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Does a Review Course Increase FE Exam Preparedness?

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Does a Review Course Increase FE Exam Preparedness?

Introduction

The Fundamentals of Engineering (FE) exam is a standardized test used to assess student knowledge near graduation in seven different disciplines, including civil engineering. Students are encouraged to take the exam at most universities, and some require it for graduation. Fourteen topic areas are tested on the multiple-choice exam [1]. Programs prepare students to take the exam in various ways, including: requiring specific courses in the curriculum, requiring students to take a course on every FE topic, providing optional review sessions outside of normal class, requiring students to pass a university-version of an FE-style exam before graduation, or requiring an FE-style review course or seminar.

Few studies have directly linked student perception of successfully passing the FE exam with their performance on assessed coursework, especially while considering the students' first or second exposure to a topic. The following study focused on students' preparedness for the FE exam as measured by their confidence and performance on FE-style questions in their courses. Three courses at three different universities were used to evaluate preparedness: an introductory reinforced concrete (R/C) course, an introductory civil engineering materials course that covered concrete materials, and an FE review course. The professors taught the topics of interest using their unique teaching styles and methods. During the semester, the same survey and the same exam questions were posed to the students at each university.

Background and Literature Review

Teaching is a complex process that typically requires repetition and different presentation styles because students are all unique and learn in different ways and at different paces. While engineering students do tend to have some similarities in learning preferences, there is no universal approach that works for every student in the classroom [2, 3]. Repetitive exposure to topics is commonly believed to be an important part of the learning process. The American Society of Civil Engineers (ASCE) maintains a civil engineering body of knowledge (BOK) that outlines 21 different outcomes along with Bloom's levels of cognitive achievement. The outcomes start with the foundational topics and then build to the engineering fundamentals and technical content. The BOK states that many of these levels of cognitive achievement can only be obtained through the process of undergraduate education, postgraduate education, and experience [4]. Additionally, the ABET Criteria for Accrediting Engineering Programs, Criterion 5 Curriculum, indicates students must build upon their "skills acquired in earlier course work" as they culminate in a final design experience. In addition, the civil engineering program criteria states graduates must apply knowledge in a series of progressive subjects [5]. The outcomes in the BOK and ABET criteria indicate that learning engineering topics takes time in a progressive learning process.

Teaching requires vertical integration of material in engineering. A study of a representative sample of civil engineering programs confirmed that most programs teach topics in a hierarchical approach starting with basic science, then mechanics, and finally civil engineering courses [6].

These topics build upon one another and require repetition. For example, it is not uncommon to see a civil engineering program require calculus, a calculus-based physics course, statics, and then mechanics of materials in succession because they all overlap and build.

A process that may be as equally difficult as teaching is assessing knowledge gains in engineering concepts. One universal method that is recognized by every state in the United States is the FE exam created by the National Council of Examiners for Engineering and Surveying (NCEES). Numerous versions of the FE exist, including a civil engineering specific exam that continues to evolve and most recently underwent changes in July 2020 [1]. Two topics are directly related to analysis and design with concrete. Structural engineering includes loads, load combinations, load paths, and reinforced concrete while materials includes concrete mix design and properties. Furthermore, student performance on the FE exam may be used to assess university curricula or ensure ABET outcomes are being satisfied [7]-[11].

Preparing for the FE exam can be accomplished in many ways. A robust civil engineering program would provide a course in every area on the FE exam. However, in recent years this has not been always been the case [12]. The breadth of material on the exam requires more courses than most programs have time to cover. Preparation can also be accomplished with an optional review course, with formal review courses, in collaboration with the university library, or through independent study [13]. A few programs require more formal FE review courses as part of a seminar class or senior level engineering course [6], [14]-[15]. Some universities have made taking the exam a requirement before graduation [16]. Several studies have examined the varied learning approaches in preparation for the FE exam [17]-[21]. While each learning approach was unique and contributed to some benefits in confidence and performance, no single approach was definitively linked to increases in scores on the FE exam. The challenge with any of these methods is quickly covering enough material to provide a comprehensive review of each topic on the exam. Dedicating time to study prior to taking the course is recommended and a host of different study materials are available [22]-[25].

Of particular interest is the preparation required for complex topics in design. Many topics in hydraulic, environmental, and structural design require multiple steps and equations to solve. A series of courses are commonly required to master these topics (such as fluid mechanics and hydraulics or structural analysis and structural design). An additional formal course or FE study method may be recommended prior to taking the FE exam to reinforce and review these subjects.

