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Mathematics and Science Subjects in Construction Management Baccalaureate Programs

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This study analyzes credit-hours of mathematics and science subjects in the American Council for Construction Education (ACCE) accredited bachelor's degree programs in Construction Management (CM). As per the current ACCE standards, a graduate of a CM program is required to complete 3 and 6 Semester Hours (SHs) in Mathematics and Science, respectively. An analysis of the credit-hours in the 75 accredited programs shows that more than 90 percent of the programs require a student to complete more hours in these subject than the required 9 SHs. The analysis also shows that 72 percent of the programs require 6 SHs or more in Mathematics and 79 percent of the programs require 8 SHs or more in Science. A strong presence of mathematics and science subjects in the CM programs indicates that the programs are striving to equip the graduates with skills in data analysis, model building, and research and innovation. Moreover, these subjects equip the graduates for a continuous academic inquiry and prepare them to understand and appreciate the natural world. The results indicate that the CM programs make a strong case for science, technology, engineering, and math designation.

Key Words: ACCE accreditation, Mathematics, Science, STEM, Student learning outcomes

Introduction

The number of workers entering the construction industry in the coming years is projected to grow and so is the demand for the construction management (CM) graduates. Hovnanian, Luby, and Shannon (2022) project that about 300,000 to 600,000 new workers will be entering in the non-residential construction sector alone each year. Furthermore, Thomasian (2011) predicted that science, technology, engineering, and math (STEM) jobs are expected to grow twice as fast as non-STEM jobs and more than 90 percent of these jobs “will require postsecondary study, with 68 percent requiring a bachelors’ degree or more” (p. 12). This trend is reflected in the growth over the years of the CM programs offering a baccalaureate degree. The number of baccalaureate degree programs accredited by the American Council for Construction Education (ACCE) increased from 60 in 2006 to 73 by the 2015-16 school year (Smith-Barrow, 2017). As of 2022, the number of CM degree programs has further increased to 75 (American Council for Construction Education [ACCE], 2022a) and there are

currently five bachelor's degree Candidate programs waiting for full accreditation and three Applicant programs under consideration for a Candidate program (ACCE, 2022b).

The CM programs have not only grown in numbers, they also have stood the test of time to establish themselves as independent programs with unique identity. Hauck (1998) and Rounds (1992) argue that, although the construction management programs in the universities started as a branch within the Engineering and Architecture departments, the programs have gained acceptance as a distinct academic area. Along with the growth in the numbers and recognition as a distinct academic area, the programs are being “developed in nontraditional academic departments, such as business, construction technology, industrial science, and industrial technology” (McDaniel, 2005, p.5). These programs, as Dietz and Little (1976) and McDaniel (2005) observe, have shifted their emphasis from basic science, mathematics, and design to focus more on construction technology and management. The trend of less emphasis on mathematics and science is reflected in the ACCE accreditation requirements too. The ACCE standards currently require a minimum of 3 and 6 Semester Hours (SHs) in the core areas of mathematics and science, respectively (ACCE, 2022c). The requirements in the years before 2016 were a minimum of 3 SHs in mathematics and 8 SHs in science with a minimum of 15 SHs required for a combination of these two subject areas such as in ACCE (2012). Effective from 2016, the ACCE standards also moved from a suggested list of subjects in various categories to a list of 20 Student Learning Outcomes (SLOs) that a student must achieve to graduate (Batie, 2018).

Although none of the SLOs is related to mathematics and science, the commentary on the ACCE standards provides rationales for these subjects. The commentary states that “construction is in part a technical process that can be best controlled by applying the principles of mathematics and statistics. An understanding of the behavior of the materials, equipment, and methods used in construction requires knowledge of the physical and environmental sciences” (ACCE, 2021, p. 13). Additionally, it can be argued, as Glaze (2018) suggests, that science literacy equips the graduates with an ability to “solve problems, make evidence-based decisions, and evaluate information in a manner that is logical” (p. 1). As Mills, Auchey and Beliveau (1996) and Hauck (1998) also argue, the cornerstone of a strong CM curriculum is balancing between practical experience, technology management and academic inquiry. Literacy in mathematics and science prepares the graduates with skills in academic inquiry and ability in evidence-based decision making. Although it can be argued that mathematics and science are essential building blocks of construction management education, it is difficult, if not impossible, to argue on the minimum required number and nature of such courses. Against this background, this study analyzes the extent to which the ACCE accredited bachelor's degree programs require mathematics and science subjects in their respective programs. The main research questions of this study are:

