The Dynamics of Civil Engineering Program Content

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Abstract

Civil engineering program content is driven by a number of factors including industry needs, accreditation agencies, general education requirements, and engineering standards. Many groups including NCEES (National Council of Examiners for Engineering and Surveying) and ASCE (American Society of Civil Engineers) have recently promoted revisions to what they recommend in civil engineering programs. Meanwhile, some states have moved to reduce the number of credits required for an engineering degree for economic reasons. The constant requirement to add non-engineering topics while reducing total credits creates a tension that requires constant adjustments to a curriculum. It can also make it difficult to provide the engineering topics needed. Although the Virginia Military Institute (VMI) requires students to take many additional non-engineering courses, it has maintained an ABET accredited civil engineering program for 85 years. During that time the number, breadth, and depth of the required courses has evolved. This study focused on reviewing the degree requirements since the program's inception. At least one university catalogue was reviewed for each decade to compare the program requirements. This included the total number of credits, the number of required courses, and the number of elective courses. The results reveal that the total number of credit hours has not changed significantly, but the distribution among civil engineering classes and engineering electives continues to change. Additionally, more engineering courses are now required at the expense of fewer science courses. The general education requirements have changed throughout time, but today remain similar to 85 years ago. The paper also provides an efficient way for program administrators to measure breadth and depth over time within a curriculum.

Keywords

ABET, Civil Engineering Program, Program Content

Introduction

The Virginia Military Institute (VMI) Civil Engineering program was one of the first ABET programs to obtain accreditation and has maintained continuous accreditation since 1936.[1] Throughout the past 90 years significant changes have occurred in engineering program accreditation policies and engineering program content. This has not stopped in the twenty-first century as new knowledge and engineering techniques continue to result in the evolution of the profession and engineering education. Change continues with respect to the breadth and depth of content in civil engineering programs.

The following project investigated how the program content in one of the original accredited civil engineering programs in the United States has changed over time. The focus was not on the sources of change or the exact point when change occurred, but the gradual pattern of change

within the accredited program content with time. One goal of the project was to develop and apply a method of determining the breadth, depth, and flexibility within the VMI civil engineering content over time. A secondary goal was to use the information to help "balance conflicting goals" as is often required when there are competing, but both valid, influences wanting to add topics to a curriculum.[2]

Background

Many different groups, both internal and external, affect the content in civil programs including ABET, the American Society of Civil Engineers (ASCE), and The Nation Council of Examiners for Engineering and Surveying (NCEES). ABET works with their constituent groups to implement changes on regular cycles of self-evaluation that maintains a high standard for engineering programs. This was most recently demonstrated in 2019 when the program criteria were changed.[3] ASCE created their first Civil Engineering Body of Knowledge (BOK) in 2004 and have published two updates since then in 2008 and 2019.[4] These BOK provide recommendations for program content and levels of achievement for civil engineers. NCEES creates the fundamentals of engineering exam (FE) for civil engineers and continues to change the content on this test as demonstrated in July 2020.[5] Many civil engineering programs highly encourage students to take the FE and try to present most of the material from the test in their curriculum.[6]

In addition, there are numerous other influences including state governments, regional accreditation boards, alumni groups and advisory boards, and changes in engineering practice and standards. The profession continues to change with the use of computer tools, new engineering codes and standards, and emphasis on new topics such as sustainability. In addition, one of the biggest influences on program content for state universities is the pressure to maintain programs of study that are no more than 4 years in length.

Cleary, the civil engineering profession is far from stagnant. Many groups provide guidance and desire influence on the content taught in civil engineering programs. Other research projects have reported on the specifics of how various groups attempt to influence civil engineering program content.[6,7] This study focuses on how one civil engineering program has responded to the changes within the profession. Influences vary in importance and effect, so the true test of their impact is whether civil engineering programs respond to their suggestions.

Research Program

The research plan consisted of two parts. First, a method was devised to collect a sample of data from a civil engineering program throughout its existence. Second, one of the oldest accredited civil engineering programs in the United States was used as a test case to review curriculum changes throughout its accredited history.

The first step was to determine how often to collect data for the study. The goal was to see patterns of change over many decades, not to collect every small programmatic change. Most changes to ABET, the BOK, and the FE exam happen after many years of review, not on an annual basis. For this study, the decision was made to start collecting data the first year the program was accredited in 1936 and then collect data every 10 years up to 2016. This provided a

reasonable data set that would identify macro program changes, but not overburden the analysis with small changes.