Research Objectives

This research study focused on two subareas of the FE exam: reinforced concrete design and concrete materials. These topics are commonly included in separate courses in an undergraduate civil engineering program. To achieve the objective of determining if an FE review course improves student confidence and performance on these topics, this study focused on answering the following questions:

1) Do students have confidence in passing the FE exam?
2) Do students have confidence in passing reinforced concrete and concrete materials questions on the FE exam?
3) Does an additional course that reviews these topics improve student confidence in passing the FE and questions on these topics?

4) Do students perform best on topics at the end of a semester course dedicated to the topic, during the beginning of their last year of study after having already completed the dedicated courses, or after taking an FE review course that provided a brief study of each topic on the FE exam?

Research Methods

Data were collected from an FE review course, a reinforced concrete design course, and a concrete materials course during the Fall 2020 semester at three different universities to evaluate student preparedness for the reinforced concrete and concrete materials portions of the FE exam. The professors in this study taught with their preferred methods and organized the semester to fit the schedule at their university. The professors were aware of each other's teaching methods and styles, but there was no attempt to unify any of the classes. The primary point of similarity was that all the surveys and exam questions administered in this study were the same and were made together. All the exam questions were presented in a multiple-choice format to reflect the most common method of questioning on the FE exam.

University A required students to take the FE exam and students were reimbursed for the exam cost if they passed. At University A, most senior students (approximately 75% or more per year) in civil engineering take the FE review course and depend on it as their sole source of preparation for the exam. Universities B and C strongly encouraged students to attempt the FE exam prior to graduation. At University B, review sessions are optional and provided outside of a formal course. At University C, a senior-level course is required that includes FE exam review. None of the universities involved in this study required students to pass the exam. No data were collected in this study regarding if and how individual students independently prepared for the FE exam.

University A - FE Review

University A is a small, public, bachelor's university in a small rural mid-Atlantic community (Carnegie Classification, Baccalaureate College - Arts and Sciences Focus). The civil engineering department graduates an average class of 55 students per year and most graduating students pursue full-time employment upon graduation.

The authors at University A taught a semester-long, three credit hour, FE review course covering all 14 topic areas on the FE exam. The only prerequisite for this civil engineering elective course is senior standing, but most students had previously taken reinforced concrete and engineering materials courses. Three professors team-taught the course and organized the topics into 18 review lessons. Additional days dedicated to practicing problems were also included. Two areas (water resources and structures) were broken up into multiple lessons. Each professor was given six 75-minute classes to present material on their topics. The class of 46 students was divided into three sections of 15 to 16 students for each review lecture. The class was designed for in-person instruction, however approximately 25% of the students joined virtually on most days during the Fall 2020 semester. An equal amount of time was used to present reinforced concrete and steel design topics during one class period. The materials topics including metals, materials testing, materials formation, materials physical/chemical properties, cement, aggregate, and

concrete were reviewed during a separate class period. One assignment that consisted of ten FE-style review questions was assigned per class.

At University A, the initial and final surveys to assess student confidence were administered at the beginning and end of the semester as anonymous surveys through the online course learning management system. All homework and exam questions were given as multiple-choice problems with the same format as the FE exam. The students took an initial practice exam the first week of class before reviewing any topics. The students were not given an opportunity to prepare for the test, were only allowed to use the FE equation manual, and the results did not negatively affect their grade; however, as additional motivation they were given a bonus point on their final grade for good performance. Included in this 75-minute exam were five reinforced concrete questions and two concrete materials questions. The tests were collected and the same questions were asked on the comprehensive final exam at the end of the semester. The final exam counted as 30% of the final grade.

University B - Reinforced Concrete Design

University B is a midsized, public, master's university in a medium density city in the West North Central Region (Carnegie Classification, Master's Colleges & Universities: Medium Programs). The civil engineering graduating class averages approximately 70 students per year and most graduating students pursue full-time employment rather than a graduate degree.

The author at University B taught an introductory concrete design course where students were exposed to reinforced concrete topics for the first time. The reinforced concrete design course is required for all students. Most students take the class within one year of graduation. During the semester when this study was performed, there were 35 students enrolled in one section of the reinforced concrete design course. During the Fall 2020 semester, this class met in an online format three days a week at set times in 50-minute intervals over the course of 41 lectures. All instruction was conducted using remote instruction technology.

