From Need Assessment to Accreditation: Lessons Learned from Creating a New Construction Engineering Program

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Abstract

Launching a new college degree program is an arduous task that requires strategic planning, meticulous coordination, and careful implementation of the plans. Due to a growing demand for construction professionals, The Citadel department of Civil and Environmental Engineering launched a new BS in Construction Engineering program in 2018. The program was accredited by ABET in 2021, and has successfully produced more than fifty construction engineering graduates over the past three years. This paper presents lessons learned from creating the BS in construction engineering program at The Citadel. In particular, we discuss the opportunities and challenges related to development of curricular content, preparation of course syllabi, adopting textbooks, assessment and accreditation, and industry relations for creating a construction engineering program. Seventeen new courses were created for the new program. The course maps of all ABET accredited construction programs in the US were reviewed, a database of skill sets required of construction engineers was established, and more than 100 related textbooks were evaluated to decide the course learning objectives and create the syllabi. A robust assessment scheme was created and used in documentation of the program's success in meeting ABET's standards of quality. The lessons learned include exploiting opportunities for cross-listing or cross-teaching construction engineering courses with civil and mechanical engineering, and project management programs, and identifying the need for new educational materials including textbooks for construction engineering programs.

Introduction

Shortage of skilled workers has become a significant challenge for construction industry in the United States. A recent U.S. Chamber of Commerce study revealed that 92% of contractors face difficulty finding skilled workers, 71% ask their skilled workers to work overtime, and 42% report turning down projects due to skilled labor shortages [1]. The aging of the skilled workforce is likely to exacerbate the problem in the next few decades [2]. In addition, the complexity of construction projects is rising, making it increasingly necessary to have a bachelor's degree in order to secure well-paying and highly sought-after careers within the construction industry[3]. Due to the increasing demand for Construction-related undergraduate programs, the College of Engineering at The Citadel established a new BS in Construction Engineering program in 2018. The program was granted ABET accreditation in 2021 and has produced over 50 construction engineering graduates in the past three years.

Launching a new college degree program is a challenging and demanding process that entails careful planning, precise coordination, and diligent execution of the plans. This paper presents our learning experiences from launching the BS in construction engineering program at The Citadel to: i) identify the key challenges and obstacles encountered in developing a new program and how they were overcome, ii) provide recommendations for best practices in launching a new college degree program, iii) to disseminate the lessons learned from the launch process and to encourage other institutions to consider similar programs, and iv) to identify areas for improvement in existing construction engineering programs and suggest strategies to implement the improvements.

An Overview of The Program Development Process

Development of the new BS in Construction Engineering program from internal discussions within the School of Engineering until ABET accreditation and final implementation of the program took about 8 years (Figure 1). In this section, we will discuss the six-phase process for developing the new program (Table 1). It should be noted that these phases were not necessarily sequential and may overlap or occur simultaneously, depending on the specific circumstances of the program development.

Figure 1: Timeline of launching BS in Construction Engineering at The Citadel

Need Identification

Discussions about launching a new Construction Engineering program began in 2013. It was noticed that many students were interested in hands-on construction work instead of desk-bound design work, which was evident from their participation in projects like the Steel Bridge and Concrete Canoe. Additionally, a review of the national and local construction markets indicated that the use of design-build projects was steadily increasing compared to the traditional design-bid-build delivery method [4] . One reason for this shift is that design-build encourages greater collaboration and communication between design and construction teams, potentially leading to better coordination and fewer errors or changes during construction. This has generated a high demand in the market for individuals who possess a strong understanding of both design and construction processes. As a result, a construction engineering program could bridge the gap between design-focused civil engineering degrees and business and management-focused construction management programs [3].

In 2014, an initial study was carried out to evaluate the requirements of the program, including learning outcomes and resource needs. To aid in market research and program development, an advisory board comprising industry professionals, faculty members, alumni, and community leaders was formed in 2015. The advisory board also facilitated partnerships and collaborations with other organizations and identified potential sources of funding for the program's development. The outcome of the need identification phase was the realization that there was a gap in the current course offerings and a demand for the new Construction Engineering program.

Conceptualization

The objectives of this phase were to define the goals of the educational program, develop course maps, and secure funding and approvals for the new program. From the moment the program idea was conceived, the School of Engineering prioritized the goal of obtaining accreditation from the Accreditation Board for Engineering and Technology (ABET) for the new program. ABET accreditation is widely recognized as a symbol of excellence in engineering and technology programs, both nationally and internationally. This recognition can be beneficial for graduates of accredited programs, especially in terms of professional mobility. For instance, engineers who relocate to a different state or country may

Table 1: The six phases of developing the new BS in Construction Engineering at The Citadel

