and D. G. Williamson, "The ASCE BOK, ABET Accreditation Criteria, and NCEES FE Exam - Are They Appropriately Aligned?" *ASEE Annual Conference and Exposition*, New Orleans, LA, June 2016. https://peer.asee.org/26089

[10] J. L. Bossart, "Recent changes to the fundamentals of engineering (FE) exam and ways engineering libraries can support students," *ASEE Virtual Annual Conference*, June 2020. https://peer.asee.org/35122

[11] J. Bowen. "Efforts To Better Understand the Relationship Between Civil Engineering Student Preparation and Success on The Fundamentals of Engineering Exam." *ASEE Annual Conference & Exposition*, Louisville, Kentucky, June 2010. https://peer.asee.org/16493

[12] M. Swenty, Shearer, C. R., Dymond, B. Z., Idewu, W. I. A., "Does a Review Course Increase FE Exam Preparedness?" *ASEE Virtual Annual Conference*, July 2021. https://peer.asee.org/36991

[13] F. King and S. Ilias, "A Study of Student Retention Using Rapid Testing and Repetitive Testing: Preliminary Classroom Results from an FE Review Course," *ASEE Annual Conference & Exposition*, Pittsburgh, Pennsylvania, June 2008. https://peer.asee.org/4295

[14] R. Malani and E. Koehn, "Review for And Assessment of The Fundamentals of Engineering Exam," *ASEE Annual Conference*, Portland, Oregon, June 2005. https://peer.asee.org/14775

[15] E. Koehn, J. F. Koehn, R. D. Malani, and R. Mandalika, "Outcome assessment of performance on the fundamentals of engineering (FE) examination," *Journal of Professional Issues in Engineering Education and Practice*, 134 (1), p 1-6, 2008. https://doi.org/10.1061/(ASCE)1052-3928(2008)134:1(1)

[16] B. N. Roszelle, M. Gordon, B. S. Davidson, and P. J. Laz, "Novel Sophomore Assessment Modeled after the F.E. Exam," *ASEE Annual Conference & Exposition*, New Orleans, Louisiana, June 2016. https://peer.asee.org/25803

[17] J. C. Morales, "Language or Problem-formulation Difficulties? An FE Exam Experiment in a Hispanic Setting," *ASEE Annual Conference & Exposition*, Columbus, Ohio, June 2017. https://peer.asee.org/28605

[18] K. Plantenberg, "Fundamentals of Engineering Exam Graduation Requirement," *ASEE Annual Conference & Exposition*, Pittsburgh, Pennsylvania, June 2008. https://peer.asee.org/3611

[19] S. J. Khatib, R. Taraban, and W. D. Lawson, "Student Confidence and Metacognitive Reflection with Correlations to Exam Performance in a FE Review Course in Chemical Engineering," *ASEE Virtual Annual Conference*, June 2020. https://peer.asee.org/35222

[20] B. J. Swenty and M. Swenty, "The Impact of EAC-ABET Program Criteria on Civil Engineering Curricula," *ASEE Annual Conference and Exposition*, Tampa, Florida, 2018. https://peer.asee.org/31106

[21] G. Liaw, P. Saha, and J. Foreman, "Preparing Minority Engineering Students to Pass the Fundamentals of Engineering Examination," *ASEE Annual Conference & Exposition*, Pittsburgh, Pennsylvania, June 2008. https://peer.asee.org/3701

[22] W. Craver, D. Schoder, C. Turner, and A. Tarquin, "Using the Fundamentals Exam as a Legislative Performance Indicator," *ASEE Annual Conference*, Nashville, Tennessee, June 2003. https://peer.asee.org/11410

[23] S. Laughton and D. D. Nale, "Student Interaction and Perception of FE-Based Formula Sheet Use in Engineering Exams," *ASEE Southeast Section Conference*, Arlington, Virginia, March 2023. https://peer.asee.org/45045

[24] J. Crepeau, Willis, B., Quallen, S., Beyerlein, S. W., Cordon, D., Soule, T., Northcutt, P., Gaffney, T. A., Kimberling, J., Shears, A. C., Miller, A., "Generation-Z Learning Approaches to Improve Performance in the Fundamentals of Engineering Exam." *ASEE Virtual Annual Conference*, June 2020, pp. 12. https://peer.asee.org/34705

[25] A. Ng and K. C. Gramoll, "Online Review and Practice Tests for the Fundamentals of Engineering Exam," *ASEE Annual Conference*, Charlotte, North Carolina, June 1999. https://strategy.asee.org/7868

[26] T. Xing, S. W. Beyerlein, J. Crepeau, "Impact of Self-Directed Learning Modules on Preparing Students to Take the FE Exam," *ASEE Annual Conference & Exposition*, Baltimore, Maryland, June 2023.