The initial and final surveys to assess student confidence were administered at the beginning and end of the semester as anonymous surveys through the online course learning management system. The technical FE-style multiple-choice assessment questions were posed to students once in this course as part of either two midterm exams that were administered during the 50-minute class time (40% of the final grade) or a two-hour comprehensive final exam that was given at the end of the semester (20% of the final grade). Students completed the exams by uploading pdf files of their hand-written solutions via the online course learning management system.

University C - Concrete Materials

University C is a small, public, doctoral university in a medium density city in the West North Central Region (Carnegie Classification, Special Focus Four-Year: Engineering Schools). An average of 50 undergraduate students have graduated per year from the civil and environmental engineering program over the past four years, with high placement in the workforce after graduation.

The author at University C taught a required introductory civil engineering materials course where students were exposed to concrete materials topics for the first time. There were 44 students enrolled in one section of the materials course during the semester when this study was performed. During the Fall 2020 semester, this class met in an asynchronous online format with a modular organization by topic including concrete, aggregates, steel, asphalt, composites, plastic, and wood. Additionally, students in the class met once a week in-person for a laboratory experience.

The initial and final surveys to assess student confidence were administered at the beginning and end of the semester as anonymous surveys through the online course learning management system. The technical FE-style assessment questions were posed to students in this course one time as part of the online quiz on the concrete materials module (10% of the final grade). Students completed the online quiz by directly answering questions on the online course learning management system.

Common Survey Questions

Student confidence was determined using initial and final surveys containing the same questions. Survey results were collected using the following five-level scale: (1) Not confident at all, (2), (3) Somewhat confident, (4), and (5) Very confident. No word-based description was provided for levels (2) and (4) in the scale.

Faculty at all three universities asked the same basic question:

> Q1: On a scale of 1 to 5, what is your confidence in passing the FE Exam?

Faculty at University A (FE review course) and University B (reinforced concrete course) both asked the same additional question:

> Q2: On a scale of 1 to 5, what is your confidence in passing the reinforced concrete section of the FE Exam?

Faculty at University A (FE review course) and University C (concrete materials course) both asked the same additional question:

> Q3: On a scale of 1 to 5, what is your confidence in passing the concrete materials section of the FE Exam?

Faculty at University A (FE review course) asked the following two additional questions at the beginning of the semester to determine the amount of time that elapsed between when students were first introduced to a topic and when they reviewed the same topic in the FE review course:

> Q4: What semester did you take the concrete materials course?
> Q5: What semester did you take the reinforced concrete course?

Common Exam Questions

Five exam questions related to reinforced concrete topics were presented at Universities A and B. Two exam questions related to concrete materials were presented at University A and C. The

professors' previous experience teaching the respective courses and an evaluation of widely used review books provided guidance when selecting a representative sample of questions from those published in a textbook or by NCEES [23]-[24]. Multiple choice questions were used in this study because they are the most common type of questions published for FE review. The five assessment questions related to reinforced concrete are shown below, with a description of the details in italics:

Q1. What is the value of phi (ϕ) that should be used in computing the flexural design strength (ϕM_n)?

This question required students to analyze a rectangular beam with one layer of reinforcement. Determination of the transition-region phi factor required the students to complete calculations for the values of a, β_1, c, ε_t, and ϕ using equations directly from the FE Reference Handbook [25].

Q2. What is the flexural design strength (kip-ft) of the reinforced concrete beam?

This question required students to analyze a rectangular beam with one layer of reinforcement. Determination of the factored nominal resistance required the students to complete calculations for the values of a, M_n, ϕ, and ϕM_n using equations directly from the FE review manual [25].

Q3. Select the correct design load for a short reinforced concrete column with the following service loads: P_D = 100 k, P_L = 250 k, and P_W = 180 k.

This question required students to factor given axial loads on a column. Determination of the ultimate axial load required one load combination equation directly from the FE review manual [25].

Q4. How long is the zone where no shear reinforcement is required? Assume such a zone exists and that this beam is not affected by pattern live loading.

This question required students to complete an analysis using factored loads and a rectangular beam that were provided. Determination of the no-reinforcement zone required the students to complete calculations for the values of V_c and ϕ using equations from the FE review manual; students also had to create and interpret a linear shear diagram [25].

Q5. If the design shear demand is V_u = 80 kips, what is the required spacing of the No. 4 stirrups for strength?