Need Identification	Conceptualization	Planning	Design	Implementation	Evaluation & Accreditation
• Market Research • Focus Group Discussions • Feasibility Assessment	• Identify Goals of the Educational Program • Create Course Maps • Secure Approvals & Funding	• Resource Allocation • Hiring • Draft Curriculum	• Curriculum Development • Course Outlines • Instructional Materials	• Student Recruitment and Support • Curriculum Delivery • Stakeholder Engagement	• Annual Program/Course Assessment • Standard Review Process • Continuous Improvement

find it easier to obtain licensure or secure employment if they hold a degree from an accredited program. Therefore, seeking ABET accreditation for the new program was considered an important step in establishing its quality and competitiveness in the field of engineering education. Accordingly, the program educational objectives and student outcomes were developed to support the department's mission, industry needs, and ABET requirements. The initial student outcomes excerpted from ABET were [5]:

Table 2: Program Student Learning Outcomes (Excerpted from ABET, 2017-2018 [5])

Student Learning Outcomes
(a) an ability to apply knowledge of mathematics, science, and engineering (b) an ability to design and conduct experiments, as well as to analyze and interpret data (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability (d) an ability to function on multidisciplinary teams (e) an ability to identify, formulate, and solve engineering problems (f) an understanding of professional and ethical responsibility (g) an ability to communicate effectively (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (i) a recognition of the need for, and an ability to engage in life-long learning (j) a knowledge of contemporary issues (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice"

The plan was to submit the proposal for the new program to Authors' Institute State Committee on Higher Education (CHE) in 2015 and launch the program in 2016. However, due to other ongoing degree programs on campus, the launch was delayed until May 2017. On 29 November 2016, the college-wide undergraduate curriculum committee approved the program. The proposal was passed by faculty senate on 12 December 2016, and by the board of visitors and the president of the college on 9 January 2017. Ultimately, the program was approved by CHE on 7 December 2017 to be implemented in 2018. Approval was received from the Author's Institution Foundation in December 2016 to raise $100,000 for the program in the coming year.

Planning

After considering the close relationship between civil and construction engineering, it was decided that the program would be offered by the Department of Civil and Environmental Engineering (CEE), rather than creating a new department. This decision offered three additional advantages: First, it allowed CEE faculty to support the new program, especially by teaching many of the design courses. Second, the new program could benefit from the robust assessment methods of CEE programs. Third, the two programs could share resources such as lab spaces, financial support, and support staff. Furthermore, it was resolved to maintain the initial two years of the new construction engineering curriculum akin to the current Civil Engineering program to ensure a high level of consistency between the two programs and offer students optimal adaptability when transitioning between the two majors.

To support the new program, two faculty lines were created. In order to strategically enhance the program's curriculum, one faculty member with specialized expertise in structural and sustainable building materials, methods, and engineering was hired. This faculty member was responsible for teaching courses related to construction materials and methods, as well as structural analysis. Additionally, another faculty member was hired with expertise in construction and infrastructure management, who taught courses related to business and management aspects of construction. This decision was made in order to provide a well-rounded education for students, and to ensure that they have access to faculty members who have specialized knowledge and experience in different areas of construction engineering.

To provide additional support for the new program, faculty members from various departments within the college were engaged for involvement. The Civil and Environmental Engineering faculty with expertise in soil and geotechnics, as well as structures courses, were expected to contribute to the program. Additionally, faculty members from the Engineering Leadership and Program Management department were to provide support for courses in project management. Moreover, the Mechanical Engineering department faculty members were also planned to be engaged in the program by teaching a course on Mechanical, Electrical, and Plumbing Systems. The collaboration between different departments and faculties was intended to provide students with a well-rounded and comprehensive education in construction engineering, covering a diverse range of topics and areas of expertise.

During the planning phase, a course map for the program was established, along with preliminary syllabi for new courses. Figure 2 demonstrates that a total of seventeen fresh courses (52 credit hours) were created, with ten of the Civil Engineering courses (26 credit hours) cross-listed for the new Construction Engineering program. Additionally, one course (3 credit hours), ACCT 205, was adopted from the business department's course offerings. The remaining 54 credit hours of the 135-credit hour program consisted of Math and Science courses, as well as General Education courses.