1. What is the variation in credit hours of mathematics and science subjects in the programs?
2. What is the extent of the mathematics subjects offered in the programs?
3. What is the extent of the science subjects offered in the programs?

Along with the above research questions, an argument based on the results of the analysis is made for considering the CM degree programs under a STEM classification.

Data consideration and assumptions

The programs considered in this study are from a current list of the ACCE accredited bachelor's degree programs as of August 08, 2022 available from the ACCE website (ACCE, 2022a). Information about the programs was collected from the webpages of the respective programs during August and September of 2022. The subjects and the corresponding credit-hours were recorded from

the suggested roadmap of the respective programs as far as available. In the case where the roadmap was not available, the required subjects were recorded from the degree requirement descriptions and the subject list available on the program webpage. Following assumptions are made in the analysis.

- The minimum required credit-hour as suggested in the course map is considered in the analysis. For example, if a student can choose between a 4-hr and a 5-hr course, 4-hr is used in the analysis.
- A course title is used to identify the nature of the course. For example, if a course title includes Precalculus, it is assumed that the course does not cover Calculus.
- In case a program offers an option to choose between Physics or Chemistry and other Science courses, other Science courses are accounted for in the analysis.

Math and Science requirements

Out of a minimum of 120 SHs required for a bachelor's degree program for the accreditation purpose, the ACCE standards prescribe only 83 SHs in General Education (GE), Business and Management and Construction categories (ACCE, 2022c). The standards state that a Degree Program can use the remaining 37 SHs in any way it wants to meet “ACCE SLOs, Degree Program-specific focus or specialization, and other institutional requirements” (ACCE, 2022c, p. 11). Moreover, as academic programs are designed to serve their respective constituencies, the programs are expected to have a certain degree of diversity in the admission requirements, subjects covered, depth and breadth of the coverage and graduation requirements. The programs accredited by ACCE, as such, also are expected to have such variations. ACCE also encourages the programs to “strive to provide offerings that exceed the ACCE standards and criteria for accreditation (ACCE, 2021, p. 12). In addition to the required credit-hours, the standards also prescribe 20 student learning outcomes (SLOs) which a bachelor's degree program needs to meet for the ACCE accreditation.

Out of the 83 SHs, the ACCE standards require a minimum of 15 SHs in the GE category and the subjects must be taught outside the degree program (ACCE, 2022c). Areas in GE include communications, mathematics and physical or environmental science with a minimum required hour for each sub-category as 6, 3 and 6 SHs, respectively. Therefore, a student must complete a minimum of 9 SHs or 7.5 percent of the total hours in mathematics and science to graduate. Despite of the hours allocated, there is no learning outcome that can be associated directly with the subjects in the mathematics and science sub-category. Although not stated explicitly in the SLOs, the expectations from mathematics and science subjects are laid out in the commentary sections of the standards. The commentary documents explain that the curriculum should be responsive to reflect the application of evolving knowledge in the behavioral and quantitative sciences and every student possesses a well-developed concept of mathematics as technical processes need application of the principles of mathematics and statistics (ACCE, 2021).

An analysis of the required credit-hours in mathematics and science in the ACCE accredited CM programs show that majority of the programs require their students to complete 10 percent or more of the total required credit-hours in mathematics and science subjects (Figure 1). Only three out of the 75 accredited programs have eight percent or less of the total credit-hours dedicated to these subjects. The credit-hours used in Figure 1 exclude required hours for Algebra and Trigonometry but include hours for Statistics. The ACCE standards state that Algebra and Trigonometry cannot be considered for the required 3 credit-hour in mathematics but hours in Statistics can be considered (ACCE, 2021 and ACCE, 2022c). A detailed discussion on the nature and composition of science and mathematics subjects in the CM programs is done in the following sections.