This design question required students to select a stirrup spacing given the ultimate shear demand on a rectangular beam. Determination of the most appropriate stirrup spacing required the students to rearrange equations for V_u and V_s while calculating V_c and A_v using three calculations from the FE review manual [25].

The two assessment questions related to concrete materials are shown below, with a description of the details in italics:

Q6. Ready-mixed concrete being delivered to a jobsite is found to have a slump less than specified. Which of the following is the most appropriate corrective action?
This question required students to apply their conceptual understanding of the combined effect that water and admixtures have on the workability and strength of a concrete mix.

Q7. The following preliminary concrete mix has been designed assuming that the aggregates are in the oven-dry condition: water = 305 lb/yd^3, cement = 693 lb/yd^3, coarse aggregate (OD) = 1674 lb/yd^3, fine aggregate (OD) = 1100 lb/yd^3. The properties of the coarse aggregate are 0.5% absorption (moisture content as SSD) and 2% moisture content as used in mix. The properties of the fine aggregate are 0.7% absorption (moisture content as SSD) and 6% moisture content as used in mix. What is the amount of water that would be used in the final mix (lb/yd^3)?
This question required students to use the Absolute Volume Method for concrete mix design. Determination of the appropriate water required knowledge of the aggregate's moisture content, physical absorption properties, and their combined effect on the addition of water to the concrete mix.

Results

Survey Results

The first three survey questions were based on the students' perceived confidence in passing the FE exam and individual sections of the FE exam. Results in Table 1 indicate that student confidence increased in all three areas after completion of the course at all universities. Initially, students at all three universities were most confident in their ability to pass the FE exam (3.12 average confidence) compared to either the reinforced concrete section (3.07 average confidence) or the concrete materials section (2.80 average confidence). However, average final survey results indicated that students were slightly more confident in passing the topic-specific portions of the exam compared to their overall performance on the exam. The average final confidence levels were approximately the same for performance on the overall exam (3.42), on the reinforced concrete portion of the exam (3.46), and on the concrete materials portion of the exam (3.50). The largest gains in confidence were made in the topic-specific courses of reinforced concrete (University B) and concrete materials (University C), with gains of 26% and 34%, respectively (Figure 1). Gains at University A related to the specific topics were less than half those at University B or C. At University A, the most significant confidence gains came in the materials topic (16%).

Table 1 - Perceived student confidence on FE-style exam questions (on a scale of 1 to 5) at the beginning and end of the semester.

	Q1: FE Exam Confidence			Q2: R/C Confidence		Q3: Materials Confidence	
	Univ. A	Univ. B	Univ. C	Univ. A	Univ. B	Univ. A	Univ. C
n =	33	35	43	33	35	33	43
Initial	3.16	3.26	2.93	3.19	2.94	2.75	2.84
Final	3.36	3.38	3.51	3.21	3.71	3.18	3.81
% Change	+6	+4	+20	+1	+26	+16	+34
Initial Avg.	3.12			3.07		2.8	
Final Avg.	3.42			3.46		3.5	