[27] N. Gnanapragasam, K. Kuder, and D. Jefferey, "Comparison Between Grade Earned in a Course and Performance in a Simulated FE Exam for Mechanics Related Courses," *ASEE Annual Conference & Exposition*, Pittsburgh, Pennsylvania, June 2008. https://peer.asee.org/4459

[28] M. R. Muqri, J. Shakib, H. Muqri, and M. Saouli, "An Electrical and Computer Startup Kit for Fundamentals of Engineering (FE) Exam," *ASEE Annual Conference & Exposition*, New Orleans, Louisiana, June 2016. https://peer.asee.org/26577

[29] S. Papanikolaou, "E-Learning and assessment in the cloud: Engineering courses," in *ASEE Annual Conference and Exposition*, Virtual Conference, 2020. https://peer.asee.org/34485

[30] E. Steinberg and B. Stuart, "Supplementing FE Exam Results for Continuous Assessment," *ASEE Annual Conference*, Portland, Oregon, June 2005. https://peer.asee.org/14172

[31] A. Miller, "FE Exam the First "Reality Show" Encounter for Engineering and Engineering Technology Undergraduates," *ASEE Annual Conference & Exposition*, Chicago, Illinois, June 2006. https://doi.org/10.18260/1-2--996

[32] G. A. Brown, M. R. Bice, B. S. Shaw, and I. Shaw, "Online quizzes promote inconsistent improvements on in-class test performance in introductory anatomy and physiology," *Advances in Physiology Education*, pp. 63-66, Jun. 2015. https://doi.org/10.1152/advan.00064.2014

[33] C. Yang, J. Li, W. Zhao, L. Luo, and D. R. Shanks, "Do practice tests (quizzes) reduce or provoke test anxiety? A meta-analytic review," *Educational Psychology Review*, pp. 87, 2023. https://psycnet.apa.org/doi/10.1007/s10648-023-09801-w

[34] L. K. Sotola and M. Crede, "Regarding class quizzes: A meta-analytic synthesis of studies on the relationship between frequent low-stakes testing and class performance,"

Educational Psychology Review, pp. 407–426, 2021. https://psycnet.apa.org/doi/10.1007/s10648-020-09563-9

[35] K. L. Kenney and H. Bailey, "Low-Stakes Quizzes Improve Learning and Reduce Overconfidence in College Students," *Journal of the Scholarship of Teaching and Learning*, Jun. 2021. https://doi.org/10.14434/josotl.v21i2.28650

[36] M. Haigh, "Sustaining learning through assessment: an evaluation of the value of a weekly class quiz," *Assessment & Evaluation in Higher Education*, pp. 457-474. https://doi.org/10.1080/02602930600898593

[37] K. L. Cooksey and P. Jonsson, "Using Pre-/Post-Quizzes Intentionally in Curriculum Development and Evaluation," *UC Santa Cruz: Leaders in effective and inclusive STEM: Twenty years of the Institute for Scientist & Engineer Educators*. https://doi.org/10.48550/arXiv.2210.01823

[38] R. K. Tener and V. Drnevich, "Opposition to Mandatory Use Of PE/FE Exams as Assessment Tools," *ASEE Annual Conference*, Seattle, Washington, June 1998. https://peer.asee.org/7325

[39] B. S. Bloom, M. D. Engelhart, E. J. Furst, W. H. Hill, and D. R. Krathwohl, "Taxonomy of Educational Objectives," Edwards Brothers, Ann Arbor, MI, 1956.

[40] J. Boyle, D. Nicol, B. Hamilton and B. Dempster, "Experience with Classroom Feedback Systems to Enable Socratic Dialogue in Large Engineering Classes," *IEEE Engineering Education 2002: Professional Engineering Scenarios*, London, UK, 2002, pp. 16/1-16/4. https://doi.org/10.1049/ic:20020097