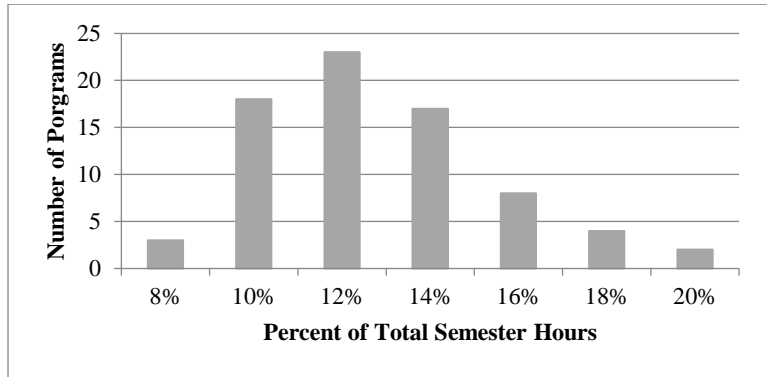


Figure 1. Mathematics and Science credit hours as a percentage of total credit hours in the ACCE accredited CM bachelor’s degree programs

Math courses in Construction Management programs

The ACCE standards state that the degree programs “shall not use a college algebra course or trigonometry course for this requirement” (ACCE, 2022c, p. 10) which implies that acceptable level of mathematics is Precalculus or above it or Statistics. The required credit-hours in mathematics in the CM programs are shown in Figure 2. In the figure, hours in Statistics are included but those in Algebra and Trigonometry are excluded in line with the ACCE criteria. For a comparison purpose, Quarter-hours (QHs) are converted to SHs by a factor of 3/4 as ACCE criteria require a minimum of 3 SHs or 4 QHs in mathematics. More than 70 percent of the programs require a student to complete two times or more than the minimum required 3 SHs to graduate from the program. Out of the 75 programs, only 13 programs require the minimum prescribed hours.

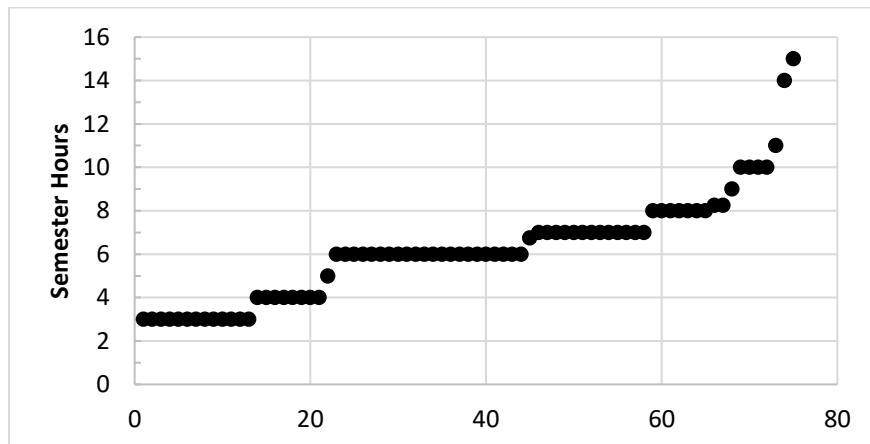


Figure 2. SHs in mathematics in the CM programs. Hours in Algebra and Trigonometry are excluded but the hours in Statistics are included.

Although Trigonometry and Algebra cannot be counted towards the ACCE requirements, many programs require their students to complete these subjects. One of the reasons for this may be that the programs have different admission requirements and students are required to complete these subjects to build the foundation knowledge for higher level mathematics and construction science courses.

Figure 3 shows information on number of programs requiring Trigonometry and Algebra courses. As can be seen in the figure, 49 programs, or 75 percent, do not require a graduate to complete any Algebra and Trigonometry course. Out of the 26 programs that require credit-hours in these subjects, 12 programs require 3 or less SHs and only seven programs require 6 or more SHs.