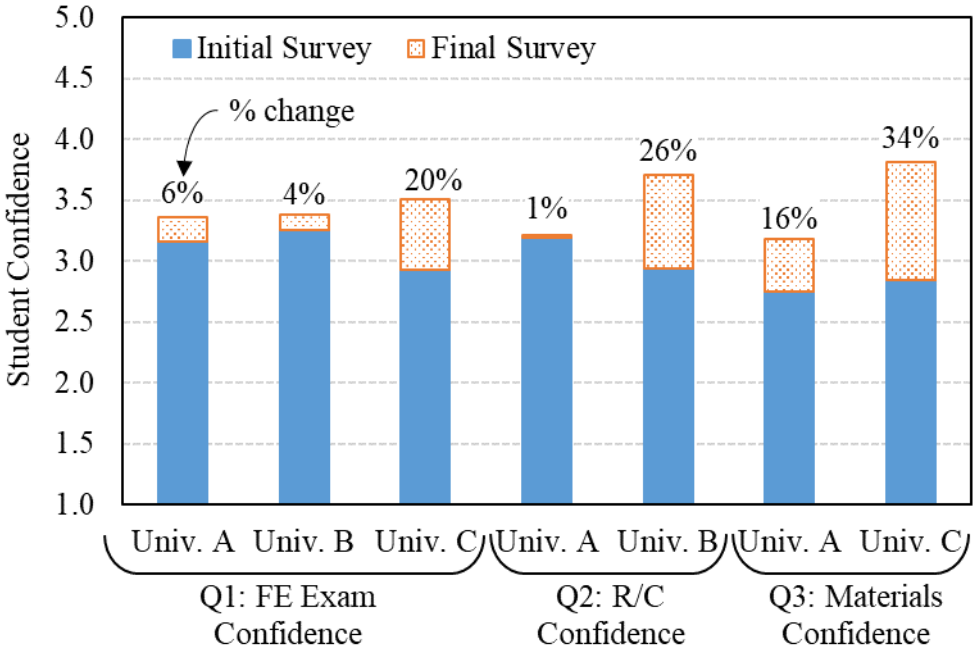

Figure 1 - Average perceived student confidence on FE exam questions.

At University A the entire semester was devoted to reviewing for the FE exam. A closer look at the change in student confidence at University A demonstrated that 64% of student's overall confidence did not change, but only 6% lost confidence (Table 2). When reviewing confidence in reinforced concrete, 24% lost confidence, but over 75% had no change or an increase in confidence. For the materials topic, the largest percent of students increased their confidence (52%). Almost the same percent lost confidence in materials as did in reinforced concrete.

Table 2 - Change in students' individual confidence (on a scale of 1 to 5) at University A from the beginning to the end of the semester.

Change in Confidence	Q1: FE Exam Confidence (%)	Q2: R/C Confidence (%)	Q3: Materials Confidence (%)
Increase	+30	+30	+52
None	64	46	27
Decrease	-6	-24	-21

The students self-reported when they had taken the reinforced concrete and materials courses. Approximately 88% of the students had taken the reinforced concrete course the previous semester and 78% had taken the materials course within the previous calendar year (previous two semesters). Data in Figure 2 indicate that the students who took a materials course within the past year (shown in parentheses on the *x*-axis) did not have as much confidence on the initial survey in two categories but made gains in every category between 0.11 and 0.48. Those who had not taken materials within the past year, lost confidence or remained the same in all three categories.

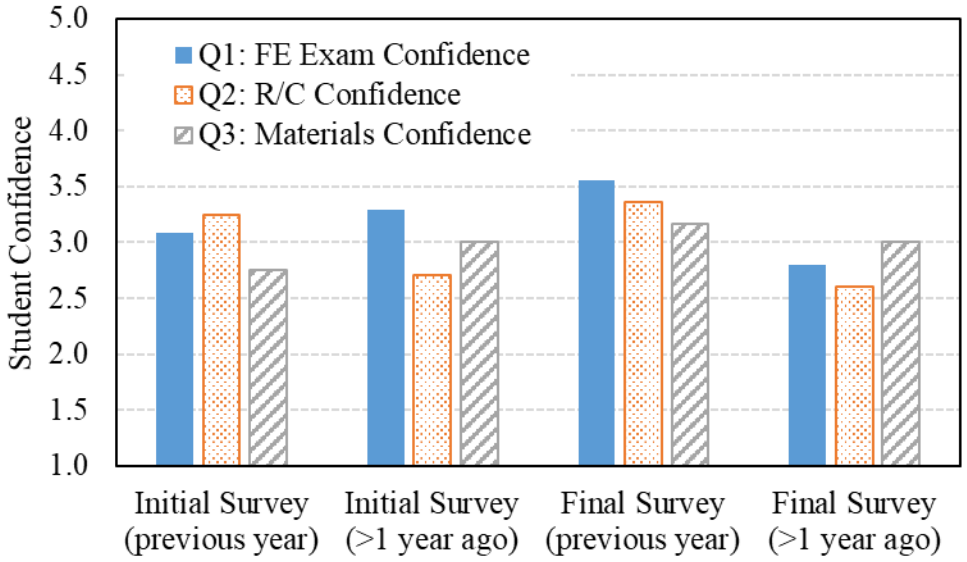

Figure 2 - Perceived student confidence at the beginning and ending of the FE review course based on when they took the materials course.

Data in Figure 3 indicate that the students who took a reinforced concrete course within the past semester started with more confidence and maintained confidence of at least 3.21 at the end. Those that did not have reinforced concrete within the past semester, started with less confidence (2.0 to 3.0) in all categories and improved to a value of at least 3.0 at the end. The patterns in Figures 2 and 3 indicate that values remained constant or went up regardless of whether a student had taken a reinforced concrete course within the past year. However, the students who did not take a materials course within the past year lost confidence by the end of the FE course in all three areas surveyed.

