Curricular Predictors for Success on the Civil - Fundamentals of Engineering (FE) Exam

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Abstract

The Virginia Military Institute (VMI) Department of Civil and Environmental Engineering (CEE) requires students to take the Fundamentals of Engineering (FE) exam prior to graduating from the program. In efforts to increase the pass rate, the department implemented an engineering elective course focused on reviewing all FE topics. The pass rate has improved; however, it is unknown whether this is due to the elective course or other factors.

This paper investigates the trends in academic curriculum among those that passed the FE exam. The students in the CEE program are given the flexibility to take seven different engineering elective courses and can focus their electives in any of the sub-disciplines of civil engineering. The elective courses of the 24 students who passed the FE exam in 2019 were analyzed to identify any significant "predictor courses." The department plans to use the data to develop advising recommendations for future students.

Keywords

Fundamentals of Engineering (FE), FE Exam, Curriculum, Civil Engineering Programs, Pass Rates, FE Review

Introduction

The Fundamentals of Engineering (FE) exam is the first test in the process to become a licensed professional engineer (PE) in the United States. This exam is administered nationally by The National Council of Examiners for Engineering and Surveying (NCEES) and is designed for recent graduates and students who are close to finishing an undergraduate engineering degree from an EAC/ABET (Engineering Accreditation Commission/Accreditation Board for Engineering and Technology, Inc.)-accredited program[1].

Each state has its own requirements for a student to sit for the FE exam. One example is Virginia Law 18VAC10-20-190. The law states that student applicants must be enrolled in an ABET-accredited undergraduate EAC or ETAC (Engineering Technology Accreditation Commission) program, have 12 months or less remaining before completion of the degree, and provide a certificate of good standing from the dean of the engineering school or his designee[2].

ABET accreditation is a form of quality assurance for computing, engineering, and engineering technology programs. While every engineering program has to satisfy ABET's standards of quality, known as criteria, to be accredited, nothing about licensure is included explicitly in the

general criteria. ABET defines licensure as "demonstration of ability or knowledge required by law before being allowed to perform a task or job". It is included in program criteria that curriculum should explain "the importance of professional licensure"[3]. ABET criteria are influenced by the American Society of Civil Engineers (ASCE) and its engineering Body of Knowledge (BOK). The BOK is outlined as the "knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level". The technical committee of the BOK third edition, published in 2019, included an awareness of the importance of professional licensure and, specifically, knowledge of the licensure process and pre-licensure experience[4].

Many civil engineers elect to pursue licensure as a professional engineer. Professional licensure is an important achievement and benchmark in the civil engineering profession. Because professional licensure demonstrates an engineers' competency, qualification, and expertise in the professional practice, it shows engineers' commitment to understand professional, ethical, and societal responsibilities and emphasizes the protection of public health, safety, and welfare within society. As such, it is important for a civil engineer to understand the importance of professional licensure and grasp the responsibilities associated with licensed practice. This includes lifelong learning to stay current with advances in civil engineering practice[4].

VMI recognizes that graduating with a degree from an ABET accredited program and passing the FE exam prior to graduation are key steps in the licensure process. Because of the importance of professional licensure to the civil engineering profession, VMI requires all civil engineering graduates to take the FE exam prior to graduation[5]. The students are not required to report whether they passed the test, but typically the faculty hear from those who do and counsel those who do not pass on their first attempt. Historically, the FE pass rates have varied, but in recent years they have trended near the national average[6].

The civil engineering department believes in the importance of preparation and provides a well rounded degree program with an option to take an FE review course as an engineering technical elective. In recent years there has been debate over which technical electives, including the FE review course, should be taken in order to have the best chance at succeeding on the FE exam. In the spring of 2019, a list of students that passed the FE exam was compiled. In order to better understand the curricular trends, the transcripts of graduates in 2019 that passed the FE exam prior to graduation were analyzed.

Background

Students are required to take electives in four categories in the civil engineering program: Engineering Science Electives I and II, Technical Electives, Design Electives, and a Natural Science Elective[5]. Each category has an approved list of courses from which they can choose. Table 1 shows the list of elective courses and the required number of courses a student must take from each category.

Table 1 – Elective Courses in the Civil Engineering Program

Engineering Science I (1 Course Required)	Engineering Science II* (1 Course Required)	Technical Electives (3 Courses Required)	Design Electives* (2 Courses Required)	Natural Science Electives** (1 Course Required)
Circuits	Hazardous Waste Treatment and Site Remediation	Construction Methods and Management	Foundations	Engineering Geology
Thermodynamics	Hydrology	FE Review	Transportation Planning and Design	General Biology
Dynamics	Advanced Mechanics of Fluids	Independent Research	Hydraulic Engineering	
	Structural Mechanics	Summer Independent Research	Environmental Engineering Unit Process Design	
	Advanced Structural Theory		Topics in Structural Design	
	Environmental Engineering Chemistry		Wood Engineering	
			Structural Steel Design	

*All Design and Engineering Science II Elective courses are also categorized as Technical Electives.
** The Natural Science Electives are 4 credit hours, while all others are 3 credit hours.

