Work in Progress: Low Enrollment in Civil Engineering Departments: Exploring High Technology as a Potential Solution

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Abstract

There is a recurring issue of low enrollments across many civil engineering departments in postsecondary institutions. While there have been moments where enrollments begin to increase, civil engineering departments find themselves facing low enrollments that have decreased by 60% over the last five years across the Middle East and the United States. There are many reasons that could be attributed to this decline, such as low entry-level salaries, over-saturation of civil engineering graduates in the job market in certain regions, and a lack of construction projects due to the impending or current recession. Low enrollment also has an effect on the availability of civil engineers, especially in times of high demand, such as the passing of the recent US legislature on rebuilding infrastructure. However, this recurring problem alludes to an intrinsic issue of the curriculum, as researchers have discovered. The societal shift to the usage of high technology such as machine learning (ML) and artificial intelligence (AI), demands individuals who are proficient at utilizing it. However, in many existing civil engineering curricula, students are not taught programming skills that would aid in using high technology and if introduced at an early level, these skills are not utilized in other courses across the curriculum. This paper aims to conduct a survey on the civil engineering curricula of the top 220 universities in the world, focusing on those in the United States based on the QS World Ranking system. Initial analysis of the survey results indicates that the majority of universities have not considered new methods of data analytics such as ML or AI in their civil engineering coursework. Based on the results of the survey, the authors will provide suggestions on how to adapt high technology concepts to civil engineering coursework, while abiding by ABET/ASCE accreditation requirements. The findings of this paper will indicate where postsecondary universities offering civil engineering can easily adapt their curricula to address the current low enrollment crisis, which in turn, supports future civil engineers for the world of high technology.

Introduction and Background

Civil engineering is the backbone of society, constructing and maintaining infrastructure that directly impacts lives [1]. Like other engineering disciplines, enrollment in civil engineering has been known to fluctuate due to industry demand and economic recessions [2]. However, the past decade has seen civil engineering enrollment steadily decrease [3]. Recently, the ASCE leadership indicated a workforce shortage as well as a decrease in enrollments [4]. This decrease imposed several challenges on the universities and the construction industry. Many universities worldwide had to close or combine the civil engineering departments with other departments [5, 6]. In addition, in the non-tenure track system, many faculty members are facing the termination of their contracts. From the construction industry's point of view, the low enrollment will cause a shortage and availability of civil engineers when needed.

Many have attributed the decreased interest to lower entry-level salaries in comparison to other engineering disciplines [7], however, this low interest can be also caused by an outdated curriculum [8]. While other disciplines have integrated techniques such as machine learning (ML), artificial intelligence (AI), and automation in their research and curricula, civil engineering students are left behind and are thus, unequipped to work in an ever-evolving technological workforce [9, 10]. There have been attempts to introduce students to programming through coursework, but this knowledge is typically not continued in future classes and is abandoned.

Globalization has also been linked to civil engineering enrollment. In the era of smartphones and voice-automated assistants, disciplines such as computer science have experienced a surge in enrollment, as these technologies dominate lives and media consumption [11]. While civil engineering has also ventured into 3D printing [12], machine learning for infrastructure management [13], and exploring materials for habitats on other planets [14], students are unaware of these innovations unless they pursue postgraduate studies. Thus, learning about these research opportunities in a first-year undergraduate class may influence enrollment and counter the effects of civil engineering being a discipline of the past [15].

This paper aims to propose possible implementations of high technology in civil engineering curricula, such as introducing this technology in a course or including examples of high technology applications in civil engineering throughout an undergraduate's career, while abiding by ABET and other accreditation requirements. As this is a work in progress, the paper in its current form evaluates how universities have integrated high technology in their civil engineering curricula, defines ABET requirements for new coursework, and provides sample questions to gauge public perception of high school students interested in engineering. Future work includes providing a sample syllabus of a new high technology course and how a four-year plan can be restructured to incorporate these concepts. Although the curriculum may not be the only factor affecting enrollment and retention, altering the curriculum to the 21st century is an action that educators can directly influence. The high technology examples used in a civil engineering curriculum can also change the perception of civil engineering to engineering freshmen, who may attribute civil engineering as a "boring" profession that only maintains existing infrastructure [16].