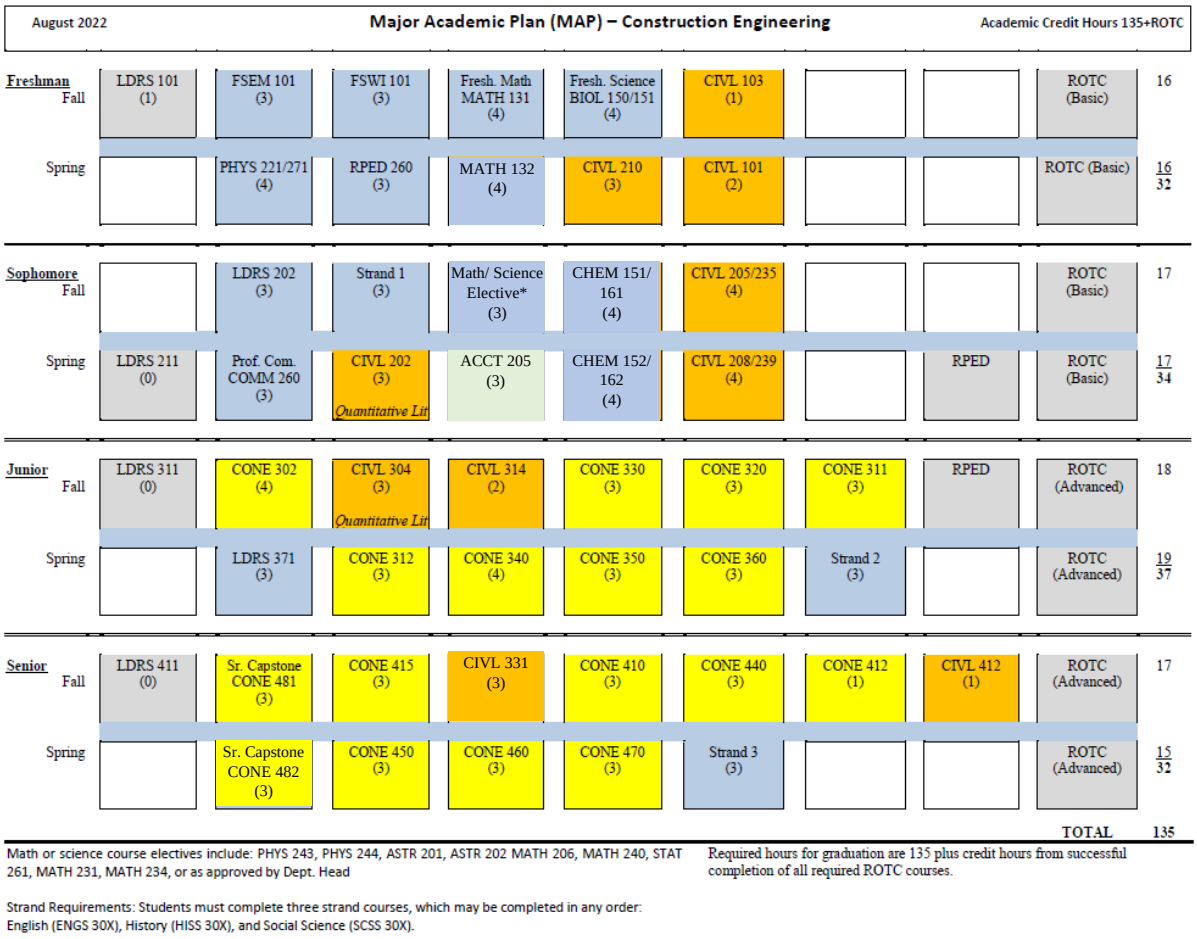

Figure 2: Course map of the new BS in Construction Engineering

Design

During the design phase of the program, the program was meticulously developed and defined, including its structure, content, and delivery methods. This involved the creation and refinement of course outlines, syllabi, and other instructional materials, as well as the development of a comprehensive curriculum. As part of this process, 17 new courses were created, including the culminating senior design courses, CONE 481 and CONE 482, which provide students with the opportunity to apply their theoretical knowledge and technical skills to real-world engineering problems. Another course, CONE 412, was specifically designed to assist students in preparing for the NCEES Fundamentals of Engineering (FE) Computer Based Exam. Details regarding the course learning objectives and delivery methods for the remaining 14 courses are presented in Table 3.

Adopting a textbook for the newly developed courses was a critical decision that required careful consideration of several factors. Some of the key factors that were considered when selecting a textbook for the courses included:

Relevance: The textbook should be relevant to the course content and learning outcomes, covering the necessary topics with appropriate depth and breadth of coverage.

Table 3: Course Learning Objectives for the BS in Construction Engineering Program

Course Title	Course Learning Objectives
CONE 302 Eng./Con. Law, Ethics, Safety, and Contracts	1. Compare and contrast the different types of construction contracts that exist and the roles and responsibilities of the contractual party
	2. Describe the role OSHA has in Construction Safety
	3. Evaluate construction site scenarios for critical safety hazards, identified by OSHA
	4. Explain how ethical problems are encountered in the engineering and construction industry
	5. Compare and contrast the different forms of formal dispute and claims resolution
	6. Explain how labor and environmental laws affect construction projects and supervision
CONE 311 Resource Estimating	1. Compare construction cost estimating methods and their uses.
	2. Explain the role of estimator and the requirements of estimating in construction projects.
	3. Discuss contracts, bonds, insurance, and project manual as they relate to resource/cost estimating.
	4. Explain Construction Estimating Code of Ethics
	5. Read and Interpret Construction Drawings and Specifications
	6. Identify types and components of overhead and contingencies
	7. Determine labor and equipment costs considering productivity adjustment.
	8. Explain the role of specialty contractors in project cost.
CONE 312 Advanced Estimating	1. Perform quantity takeoff for different construction work types/divisions given a set of plans.
	2. Use Microsoft Excel to assist in estimate preparation.
	3. Create a bid package, write a proposal letter, and submit a bid using standardized bid documents.
	4. Effectively communicate in writing.
CONE 320 Engineering Materials and Methods (& Lab)	1. Utilize ASTM specifications, building codes, and technical guidelines
	2. Articulate unique characteristics of foundation system construction
	3. Articulate unique characteristics of concrete, stone, & masonry construction
	4. Articulate the unique characteristic of steel construction
	5. Articulate the unique characteristics of wood (timber) construction
	6. Explain different cladding and façade systems
	7. Discuss different interior finish systems
	8. Prepare (write) a technical laboratory report and site visit report
CONE 330 Quality Management and Labor Relations	1. Apply quality management tools, techniques and standards for construction engineering.
	2. Explain the implications of project delivery methods, contract documents, and contract language on the quality of construction projects.
	3. Discuss common quality issues in life cycle of construction projects.
	4. Describe bond, guaranty, and warranty as they relate to quality of construction services and project deliverables.
	5. Recognize the methods to balance competing interests of time, money, and quality for engineering and construction.