The topics on the NCEES Civil Engineering FE Exam address 18 different categories[1]. Because the curricular requirements have a degree of flexibility, most students do not take multiple courses in every sub-discipline of civil engineering. Some may even limit their electives to two or three sub-disciplines, reducing their breadth of exposure to some topics on the exam (Table 2).

Table 2 – FE Civil Exam Topics

FE Subject[1]	Required Credit Hours at VMI*
Mathematics	13
Probability and Statistics	3
Computational Tools	2**
Ethics and Professional Practice	1**
Engineering Economics	1**
Statics	3
Dynamics	0
Mechanics of materials	3
Materials	3
Fluid Mechanics	3
Hydraulics and Hydrologic Systems	3
Structural Analysis	3
Structural Design	3
Geotechnical Engineering	3
Transportation Engineering	3
Environmental Engineering	3
Construction	3
Surveying	3

* The program is 140 credit hours and a typical course is 3 credit hours.
**Part of a class that covers this topic.

Research Plan

In the 2018-2019 academic year, every VMI civil engineering student nearing graduation took the FE exam. Of the 42 graduates in May 2019, the department recorded that at least 24 passed the FE exam. Reporting their results is not required for graduation, but those that pass generally report it to the department, since they are reimbursed for their exam fees. Those who do not pass do not always report their results. While it is possible a few others passed the FE, only those that were confirmed to have passed the exam by the Spring of 2019 were included in this data set. This analysis focuses on those students who passed the FE exam and graduated at the Spring 2019 commencement.

The final transcripts for all of the students in the data set were reviewed. Any course that is considered an elective course in engineering, science, and math was mapped for every student. In addition, the students' GPA, transfer credits, average credits taken per semester, and minors were recorded. The values for all of the students were averaged and patterns were identified.

Results

Data were available for 24 of the 25 graduates who passed the FE in the Spring of 2019. Several trends were noted among the students. The first set of patterns that was observed were with the overall, final grade point average (GPA). The average GPA for those that passed the FE was 3.331 and 17 out of 24 had a GPA of at least 3.0. Only two students who passed had a GPA below 2.75 and one student was below 2.66 (Figure 1).

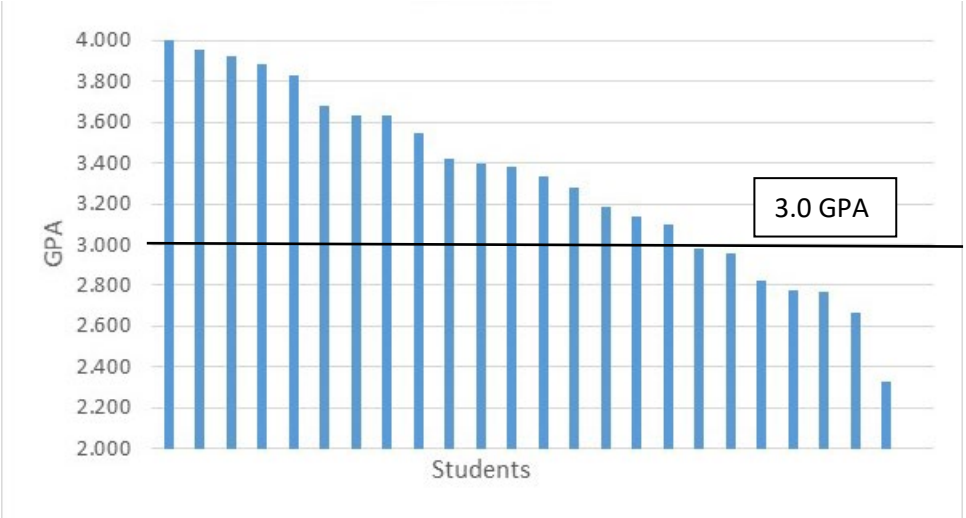

Figure 1 – Final, Overall GPA of students who passed the FE exam

Students traditionally graduate in eight semesters in residence and all but three accomplished this goal. One student graduated in seven semesters, one took nine semesters, and one participated in international study for one semester, but still graduated in eight semesters. The average number

of credits taken per semester was 16.70 and the range for these averages was between 18.44 and 15. However, the average range of credits taken during each individual semester for all 24 students was 6.13 credit hours. The range was extensive and varied considerably over the eight semesters. Part of this was because the average student transferred in 14.1 credit hours prior to matriculating. The transfer credits varied significantly from zero to thirty credit hours, however, 71% transferred at least 3 credit hours. Six of the 24 students obtained a minor in math and two earned a minor in chemistry and physics, respectively.

When reviewing the elective courses, they were divided into categories. The first course of interest was the FE review course, a course with an objective to prepare students to pass the FE exam. Out of the 24 students who passed the FE, 19 or 79% took the course. Interestingly, of the 39 students enrolled in the FE review course, at least half went on to pass the FE exam. Of the remaining elective courses, at least 50% of the students took two structural engineering courses (Topics in Structural Design, Structural Steel Design) and Engineering Geology (Table 3).