Upon selecting the years to collect data, the university catalogues from the respective years were reviewed and data was taken on every class in the program. Three major categories were used: Engineering, Math and Science, and Humanities/Social Science/Other. Within these categories, specific subcategories were computed to include math, basic science, general education, engineering electives, engineering background, mechanics, and civil engineering courses. The breakdown of the types of courses included in each category are shown in Table 1. After collecting the data from each category, the number of required course credits was computed and compared. Each course was recorded as either required or an elective.

Table 1 – Courses in each category.

Math and Science		**Humanities/ Social Science/ Other**	**Total Engineering**			
Math	**Basic Science**	**General Education**	**Engineering Electives**	**Engineering Background**	**Mechanics**	**Civil Engineering Courses**
Algebra Trigonometry Geometry Calculus Diff. Eq. Statistics Linear Alg.	Chemistry Physics Geology Sci. Elec.	English History Languages Speech Leadership Economics ROTC PE Gen. Ed. Elec. Free Elec.	Design Elec. Eng. Sci. Elec. CE Eng. Sci. Tech Elec. CE Elec	Intro to CE Computing Programming Ce Methods CAD/Drawing Circuits Thermo.	Statics Solid Mech. Dynamics Fluid Mech.	Surveying Struc. Theory Soil Mech. Enviromental Materials Hyrology Water Res. Concrete Steel Bridge Eng. Systems Eng. Transportation Proj. Manag. Prof. Practice Seminar CE Labs Thesis CE Design

Results

The number of credits in the program per year in the specific categories are shown in Table 2. Since 1936, the total number of credits required has averaged 142.4 with a margin of error of approximately 2.42 for a 95% confidence interval. The current total number of credits currently required is 140, a value at the low end of, but still within, the 95% confidence interval. The total number of credits do include required credits for mandatory ROTC (Reserve Officers' Training Corps) and physical education courses that have ranged from approximately 12 to 16 credits a

year. Currently, 16 credits in these two areas combined are required. Subtracting this from 140 produces 124 total credits.

Table 2 – Programmatic courses by year

Subject/Year	2016	2006	1996	1986	1976	1966	1956	1946	1936	Avg
Math	16	15	18	18	18	18	18	16	18	17.2
Basic Science	16	19	19	19	19	23	27	25	24.5	21.3
General Education	41	39	38	44	43	40	33	47.5	46.5	41.3
Engineering Electives	21	15	15	18	33	26	0	6	0	14.9
Engineering Background	4	6	4	5	5	13	11	10	11.5	7.7
Mechanics	9	12	12	12	12	10	12	11	10.5	11.2
Civil Engineering Courses	33	33	32	28	13	19	38	30.5	33	28.8
Total Credits Required	**140**	**139**	**138**	**144**	**143**	**149**	**139**	**146**	**144**	**142.4**

Figure 1 shows the trends within each category from 1936 to 2016. As shown, there have been two relatively stable periods: up until approximately 1950 and from the mid 1990's until present. The category Engineering Electives has increased the most over the years from 0 credits in 1936 to 21 credits in 2016 with a peak of 33 credits in the 1970s. The category Basic Sciences has steadily decreased from approximately 24.5 to 16 credits. At the same time the number of Engineering Background courses was steady until it moved downward in the 1970s and has been steady since. The number of credits in the category Civil Engineering Courses has, after taking a dip for a few decades, now reached the same level as it was in 1936, approximately 33 credits. The most stable categories have been Math and Mechanics classes with a variation of only 3 credit hours throughout time in each category. General Education credits has varied between 33 and 47.5, but stayed within 3 credits of the average for the past six decades.