	6. Identify risk of quality failure in construction projects and be able to implement risk mitigation plans.
CONE 340 Structural Analysis and Design	1. Examine load path of lateral and gravity loads on a building
	2. Examine the behavior and performance of individual structural members and their role in the overall structure
	3. Develop an organized approach to determine the required sizes for structural columns, beams, tension members, and foundations in accordance with appropriate code provisions
CONE 350 Commercial Construction and Engineering Equipment	1. Describe the basic principles of soil mechanics and their impacts on construction processes and assess different methods for improving soil characteristics.
	2. Appraise appropriateness of earthmoving and excavation methods as well as construction equipment used for hoisting materials, erecting structures, and earth moving.
	3. Estimate the productivity of different construction equipment and evaluate equipment management techniques (economics, planning, cost estimation, and maintenance).
	4. Compare different equipment use plans with respect to cost and schedule objectives of construction projects
CONE 360 Soils and Foundations (& Lab)	1. Develop an organized approach to solving soil mechanics problems
	2. Describe the physical properties of soil.
	3. Interpret and explain a geotechnical report
	4. Explain principles of shallow foundation construction.
	5. Explain principles of deep foundation construction.
CONE 410 Project Scheduling	1. Prioritize tasks based on their importance and urgency using Time Management Matrix.
	2. Compare the advantages and disadvantages of different scheduling techniques.
	3. Create a bar chart schedule for a construction activity.
	4. Discover critical path for completion of a construction project.
	5. Manage time and space buffer in horizontal projects using linear scheduling.
	6. Compress schedule via fast tracking or crashing.
	7. Identify other scheduling methods including Activity on Arrow and PERT.
CONE 415 Project Management and Engineering Administration	1. Compare different construction sectors.
	2. Distinguish the role of different participants in the life cycle of a construction project.
	3. Compare different organizational structures and contract types.
	4. Forecast and balance resources.
	5. Classify various project control metrics.
	6. Assess time and cost performance of construction projects using Earned Value metrics.
	7. Identify basic financial and accounting documents.
CONE 440 Con. Methods and Temp. Str. Design	1. Articulate the unique characteristics and appropriate applications of a number of temporary structures
	2. Prepare (write) a technical site visit report
CONE 450 Facilities Operations and Maintenance	1. Define facility management
	2. Describe building Sustainability for existing buildings and new construction
	3. Create BIM model with architectural elements

	4. Create BIM model with structural elements
	5. Use and manipulate BIM and other emerging technologies for creating construction documents
CONE 460 Mechanical and Electrical Systems	1. Fundamentals: Explain how indoor environmental quality is affected by the electrical and mechanical systems.
	2. Mechanical: Select devices for providing thermal control within a building.
	3. Mechanical: Select the heat flow within and throughout a building and estimate load calculations.
	4. Plumbing: Identify and explain plumbing material used for water supply, sanitary drainage and vent, and storm water drainage systems.
	5. Electrical: List and define the major components of the electrical systems of building.
	6. Electrical: Calculate electrical quantities for Ohm's and Power formulas; calculate what is needed to layout an electrical design for a building.
	7. Code: Apply code to overall MEP design and specifications.
CONE 470 Production Processes and Rapid Product Development	1. Construction processes. Construct solutions in residential construction by applying principles of engineering, tailored to the specific needs of the site and stakeholders.
	2. Project reporting. Develop project status reports based on observed field conditions.
	3. Communication skills. Apply effective oral and written communication skills to convey information to the broader project team.
	4. Stakeholder management. Identify stakeholders and apply appropriate communication skills with relevant project stakeholders.
	5. Risk. Determine project risks within a specific context.

Pedagogy: The textbook should be well-written, clear, and concise, with suitable examples and explanations that facilitate student learning. It should also include exercises and other learning activities that engage students and promote active learning.

Current relevance: The textbook should be up-to-date and reflect current thinking and practices in the field, including the latest research and developments in the subject area.

Cost: The cost of the textbook should be reasonable and affordable for students. The textbook should be available in both print and digital formats, and options for rental, used, or electronic versions should be available to help reduce costs.

Accessibility: The textbook should be accessible to all students, including those with disabilities. The textbook should be available in alternative formats such as braille, audio, or electronic text.