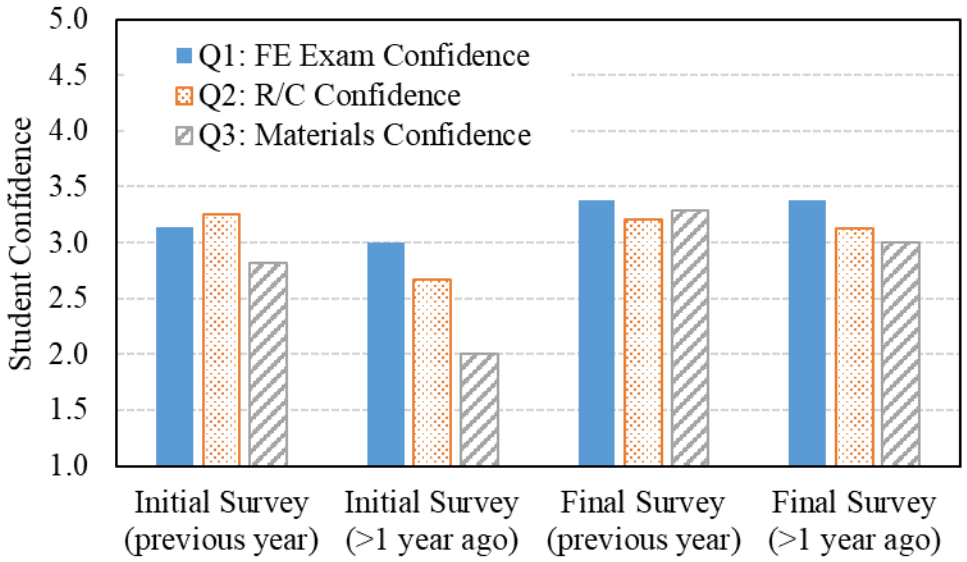

Figure 3 - Perceived student confidence at the beginning and ending of the FE review course based on when they took the reinforced concrete course.

Exam Question Results

Comparisons were made to determine if students who took an FE review course after taking the topic-specific course (University A) performed better than students learning the material for the first time (reinforced concrete at University B and concrete materials at University C). Students at University A completed the same test questions before and after reviewing the respective topics in the FE review course to determine what base knowledge they retained from their first exposure to the topic and if a second exposure to the topic led to better performance.

Assessment results for the reinforced concrete questions Q1 through Q5 (Table 3) indicated that students at University A improved their scores on three of the questions, remained about the same on one question (Q2), and did worse on one question (Q4). Q4 was the only question that forced students to use equations that were not directly in the FE manual, required the most steps to solve, and focused on shear, which is one of the most difficult topics in reinforced concrete. At University A, students had the best initial performance on Q3, which was covered in multiple previous courses. Q5 had the lowest initial percentage correct and the biggest increase; this was the only design problem on the test. An analysis of the difference in correct answers, pre- and post-FE review at University A revealed a statistically significant increase in scores for Q1, Q3, and Q5 at a 95 percent confidence level.

Table 3 - Average assessment results for reinforced concrete questions Q1 through Q5 at Universities A and B.

Question	Q1		Q2		Q3		Q4		Q5	
University (*n*)	A (34)	B (35)	A (34)	B (35)	A (34)	B (35)	A (34)	B (35)	A (34)	B (35)
Initial % Correct	35	97	47	83	56	66	44	43	12	54
Final % Correct	77	----	44	----	74	----	29	----	47	----
% Difference	117%	----	-6%	----	31%	----	-33%	----	299%	----

The performance of students at University B generally followed a similar trend as those at University A (higher percentage correct on Q1-Q3 and lower percentage correct on Q4-Q5). Data in Table 3 also show that the initial scores of students at University A were lower than the scores of students from University B on four of the five questions (Q4 was approximately the same). However, the final scores of students at University A aligned closer with the scores from students at University B on three of the five final questions (Q1, Q3, Q5). Students at University B still had better performance on four of the five questions after being immersed in a topic-specific course; on four of the five questions, student performance at University A did not reach the level of student performance at University B, even after reviewing the material for a second time.