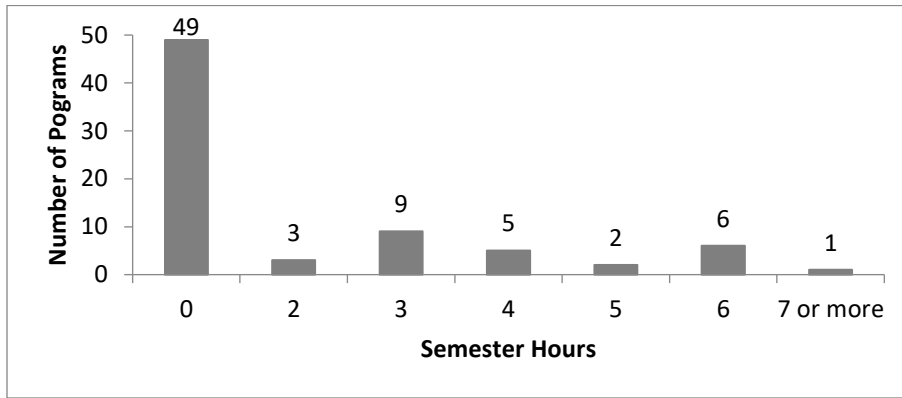


Figure 3. Semester Hours in Algebra and Trigonometry in the CM programs

Figure 4 shows status of Pre-calculus, Calculus and Statistics, which are the subjects that can be used against the ACCE requirements, in the CM programs. Statistics is considered more applied mathematics than a pure mathematics subject. For example, Johnson and Kuennen (2006, p. 1) consider that “while advanced statistics is very much a mathematical discipline, introductory statistics is generally considered not to be a mathematics course”. However, the ACCE standards consider that Statistics can be used to meet the ACCE requirements in mathematics. Out of the 75 programs, three programs (four percent) use only Precalculus to meet the ACCE criteria. Among the programs, 70 percent have at least one Calculus course and 75 percent have at least one Statistics. Forty nine percent programs require at least one course of both Calculus and Statistics.

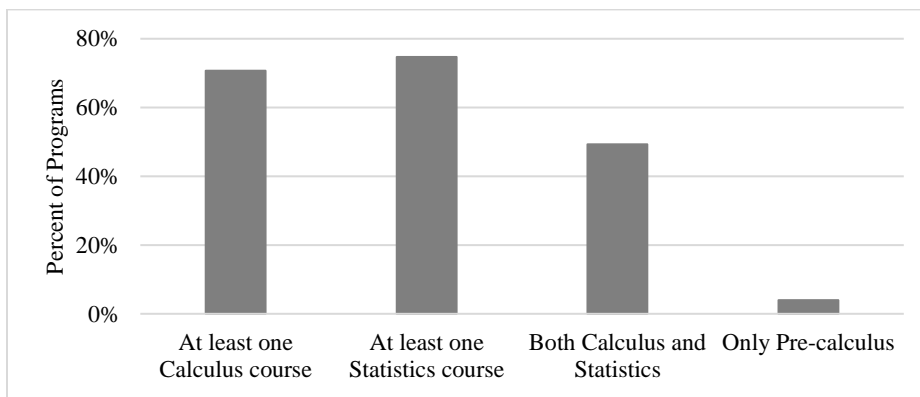


Figure 4. Precalculus, Calculus and Statistics in the CM programs

Science courses in Construction Management programs

The ACCE standards include physical and environmental science in the category of science subjects and require that the subjects shall be analytically based and not descriptive (ACCE, 2022c). Furthermore, the science subjects are expected to be taught outside of the degree program. The ACCE

standards further recommend that the courses in the science category “should include the use of analytical skills, such as mathematics and scientific reasoning—often associated with lab skills” (ACCE, 2021, p. 15). Figure 5 shows the credit hours in science subjects in the 75 ACCE accredited degree programs. Six programs require a student to complete only the minimum required credit hours required by ACCE. As can be seen in Figure 5, many of the programs require a student to complete 8 or more SHs which is 1.3 times higher than the minimum required credit-hour in science.