The term "high technology" mostly refers to Artificial Intelligence in this paper. Artificial Intelligence (AI) is a field of Computer Science that focuses on developing intelligent machines that rival or even surpass the intelligence of humans. There are many advanced technologies that utilize AI such as 3D printing. The integration of AI into the civil engineering curriculum will aid in altering the perception that the field is a low-technology field [8]. While civil engineering has always co-existed with technology, the field has been trailing behind in civil applications using current high technology. Integrating AI into the curriculum will showcase the use of high technology in civil engineering. It must be emphasized that civil engineering has always co-existed with high technology. Some of the first mentions of computing in civil engineering were in the development of defense and space programs, where a whole new range of structural response modeling capabilities was required [17]. Discourse about the integration of high technology into the curriculum existed as early as 1983 when many members of the public did not know what civil engineers do and that high technology is a part of civil engineering [18]. There have been suggested attempts in the literature to address the above concerns. Many of the solutions include adjusting the curriculum to integrate civil engineering applications of high technology.

This paper proceeds as follows, Section 1 evaluates United States universities' civil engineering curricula based on the QS World University Ranking. Section 2 considers the Accreditation Board for Engineering and Technology (ABET) accreditation criteria. Section 3 shares work in progress and plans for future work. The concluding remarks reiterate these findings and discuss future developments for this paper.

1. Curriculum Evaluation

The following section explores civil engineering curricula and how they have integrated 21st-century concepts, such as machine learning, artificial intelligence, and sensors. These concepts are considered in the search as machine learning and artificial intelligence has been integrated into daily lives and other engineering disciplines, thus, should be introduced to civil engineering undergraduates as well. Curricula that integrate other concepts such as project management are out of the scope of this analysis. General civil engineering curricula, which did not focus on specific concentrations such as structures or transportation, were within the scope of the evaluation.

Curriculums were evaluated based on their QS World University Ranking [19], specifically focusing on universities in the United States and the top 220. Based on these conditions, 39 universities were evaluated, as the remaining 181 universities in the top 220 are located outside of the United States. Universities were evaluated by visiting the Civil Engineering Department's website and viewing their four-year degree plan for undergraduate students and the separate specialization track. Classes that mentioned "data science", "computation", "sensors", "machine learning", "neural networks", "computer vision" or other topics pertaining to high technology were further evaluated. 64% of the 39 have stated that their curricula have been updated in the last two years; 20% of all schools have included high technology courses as a requirement or an optional elective - Table 1 summarizes the findings of the survey. Programming courses included introducing programming languages such as Matlab or Python and teaching concepts such as program formulation and loops.

Table 1: Survey findings based on US schools ranked in the QS World University Ranking

Number of Schools	Integration of High Technology Courses	Integration of Programming Courses	Types of High Technology Courses Offered
13	No	-	-
18	No	Yes	-
4	Yes	Yes	Data Science for Civil Sub-disciplines; Machine Learning for Smart Cities; Neural Networks and Computer Vision;
4	Optional	Yes	Computation and Data Science; Sensor Technology in Civil Engineering

From the 39 US schools, eight included high technology courses with only four requiring students to take these courses. One school offers these high technology courses in the last year of undergraduate, where students are unable to build upon these concepts in further classes. One school required students to enroll in a data science course that discusses data analysis using computational thinking. Students are able to build upon this in electives such as data science applications for smart cities and aviation. One school requires freshmen to enroll in an engineering computation course that introduces simple machine learning models for civil engineering applications, students can build upon these concepts in their specialized tracks. One school requires students to register in a data science course that builds upon these concepts in an advanced computing course that discusses optimization and automation applied to civil engineering problems in various specialties.

Universities that offer optional high technology courses provide them in the form of electives or requirements for specialty tracks such as material science or structural engineering. These courses teach students about machine learning and artificial intelligence in their respective tracks, however, they do not require them in future courses as a prerequisite. Universities may also encourage or require students to complete relative minors in computer science to complete their specialties; this is common in universities specializing in smart cities.

While 67% of US universities in the top 200 have made progress in introducing newer concepts into their curriculums such as Python and Matlab, additional work should be conducted in integrating high technology concepts. As an example, machine learning and artificial intelligence can be introduced in introductory programming classes. Implementing these methods to civil engineering problems in major requirements and electives can be mentioned to allow students to recall these concepts throughout their undergraduate career. High technology will only become more available, such as ChatGPT, and instructors and lecturers must prepare students for a workforce that can use these methods for their own professional benefit. Section 2 provides more details on how universities can consider ABET accreditation when making high technology changes in their curriculums.