By carefully considering these factors and reviewing the textbooks for accuracy, bias, and appropriateness, the faculty of the new program selected textbooks that met the needs of their courses and helped students achieve their learning goals. Appendix A shows some of the textbooks that were reviewed, along with their advantages and limitations. It should be noted that for several of the courses, no single textbook met all the requirements of the course, and the faculty decided to supplement the instructional material with other resources.

Implementation

During the implementation phase, the program was introduced and launched. The required infrastructure, such as classrooms and labs, was allocated to the program, and the program was marketed

to potential students. To ensure a smooth launch, the program was initially piloted in 2018 with eight sophomore students who switched majors from Civil Engineering to Construction Engineering. This approach helped expedite the graduation of the first group of students by a year and aligned the program's first ABET visit with the reaccreditation of the Civil Engineering program for greater efficiency.

To support students' success in the program, a process for student development was established. All students, including freshmen, have a designated advisor within the program who they meet with before pre-registration and at the beginning of each semester. If poor performance is reported or mid-term grades are low, additional advising sessions may be scheduled. Students can also seek feedback and support through informal discussions with faculty. Advisors maintain records of students' progress, and access up-to-date information through a web-based college data service. During advising sessions, advisors verify students are taking the proper courses in the right sequence and have fulfilled prerequisites. While the web-based registration system checks for prerequisites, it does not verify successful completion of those courses, so faculty must confirm that before students can enroll in follow-up courses. A hold is placed on student registration until they participate in an advising session, and advisors check each student's semester registration at the beginning of each term to confirm compliance. If any issues arise, students are notified via email before the add/drop date. The program is working with the Registrar's Office to automate the process of verifying successful completion of prerequisites.

Assessment and Accreditation

Figure 3 illustrates the Program's overall assessment philosophy and integration between process components. This figure illustrates how guiding principles such as the adopted Mission Statement and established Core Values connect with program educational objectives and student outcomes. In addition, the flowchart identifies how various forms of data from our constituents provide feedback to our program, especially aspirational program educational objectives. Figure 4 presents the specific process flow chart dubbed the Program's Global Program Assessment Process. Primary components include Program Educational Objectives, Core Values, Mission Statement, and in part Student Outcomes. As illustrated, there are multiple paths that result in changes to these global assessment items. The first is a standard review process. The faculty and Program Director review these items on an annual basis. The Advisory Board reviews every three years and the School of Engineering (SOE) Dean reviews every two years. The Program Director and Dean review for consistency with college policies, the Program faculty reviews for consistency with educational trends and practices, and the Advisory Board reviews for consistency with professional standards and expectations. If any concerns are identified by any of these stakeholder groups, they are flagged for follow-up by Program Director and Construction Engineering (CONE) faculty for further action. Another path within the process that results in changes to the Global Assessment items is through direct measurement. Embedded Indicators and surveys are two tools used to receive both direct and indirect feedback. The process has a built-in loop to make improvements to the tool itself but if the process is deemed effective, then any concerns are identified and flagged for follow-up by the by Program Director and CONE faculty for further action. CONE faculty are presented with the concerns that come out of the process and task with developing a proposal, which will address issues identified as concerns or items needing improvement. The Advisory Board as well as SOE Dean reviews the proposal and any feedback is incorporated into the proposal. The final version is reviewed and approved by faculty and the process is documented and filed in the Programs' Annual Assessment documentation. Resulting actions are implemented to resolve the issue/item and/or changes are made to the Global Assessment component of concern.

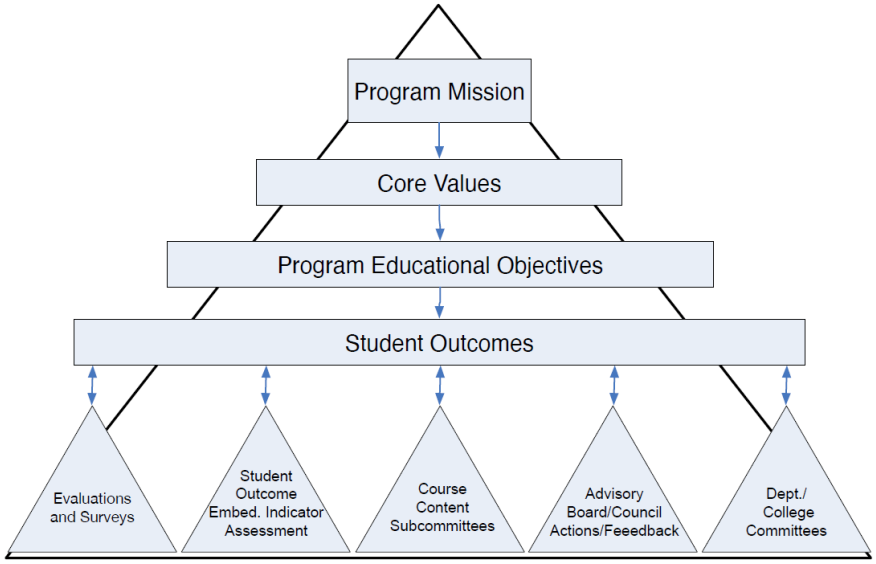

Figure 3: CONE Program Assessment Pyramid

Lessons Learned and Conclusion

The launch of the BS in construction engineering program at The Citadel was a challenging but rewarding process that provided valuable insights into the creation of new college degree programs. Through this experience, several key challenges were identified, as well as obstacles that emerged during the conceptualization, design, planning, implementation, and assessment phases of the program launch.