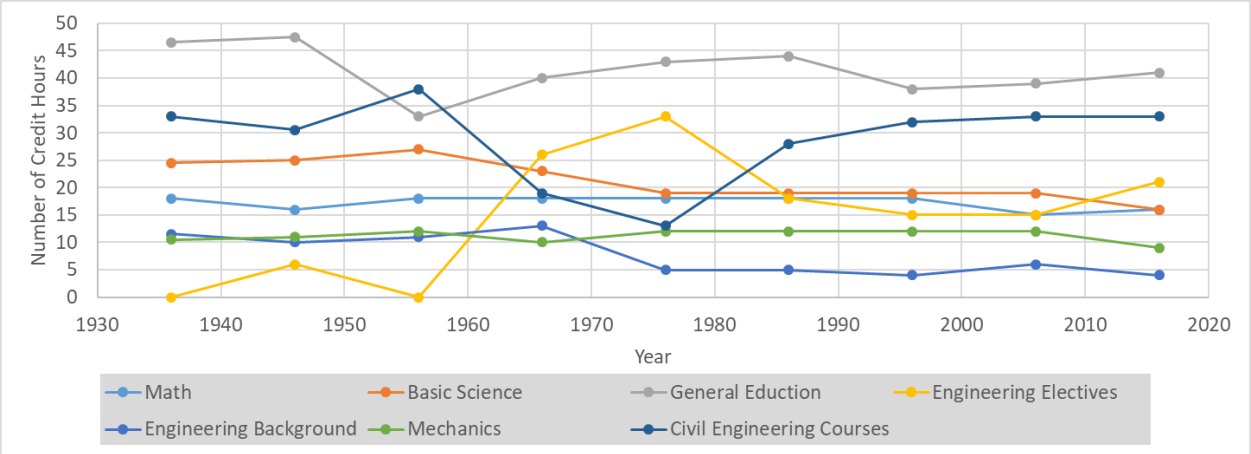

Figure 1 - Programmatic Courses by Year

Three major categories were created out of the data in Figure 1. Total Math and Science are a combination of the Math and Basic Science categories. The total Humanities/Social Science/Other category is the same as the General Education credits. The Total Engineering credits was computed by adding the Engineering Electives, Engineering Background, Mechanics, and Civil Engineering required courses. The trends are shown in Figure 2.

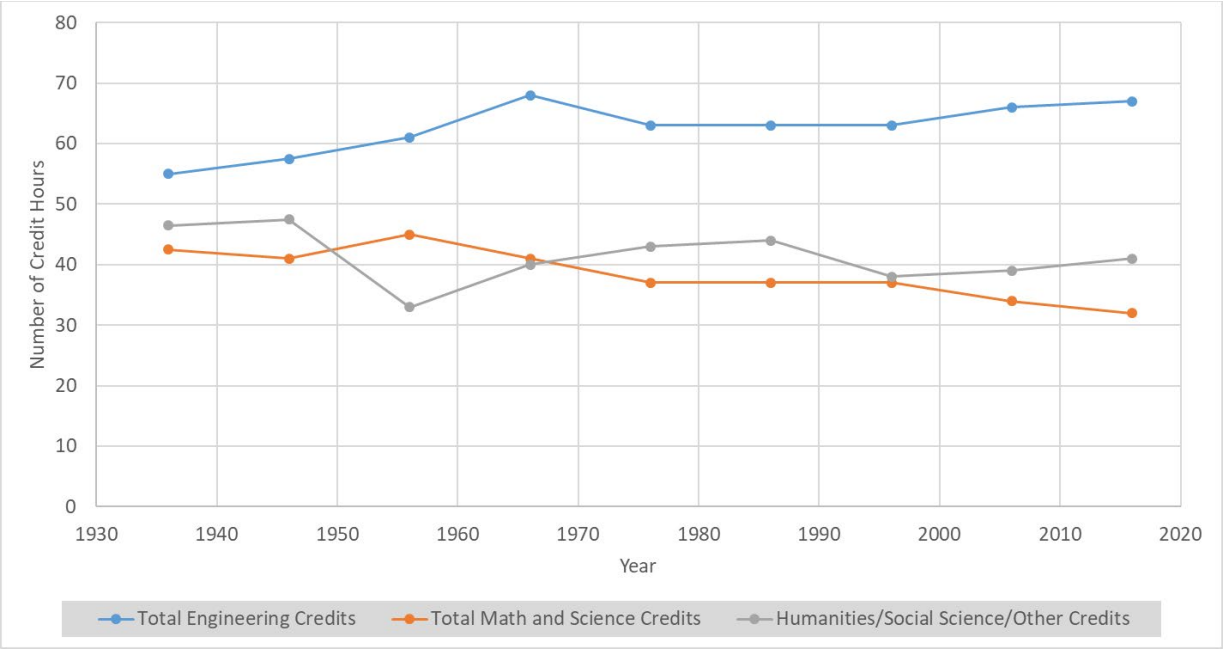

Figure 2 – Total Credits Hours Per Category

Looking at the results in the three general categories demonstrates that overall the number of engineering credits has increased with time while the overall number of science credits has decreased over time. As mentioned previously, the remaining courses have some variation with time, but have stayed within 3 credits of the average for the past six decades.