The engineering science I elective courses showed one of the most distinct patterns. All but three students (87.5%) took dynamics and passed the FE exam (Table 4). No one that passed took thermodynamics and only three took circuits.

Table 3 – Most common elective course chosen in the Civil Engineering Program.

Engineering Science II* (%)	Technical Electives* (%)	Design Electives* (%)	Natural Science Electives (%)
Environmental Engineering Chemistry (4.2)	Construction Methods and Management (25.0)	Foundations (33.3)	Engineering Geology (66.7)
Hydrology (20.8)	FE Review (79.2)	Transportation Planning and Design (4.2)	General Biology (33.3)
Advanced Mechanics of Fluids (16.7)	Independent Research (37.5)	Hydraulic Engineering (16.7)	
Structural Mechanics (45.8)	Summer Independent Research (8.3)	Environmental Eng. Unit Process (29.2)	
Advanced Structural Theory (29.2)		Topics in Structural Design (66.7)	
Hazardous Waste Treatment and Site Remediation (29.2)		Wood Engineering (20.8)	
		Structural Steel Design (62.5)	

*All Design and Engineering Science II courses are also categorized as Technical Electives

Table 4 - Engineering Science I Results

Course	Completed the Course (%)
Circuits	12.5
Thermodynamics	0.0
Dynamics	87.5

The sub-disciplines of civil engineering include construction, environmental, soil mechanics, structures, transportation, and water resources. Elective courses were offered in every sub-discipline for this cohort of students, although more elective courses were available in water resources, environmental, and structures. Those that took at least one elective in an area are shown in Table 5. Structures was the most common sub-discipline (91.7%) followed by Environmental (50.0%), water resources (45.8%), and construction (45.8%).

When reviewing the average number of courses taken in each sub-discipline, the pattern is similar to the percent taking a course in each category. However, the one exception is that, on average, students took 2.25 structures courses. This was significantly more than the other categories. Students took on average of 0.79 environmental, 0.54 construction, and 0.54 water resources elective courses.

Table 5 – Percent of students taking engineering electives in each sub-discipline

Engineering Elective Courses in Civil Engineering					
Construction	Environmental	Soil Mechanics	Structures	Transportation	Water Resources
45.8	50.0	33.3	91.7	4.2	45.8

Table 6 – Average number of courses taken in each sub-discipline

Engineering Elective Courses in Civil Engineering					
Construction	Environmental	Soil Mechanics	Structures	Transportation	Water Resources
0.54	0.79	0.33	2.25	0.04	0.54

Another area reviewed was how many sub-disciplines do students take electives in, on average, and pass the FE exam. The number of sub-disciplines ranged from one to four with an average of 2.71. Only two students took all of their engineering electives in one sub-discipline and in both cases it was the structures area. The most common number was 2 (9 students) followed by 3 (7 students). The maximum, four areas, was accomplished by five students. In every case but two, one of their sub-disciplines of coursework was structures. In those two exceptions, the students pursued electives in environmental and water resources.

An interesting note is the humanities course selection. At VMI humanities courses are part of the core civilizations and cultures curriculum. These courses are offered in every department including engineering, math, and physics, but most are focused in the humanities disciplines. However, 92% of the students who passed the FE took at least one humanities class in the engineering, math, or physics departments and 46% took both humanities in these departments.

Ongoing Research

Our future research will gather additional data for lateral and longitudinal comparison. The data set included in this study focuses only on those that passed the FE exam in the Spring of 2019. Some clear patterns have been shown about these students that passed the FE exam, however questions remain whether this is a repeatable long term pattern. In addition, the next step is to further analyze and compare the results of the students who did not pass the FE exam. In the coming year, data will be gathered to better ensure a complete record of the FE results for every graduate.

Additional factors to be considered could include the number of hours taken during summer school, athletic participation, grades earned during the first year, grade point average of the core required civil engineering courses, and incoming standardized scores.

Conclusion

With the current civil engineering FE exam, there were patterns in the curriculum for the students that passed. This included the following observations:

1) The fundamentals of engineering review course in the department was taken by 79.2% of the students who passed the test.

2) Students are required to take at least 1 credit hour of coursework in every area covered on the FE except engineering dynamics. However, they are not required to take more than 3 credit hours of coursework in any area covered by the FE except math.

3) The vast majority who passed the FE took engineering dynamics (87.5%) for the engineering science I elective.

4) The average grade point average was 3.317 and only 21% had a GPA below 2.96 that passed the FE exam.

5) Students that passed took engineering elective courses in at least two and in many cases three or four sub-disciplines of civil engineering. Only two that took all their electives in one sub-discipline passed the FE and in both cases they took all structures electives.

6) Over 90% of the students who passed took at least one course in the structures sub-discipline. Students who passed tended to take at least one structures course for one of their engineering electives. Most took a higher percentage of structures courses than any other sub-discipline by an average factor of about three.

These data are useful for the civil engineering department to consider how to advise students in order for them to increase their odds of passing the FE exam. While it is accepted that this does not guarantee success, a pattern of success has been observed with this class of students. The data can also be used when determining if curriculum changes need to be made in the future within the department in order to add breath to the depth of the current civil engineering curriculum.

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