1. Defining Program Goals and Objectives: A critical first step in launching a new degree program is to define its goals and objectives. It is essential to identify the program's target audience, its relevance in the current job market, and the knowledge, skills, and abilities required to meet industry needs. In our case, we identified the need to train a new generation of construction engineers capable of managing the complexity of modern construction projects while addressing the shortage of skilled workers in the industry.

2. Collaborative Planning and Coordination: Developing a new college degree program requires close collaboration between different departments and stakeholders within the institution. We found it essential to involve faculty members from different disciplines, industry representatives, and students in the program development process. It was crucial to develop a shared vision for the program and ensure that everyone was aligned with the program's goals and objectives.

3. Curriculum Design and Development: The curriculum is the backbone of any degree program, and developing a relevant and up-to-date curriculum is crucial for program success. We found that involving industry representatives in curriculum design helped ensure that the program's content was aligned with industry needs. It was also essential to incorporate experiential learning opportunities, such as internships, co-ops, and hands-on projects, to provide students with practical experience.

4. Instructional Material: After reviewing an extensive range of textbooks and resources, we have

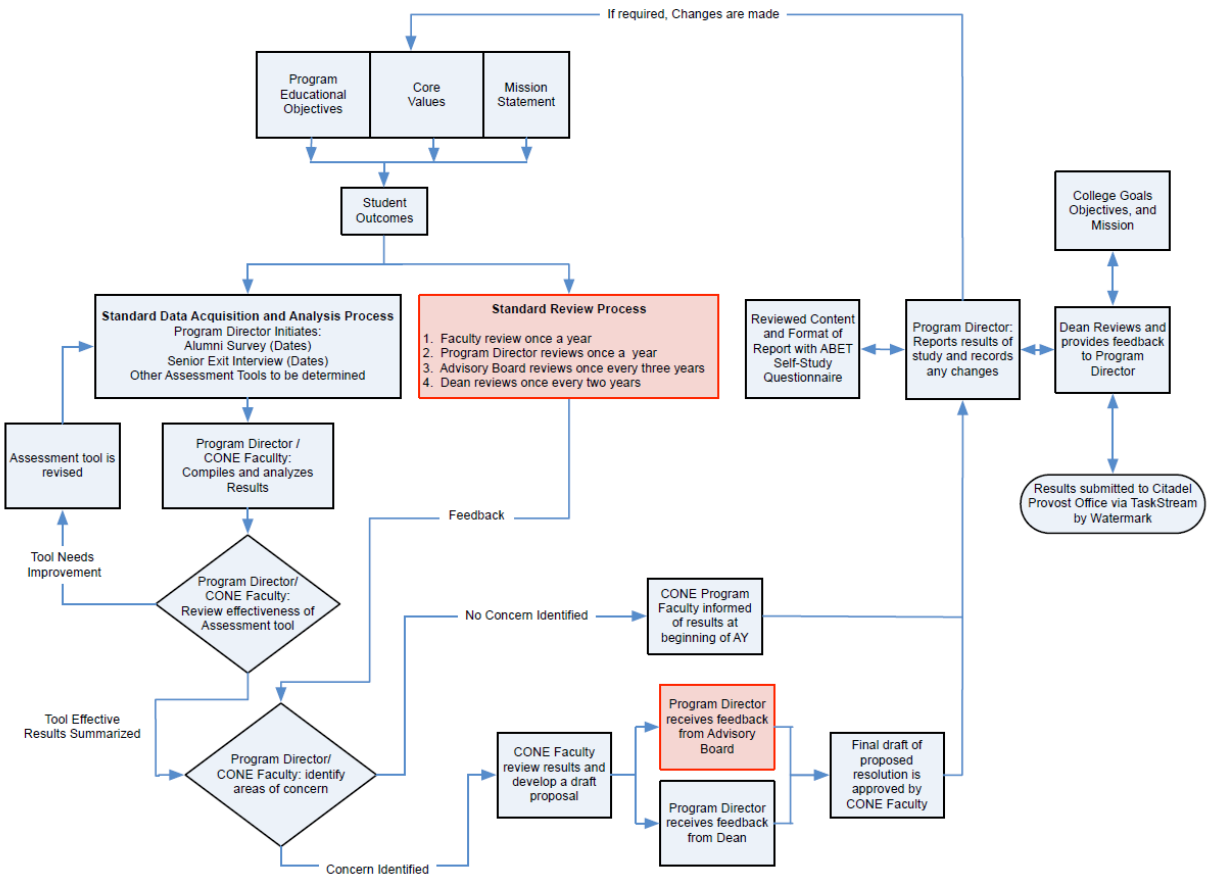

Figure 4: CONE Global Program Assessment Process

concluded that there is a significant demand for new instructional material and resources in Construction Engineering programs. Our evaluation revealed a particular need for updated textbooks and enhanced content related to quality management and the design of temporary structures. Furthermore, the material covering construction equipment is increasingly becoming outdated in light of the latest advancements in construction automation and robotics. Consequently, we strongly recommend the development of a comprehensive textbook that focuses on construction automation and robotics to meet this urgent need.