2. Accreditation and continuous improvement

Civil engineering programs seek accreditation in order to ensure their program meets defined standards of quality set by an accreditation organization. Accreditation also ensures that their graduates possess the required educational background and skills necessary to join the workforce. In addition, innovation and emerging technologies are usually some of the standard qualities required by the accreditation agency. It is important to note that educational programs are required to periodically renew their accreditation to maintain quality and continuously improve the curriculum.

The Accreditation Board for Engineering & Technology (ABET) publishes general criteria which apply to all engineering programs. In addition, specific program requirements are set by a leading society, such as the American Society of Civil Engineers (ASCE) for the civil and construction engineering programs. In addition, other accreditation authorities such as Ministry of Education in several Middle Eastern countries started requiring the addition on AI, machine learning and data analysis to all engineering disciplines. Table 2 provides a summary of ABET accreditation requirements and minimum credit hour requirements for math, science, and engineering topics.

[20] conducted an extensive survey of all civil engineering programs accredited by ABET. The following was found to be the common distribution for civil engineering curricula: 30 credit hours of math and science, 60 to 65 credit hours of core courses, 9 to 12 credit hours of major electives, and 21 to 29 credit hours of general education. This distribution led to an average number of credit hours in the range of 128-132. Therefore, the possible approach to improve a curriculum is to infuse any changes within the courses to avoid adding more credits or scarifying the required fundamentals. This allows high technology integration to be achievable, as new courses do not need to be added, thus abiding by ABET requirements. Future work will provide an example on how to restructure a civil engineering undergraduate education while aligning with the ABET requirements presented in Table 2. Section 3 provides more information on future work incorporating concepts from sections 1 and 2.

Table 2: Summary of ABET accreditation requirements - General and program criteria

	Minimum number of credit hours
General criteria	
College-level mathematics and basic sciences with experimental experience appropriate to the program	30
Engineering topics appropriate to the program, consisting of engineering and computer sciences and engineering design, and utilizing modern engineering tools	45
General education component that complements the technical content of the curriculum and is consistent with the program educational objectives	No minimum
Major engineering design experience	Should include: -Appropriate engineering standards and multiple constraints -Build on knowledge and skills acquired in earlier course work
Program criteria	
Math and science requirements, apply probability and statistics to address uncertainty	At least one additional area of basic science
Analyze and solve problems in at least four technical areas appropriate to civil engineering	
Conduct experiments in at least two technical areas of civil engineering and analyze and interpret the resulting data	Design a system, component, or process in at least two civil engineering contexts
Include principles of sustainability in design; explain basic concepts in project management, business, public policy, and leadership; analyze issues in professional ethics; and explain the importance of professional licensure.	

3. Future Work

In order to understand the reasons high school seniors choose their intended undergraduate major, a survey must be conducted. This survey will include questions on their perception of civil engineering (CE) and if high technology plays a role in their decision for their program of study. The answers to these questions will guide future work on how coursework can be made more appealing to those considering civil engineering but worried about their place in it in a technologically advanced society. The questions will also be further developed with social scientists in order to retrieve useful and valid answers.

SOME SAMPLE HIGH SCHOOL SURVEY QUESTIONS

1. What are some things that Civil Engineers (CEs) do that impact your daily life?
2. What kind of skills do you think you need to have to be a CE?
3. Do you think CE is a discipline that has high technology (The term “high technology” here refers to Artificial Intelligence (AI) and machine learning) Why or why not?

4. What areas are you interested in pursuing in university? Why?

Future work also includes developing a suggested curriculum for universities to adapt in their civil engineering departments and if suggested civil engineering curriculum changes could influence incoming university freshmen's decision on becoming a civil engineer.

Concluding Remarks

With civil engineering undergraduate enrollment declining while the demand for civil engineering professionals increasing, there is a need to evaluate what could cause disinterest in civil engineering. One possibility is the perception of civil engineering being an "outdated" discipline when other engineering disciplines have integrated concepts such as programming and machine learning into their curriculums. This work in progress aims to review the literature on high technology and civil engineering as well as review the curriculums of US schools in the top 220 based on the QS World University Ranking. 4 out of 39 universities implemented high technology courses in several ways in their curriculum, while 4 out of 39 made it optional in the form of subdiscipline electives. These results highlight the need for curriculum reform in unique ways, such as requiring students to use high technology methods to solve problems in traditional civil engineering major electives.

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