Analysis of Results

While many factors remain nearly constant, clear progressions of change have occurred over the life of the VMI civil engineering program. One of the most obvious changes has been the type of engineering courses required in the program. Initially, there were almost no engineering electives and over 30 credit hours of required civil engineering courses in the program. Around the 1950's a large change occurred when the number of civil engineering courses required was replaced with more general engineering courses. Further engineering background courses were also reduced in half during that time period. By the mid-1980's these trends were reversed for the civil engineering courses and engineering electives, however the engineering background courses stayed at a lower rate. This demonstrates that the school of thought on how flexible the engineering program should be has changed over time. Recently, the program has become more prescriptive, but not as much as when the program was created. Scheduling constraints due to requirements outside of the department have contributed to the more prescriptive program.

The number of math and science courses has clearly gone down with time. There were drops in the 1960s and early 2000's. A closer examination shows most of this drop has been in the science category and not in math. There used to be more basic physics and chemistry courses in the program. While math credits have been constant, the first few decades of the program focused more on algebra, geometry, and trigonometry, whereas today those classes are prerequisites expected of incoming students. It is possible that students are also expected to have a general understanding of chemistry and physics, hence the reduced number of science credits. The other explanation may be that the science credits have been reduced in favor of requiring more engineering credits. The number of total engineering credits has gone up 22% while the number of math and science credits has gone down 25%.

Although the current curriculum requires a higher level of math, many cadets do not have sufficient mathematical skills to enter at the level required. In fact, approximately 40% of the entering freshman are required to take pre-calculus, which does not count towards the final degree. This causes about 40% of the student body to be instantly behind in the curriculum.

The general education has seen little variation in the past six decades. It must be noted that with the exception of the 1950's VMI has always required 12 credit hours of ROTC classes and approximately 4 credit hours of PE credits. This has consistently kept the total number of credit hours above 138 credit hours.

The total number of credit hours has not changed significantly with time. The period in the 1960s appears to be one of the most dynamic times of change in the program both in content and total number of credit hours. Outside of this decade there was generally little change in overall credit hours. As one category of classes increased another had to decrease to keep the totals unchanged.

Conclusions

The program requirements of one of the first ABET accredited civil engineering programs was analyzed. Each course was recorded and categorized to observe trends in the change in macro requirements over time. The following conclusions were drawn from the process of analyzing the program and the results of the analysis.

1) Clear trends were captured by analyzing the program once each decade. When analyzing for long-term patterns, this was sufficient data without requiring an overwhelming amount of work.

2) The analysis process is useful when changes are under consideration for an engineering program. As this program demonstrates, numerous changes have occurred to the engineering electives, core engineering courses, and science courses over the program's history. Perspective is gained by viewing these changes. The results also provide ideas for program administrators to consider as the program's curriculum continues to evolve.

3) The VMI program has maintained a nearly constant number of total credit hours over time. There have been relatively few changes in the engineering mechanics and math credits. Many colleges, under pressure from state legislatures, have reduced the total number of credits required to graduate. However, VMI has shown that it is possible to

keep a high number of credits required and still maintain a high graduation rate. The six-year graduation rates for the 2013 and 2014 cohorts were 80% and 85% respectively per the Office of Assessment and Institutional Research.

4) The biggest changes occurred in the engineering electives and civil engineering courses. There has been an oscillation between requiring more electives versus requiring more civil engineering courses.

5) The total number of science courses has slowly decline by 25% as the total number of engineering courses has increased by 22%. These trends have been very gradual but consistent with time. Some of the science courses are now required at the high school level.

6) General education requirements have not changed significantly, but the overall trends seem to be relatively constant around an average of 41 credits. A robust core curriculum requirement has helped to make sure that general education requirements have not been abandoned. During the recent economic challenges, an attempt to do more with less has resulted in the administration wanting more engineering professors to teach general education courses. The idea of "double dipping" and using a course both as a CE Tech Elective and as a General Education elective is appealing from a monetary standpoint, but ultimately reduces the breath of the curriculum.

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