5. Accreditation: Obtaining accreditation for a new degree program is a rigorous process that requires significant effort and resources. We found that starting the accreditation process early in the program's development helped us identify areas for improvement and ensure that the program met ABET accreditation standards.

6. Marketing and Recruitment: Launching a new program requires effective marketing and recruitment strategies to attract potential students. We found that engaging with high school students, attending career fairs, and partnering with industry organizations were effective strategies to raise awareness about the program and attract prospective students.

In conclusion, the launch of the BS in construction engineering program at The Citadel provided valuable insights into the creation of new college degree programs. Our experiences highlighted the importance of collaborative planning and coordination, curriculum design and development, accreditation, and marketing and recruitment. We believe that our lessons learned can help other institutions navigate the

challenges of launching new programs and improve existing construction engineering programs.

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Appendix A: Textbooks Reviewed for the new courses

Textbook Evaluated	Advantages	Limitations	Adopted Topics (if any)
CONE 302: Engineering/Construction Law, Ethics, Safety, and Contracts			
Werremeyer, Kit. Understanding & Negotiating Construction Contracts, A Contractor's & Subcontractor's Guide to Protecting Company Assets. RS Means. 2006.	Great contractor's perspective for contractual issues (unique)	Portions are dated for current law. No instructor guides. Majority of material not used in class	Portions of: Assurance of Performance, Insurance, Indemnity
Kelley, Gail S. Construction Law, An introduction for Engineers, Architects, and Contractors. RS Means. 2013.		No instructor guide or examples, lack of depth on required topics.	The Procurement Process
Yates, J.K. Engineering and Construction Law and Contracts. Prentice Hall. 2011.	Instructor resources with chapter question solutions.	Large portions of the book not used in class, >$150	Portions of: Forming Engineering and Construction Contracts, contracts for engineering and construction services, contract terms and conditions, change orders and claims
Hill, Darryl C (editor). Construction Safety Management and Engineering. American Society of Safety Engineers. 2014.	Learning Objectives and review exercises provided for each chapter	>$200, no instructor guide, too deep and thorough for a 4-5 week safety module	Design for Construction Safety and Health
Sweet, Justin. Legal Aspects of Architecture, Engineering and the Construction Process		>$200, no instructor guide, too deep and thorough for a 4-5 week construction law module	
Other Resources: Targeted guest lectures from industry, a Sr VP on construction contracts, a construction director of safety, and a construction law attorney (All CO); osha.gov; Markkula Center of Applied Ethics at Santa Clara University, Ethics resources, www.scu.edu/ethics/ethics-resources			
CONE 311: Resource Estimating			
Dagostino, Frank R. and Peterson, Steven J., Estimating in Building Construction, 9th Edition, Pearson Prentice Hall, 2015.	Comprehensive coverage of building construction cost estimation, contains rich instructor resources including example problems and a sample bidding project	Instructor resources does not include sample test questions.	Ch 1-7, 9, 20, 22

Huth, M. W. (2014). Understanding construction drawings. Cengage Learning. ISBN 978-1-285-42323-3.	A comprehensive coverage of construction drawings, including plans, elevations, sections, and details, among others, rich instructor resources including complete sets of drawings, exercises, review questions, and sample test questions	Focused only on plan reading and does not contain information on quantity take-off or cost estimation, Outdated with regards to rapidly evolved technologies such as digital drafting tools and Building Information Modeling (BIM)	The entire book, particularly units 1-33
Ding, A. (2021). Construction Estimating: A Step-by-Step Guide to A Successful Estimate. Independently published. ISBN 979-8506983812.	Easy to understand, include topics related to programming, costing, and scheduling projects	Lacks instructor resources, Does not cover plan reading or quantity takeoff, or estimating software	N.A.
DelPico W. (2015), Builder's Essentials: Plan Reading & Material Takeoff, John Wiley and Sons, ISBN 978-0-87629-348-5	Practical information on plan reading and material takeoff	Does not come with instructor resources and complete sets of plans, Does not come with example problems and exercises, Low quality images, Outdated	N.A.
Other Resources: Construction Estimating Code of Ethics (ASPE, 2018)			
CONE 312: Advanced Estimating			
Dagostino, Frank R. and Peterson, Steven J., Estimating in Building Construction, 9th Edition, Pearson Prentice Hall, 2015.	Comprehensive coverage of building construction cost estimation, contains rich instructor resources including example problems and a sample bidding project	Instructor resources does not include sample test questions.	Ch 10-19+ Real Estate Office Bidding Project
Peterson Steven J., Construction Estimating Using Excel, 3rd Edition, Pearson, 2018.	Comprehensive coverage, focus on practical excel skills for estimating, Extensive instructor resources, example problems, and test banks	Is more focused on Excel skills and includes less clear explanation for novice estimators and undergraduate students.	Example problems from across the textbook
Pratt, D. (2018). . J. Ross Publishing.	clear, straightforward language to describe the basic arithmetic of residential construction work, along with logical explanations of how to prepare takeoffs	Lacks instructor resources such as test banks, slides, and additional problems	N.A.
CONE 320 Engineering Materials and Methods (& Lab)			