Assessment results for the concrete materials questions Q6 and Q7 (Table 4) indicated that students at University A had better performance on the final test versus the initial test, but the final percentages were both less than 50%. The scores at University C were both higher than the initial and final scores at University A. In both cases, the results improved on both questions for University A, but not enough to reach the levels of those students at University C. Again, student performance at University A improved but did not reach the level of student performance at University C, even after reviewing the material for a second time.

Table 4 - Assessment results for concrete materials questions Q6 and Q7 at Universities A and C.

Question	Q6		Q7	
University (*n*)	A (34)	C (44)	A (34)	C (44)
Initial % Correct	21	71	30	50
Final % Correct	47	----	41	----
% Difference	129%	----	40%	----

In the FE review course at University A, about half of the students (46%) approved the faculty to trace their test and survey responses back to a personal identifier. An analysis was conducted to determine how many students improved or maintained their score on the test questions. Data in Table 5 indicate that the students' overall performance was the same or better for 91% of the students on the reinforced concrete questions and 81% of the students on the materials questions. The students' overall performance was better for 67% of the students in reinforced concrete and 47% of the students in materials. Their average confidence in passing the FE exam remained the same or increased for 86% of the students, but only 24% of students improved their confidence.

There was not a significant change in confidence in these students even though the majority did better on the final exam.

Table 5 - Individual student data for reinforced concrete and materials in the FE class offered at University A.

	Pre- vs. Post-Test		Pre- vs. Post-Survey	
	Score the same or improved	Score improved	Confidence the same or improved	Confidence Improved
Students in R/C	91%	67%	86%	24%
Students in Materials	81%	47%		

Using the same data set of about half of the students (46%), the results for each students' test questions and confidence in each topic were evaluated independently (Table 6). First, the number of students who improved on at least one question was computed. This was then compared to whether their confidence in that area changed. The number of students that improved on at least one question was 77% in reinforced concrete and 43% in materials. The confidence generally improved more in materials than reinforced concrete, but the number who improved their score and gained confidence in both topics was only between 24% and 14%, respectively. The improvement in scores and changes in confidence varied throughout.

Table 6 - Individual student data for reinforced concrete and materials in the FE class offered at University A.

	Pre- vs. Post-Test	Pre- vs. Post-Survey		Pre- vs. Post-Test and Pre- vs. Post Survey
	At Least 1 Question Improved	Confidence the same or improved	Confidence Improved	Confidence and At Least 1 Question Improved
Students in R/C	77%	67%	19%	14%
Students in Materials	43%	81%	57%	24%

Correlation of Results for FE Review Course

At University A, student-reported confidence and the difference in scores for the reinforced concrete and materials questions were analyzed using the Pearson's correlation test. Specifically, the following items were analyzed for significance (correlation was considered significant at the 0.01 level using a two-tailed analysis):

- Increase in score for the materials section on the final test
- Increase in score for the reinforced concrete section of final test
- Confidence passing the FE exam
- Confidence passing the reinforced concrete section of the FE exam
- Confidence passing the materials section of the FE exam

Results from Pearson's correlation tests (Table 7) suggest that there was not a significant correlation between performance and confidence among the population of students who took the FE review course. In fact, one of the strongest correlations revealed a negative relationship between increases in reinforced concrete scores and increases in materials scores (-0.638). The only strong positive correlation was between confidence in passing the reinforced concrete questions and confidence passing the F.E. exam. The correlation analysis also suggested that students outperformed their confidence and increased their overall scores in reinforced concrete despite a relatively low confidence in passing the reinforced concrete portion of the FE exam. The reverse was true for the concrete materials confidence and score correlation.

Table 7 – Correlation between Increased Exam Question Performance and Self-reported Confidence Passing all of Parts of the FE Exam. Correlation was considered significant at the 0.01 level using a two-tailed analysis.

	Increased R/C Question Scores	Increased Materials Question Scores	Confidence Passing FE	Confidence Passing R/C FE	Confidence Passing Materials FE
Increased R/C Question Scores	1	-0.638*	-0.260	-0.135	0.259
Increased Materials Question Scores	-0.638*	1	-0.191	-0.222	-0.085
Confidence Passing FE	-0.260	-0.191	1	0.663*	-0.093
Confidence Passing R/C FE	-0.135	-0.222	0.663*	1	-0.140
Confidence Passing Materials FE	0.259	-0.085	-0.093	-0.140	1

*Strongest correlations are +/- 0.6.