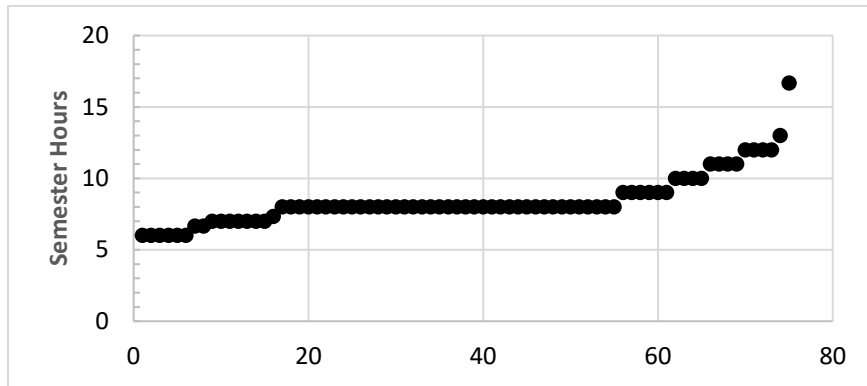


Figure 5. SHs in Science subjects in the CM programs

Figure 6 shows the percentage of programs requiring Physics and Chemistry subjects a student must complete to graduate from the degree program. Ninety-five percent of the programs require that the students complete at least one Physics course but only 15 percent of the programs require a course in Chemistry. As seen in the figure, 32 percent of the programs require to complete 6 SHs or more of Physics which is sufficient to meet the accreditation requirement in science. Forty four percent of the programs require students to take both Physics and Chemistry such that the combined hours are sufficient to meet the requirements in science.

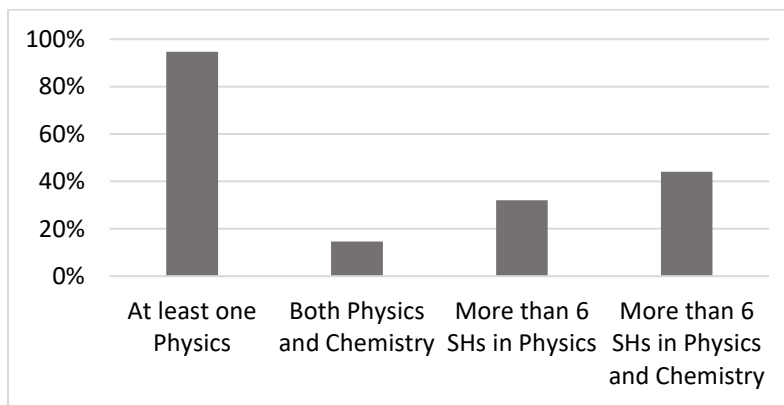


Figure 6. Physics and Chemistry courses in the CM programs

Discussion on ACCE learning outcomes and STEM classification

Mathematics and science learning outcome

The hallmark of the ACCE standards has been layering of construction courses, comprising of construction technology and construction management, with foundational courses on mathematics and science. It can be argued that mathematics and science subjects are required in construction management for three reasons. First, they bridge the gap between what the students have learned in high school and what is required for successfully completing the construction courses. Second, the courses in mathematics and science prepare the graduates to formulate a problem, build a model, develop and conduct experimentation, analyze and interpret the data and make arguments based on evidence. Third, and most importantly, the courses prepare a graduate for continuous academic inquiry and to understand and appreciate the diversity and unity of the natural world. Overall, the epistemic practices and the learning and knowledge “produced through such practices as building models, argument from evidence, and communicating findings” (Moon & Singer, 2012, para. 6) in mathematics and science prepare the graduates for application of the construction management knowledge in professional practice and engage in a life-long pursuit of academic inquiry.