Discussion

Survey Discussion

By the end of the semester at University A, the three questions related to confidence in passing the FE exam had values that ranged from 3.18 to 3.36 (out of a maximum of 5). The average confidence improved from the beginning to end of the course for all three questions by 1% to 16%. Initially, students were less confident passing the materials section of the FE exam, but the confidence increased by the end of the FE review course such that the students were equally confident passing concrete materials questions, reinforced concrete questions, and the overall exam. A low number of students lost confidence in passing the overall FE exam by the end (6%), and confidence did not change for nearly two-thirds of the students (64%).

Perceived student confidence in passing the concrete-specific portions of the FE exam increased more for students enrolled in the concrete-specific courses compared to students who took the FE review course. By the end of the semester the confidence on all three questions ranged from 3.38-3.81 (out of a maximum of 5). Confidence went up on all questions at University B and C an average percent of 4% to 34%.

Exam Question Discussion

The FE review course did not return students to the level of knowledge observed at the conclusion of a one-semester course based on the exam question scores in both reinforced concrete and concrete materials. The FE review course did improve most student scores throughout the semester on both topics, but not enough to match the performance of students in the one-semester courses. On five of the seven exam questions, over half of the students still did not select the correct multiple-choice answer on the final test. Many students struggled on fundamental topics including computing nominal moment (M_n), designing shear stirrup spacing (s), and concrete mix designs even after the review course.

The results were promising when reviewing the data from University A on a per-student basis. Between 47% and 67% of the students performed better on their final individual tests in concrete materials and reinforced concrete, respectively (Table 5). Less than 20% performed worse at the end of the review class. About 14% had less confidence in passing the FE. The surprising trend was only 24% felt more confident in passing the FE. An increase in score did not indicate an increase in confidence for most of the students.

The FE course helped many students improve their score for the individual subjects, although the overall percent correct for the class on any given question remained less than 50% on five of seven questions. The review class did not universally help all students in every subject, but rather helped most students improve in at least one area as indicated by the individual analysis versus the overall question trends.

All questions were taken from FE review manuals or books. A post-study analysis of the questions revealed the number of steps to solve all the reinforced concrete questions would likely take five minutes or more. The average question on the FE exam should take approximately three minutes to solve, so time may have been an issue. The questions selected may have been some of the more difficult and complex problems on the exam. Test taking strategies discussed in the FE review course (University A) may have led some students to guess on these difficult questions due to time limits.

Conclusions and Recommendations

This study evaluated student preparedness for the FE exam as measured by their confidence and performance on the same FE-style exam questions administered in three different courses. Two of the three courses were introductory courses, one on reinforced concrete design and one on concrete materials. The third course was an FE review class where most enrolled students had already been exposed to the subject matter in previous introductory courses. The following

conclusions and recommendations were drawn from analysis of data obtained from a semester-long study on perceived student confidence and performance on FE-style exam questions.

- The FE review course improved perceived student confidence on taking the overall FE exam and on topic-specific sections (i.e., reinforced concrete design and concrete materials). However, a greater increase in student confidence on topic-specific sections was observed for students taking a course on the topic for the first time.
- The FE review course improved some students' knowledge on reinforced concrete and materials as measured by performance on FE-style test questions. Specifically, 77% and 43% percent of students did better on at least one question in reinforced concrete or materials questions after completing the course compared to their score prior to the course, respectively. However, the overall percent correct at the end of the FE review course was still less than 50% on most questions. All students made measured gains but not in the same specific area as measured by the exam questions.
- For students learning about the topic for the first time, scores were higher for most FE-style questions compared to the students in the FE course, even after reviewing the topic for a second time.
- For students taking the FE review course, confidence and exam performance were not strongly correlated. While confidence averages did increase overall for the class, nearly two thirds of the students' individual confidence in passing the FE exam did not change.
- This limited FE review course helped students review select topics, possibly those they had previously been proficient in, but not the entire subject matter.
- A review session longer than 75 minutes per single topic is likely needed to review topics in enough depth to help all students. Questions that require a deeper understanding of theory and design concepts were not adequately covered based on the test question results. If a student did not master this topic originally, then this review course was not enough to help them learn the topic.
- For civil engineering or other programs encouraging students to take the FE exam, an FE review course likely helps students review material they previously encountered and provides them with a degree of increased confidence. However, a review course cannot replace the depth of study and understanding provided by a course dedicated to each topic on the FE exam based on results from student performance on FE-style test questions administered in this study.

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