It appears that the intention of the ACCE standards in prescribing the requirements in mathematics and science is related with all the three aspects explained above. Although none of the current 20 SLOs in the ACCE standards is related to the mathematics and science subject areas, the intention is stated in the commentary. The commentary on the ACCE standards states that “construction is in part a technical process that can be best controlled by applying the principles of mathematics and statistics. An understanding of the behavior of the materials, equipment, and methods used in construction requires knowledge of the physical and environmental sciences” (ACCE, 2021, p. 13). Given the intention of the standards and the presence of mathematics and science course in the CM programs, it seems logical that the ACCE standards include at least one comprehensive learning outcome to capture the essence of what graduates are expected to accomplish from completing the mathematics and science courses.

STEM classification of CM program

The definition of what exactly is STEM and which majors fall under the STEM field are still to be settled. Despite the proliferation of STEM related policies and entities, the exact understanding of STEM branding itself is still elusive (Moon & Singer, 2012). While the National Science Foundation uses a broader definition of STEM to include psychology and the social sciences, Department of Homeland Security (DHS) uses a narrower definition which excludes social sciences and focuses on areas like mathematics, chemistry, physics, and engineering (Gonzalez & Kuenzi, 2012).

Although the definition of STEM fields is still to be settled, CM programs with a mix of science, math, technology, and management subjects are considered, by default, as the STEM subjects, for example, in Jones, Rusch and Waggenspack (2014) and John and Chen (2017). The DHS’s latest STEM designated degree program list, however, does not include Construction Management in the STEM field (Department of Homeland Security [DHS], 2022). The DHS program list is used for the purpose of 24-month STEM optional practical training extension. Therefore, a program with a STEM designation can attract more international students as they will be eligible to apply for an extension of 24 months of work visa. STEM classification can be attractive to domestic students too as such a classification carries more weight than ever (Kullman, 2019) and students can have a competitive

edge in the job market. “Construction Management” falls in the category of Business, Management, Marketing, and Related Support Services under the current Classification of Instructional Programs (CIP) which is used by DHS to prepare the STEM list. As of 2022, DHS lists only “Management Science”, “Business Statistics”, “Actuarial Science”, and “Management Science and Quantitative Methods, Other” under the STEM field within this CIP category.

Although a STEM designation can boost the number of applicants and can be instrumental in solving the gap in skilled workers in the construction industry, there is more to a STEM designation than to increase the enrollment. As the construction industry needs to evolve, adapt to and be at the forefront of the technological innovations that are sweeping through the industry, the programs also need to prepare the graduates to lead the industry through these changes. A STEM designation can steer the programs to prepare the graduate to be at the forefront of technological innovation and to apply data analysis, risk management, modeling and research and innovation. Realizing the need for STEM classification, many business and management programs, including the CM programs, have recently moved from a non-STEM to a STEM classification. All three MBA programs of UC-Berkeley’s Haas School of Business were reclassified from “Business Administration and Management, General,” to “Management Science,” which falls under the STEM field (Ethier, 2019). Similarly, Arizona State University’s CM program was moved from a “Business Management” program to a “Construction Engineering Technology/Technician” classification which is a STEM field (Kullman, 2019). As the ACCE criteria already require several foundational courses in mathematics and science and courses in construction science and technology, the CM programs meet the requirements for a STEM classification on their own instead of them requiring to change the departmental affiliation. In addition to the requirements in mathematics and science, the ACCE standards require a graduate to be able to create cost and schedule estimates, analyze methods, materials and equipment, apply surveying techniques, understand accounting, cost control, risk management and structural behavior and apply digital technology for managing construction processes. Therefore, it can be argued that the CM programs have a genuine case for the STEM designation.

Conclusion

An analysis of the credit-hours of mathematics and science subjects in the ACCE accredited CM programs shows that the programs require a graduate to complete more hours in these subjects than required for the accreditation. More than 90 percent of the CM programs require graduates to complete more hours in mathematics and science subjects than required by the ACCE accreditation. As the current list of SLOs required for accreditation does not have an outcome related to these subjects, it is argued that the standards should have at least one learning outcome related to mathematics and science subjects. The ACCE accreditation standards require that the CM graduates are not only equipped with managerial skills, but they are also prepared for data analysis, innovation and research, and scientific reasoning. Therefore, CM programs make a convincing case for STEM recognition in the CIP classification and the DHS’s list.

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