Allen, Edward, and Joseph Iano. Fundamentals of Building Construction: Materials and Methods. 2013.	Good Instructor resources, 6th edition provided great assignments and solutions, as well as ppt presentations	7th edition no longer has the same instructor resources, cost is highly variable for students	Textbook adopted fully with supplemental site visits and labs
Several labs (Soils, concrete, steel, timber, IR camera), with lab procedures established by the instructor guided by ASTM. 4-5 targeted site visits to a varied level of completion projects of a steel, concrete, masonry, timber (ALL CO and topics)			
CONE 330 Quality Management and Labor Relations			
Howarth, Tim, and David Greenwood. Construction quality management: Principles and practice. Routledge, 2017	Well-structured and easy-to-follow	Lacks practical guidance on how to apply quality management principles in real world, lacks problems and exercises, Lacks instructor resources	Select topics used from across the textbook
Evans, J. R., & Lindsay, W. M. (2013). Managing for quality and performance excellence. Cengage Learning.	Comprehensive coverage of quality management principles, practices, and tools, Real-world examples and case studies	Not focused on construction industry, relatively high price, the book's language may be too generic for students with a background in construction	Select topics used from across the textbook
Rumane, Abdul Razzak. Quality management in construction projects. 2nd Edition, CRC Press, 2016	Emphasis on the importance of quality management in the construction industry, In-depth coverage of technical aspects of construction quality management, such as inspection, testing, and compliance	Lack of practical examples and exercises for students, Lack of instructor resources, the book's technical focus does not provide enough guidance on leadership, strategic planning, and customer satisfaction	Select topics used from across the textbook
Frank, George C. Construction quality: do it right or pay the price. Prentice Hall, 2011	Practical guidance on implementing quality management practices in construction projects, with clear examples and case studies, Focused on contractual, legal, and economic consequences of poor-quality management	Limited coverage of technical aspects of construction quality management, Lack of practical examples and exercises for students, Lack of instructor resources,	Select topics used from across the textbook
CONE 340 Structural Analysis and Design			
Ambrose, James, and Patrick Tripeny. Building Structures. 2011.	Instructor Guide (not evaluated)	Not engineering science based (requirement)	None

Underwood, James R., and Michele Chiuini. *Structural Design: A Practical Guide for Architects*. 2007. *Bowker*, https://doi.org/10.1604/9780471789048.	Instructor Guide (not evaluated)	Not engineering science based (requirement)	None
Aghayere, Abi, and George F. Limbrunner. Reinforced Concrete Design (8th ed). 2014.	Instructor guide with worked assignment problems	> $200, based on a later ACI code	Assignments inspired by provided problems (but were updated for code)
Segui, William T. *Steel Design*. 2018.	not evaluated	>$250, too advanced	
McCormac, Jack C. *Structural Analysis: A Classical and Matrix Approach*. Wiley, 1997. *Bowker*, https://doi.org/10.1604/9780471364115.		too advanced	
ASCE Minimum Design Loads for Buildings and Structures (excerpts)			adopted excerpts as resources
ASCE Minimum Design Loads for Buildings and Structures (excerpts)			adopted excerpts as resources
AISC Steel Construction Manual	student pricing		adopted
ACI 318 Building Code requirements for Structural Concrete (excerpts)			adopted excerpts as resources
Other Resources: 2-3 targeted site visits to a steel fabricator, concrete construction project, and/or parking deck (ALL CO and topics)			
CONE 350 Commercial Construction and Engineering Equipment			
Peurifoy, R., Schexnayder, C., Shapira, A., Schmitt, R. Construction Planning, Equipment, and Methods, 9th Edition, McGraw-Hill.	Comprehensive coverage of construction equipment, planning, and methods, focus on practical application in construction projects, Clear and concise language, Useful learning resources	Limited coverage of emerging trends and technologies, some topics are outdated	Adopted as main textbook for the course
Nichols, H.L., Jr. & Day, D.A., P.E., Moving the Earth, 6th Edition, McGraw-Hill, (ISBN: 978-0071502672)	Emphasis on safety and efficiency in earthmoving operations, with clear guidelines and recommendations, Clear and concise language	Limited coverage of earthmoving equipment and techniques, Limited coverage of emerging trends and technologies	N.A.

Gransberg, D., Popescu, C., Ryan, R., Construction Equipment Management for Engineers, Estimators, and Owners, CRC Press	Focused on management of construction equipment, Practical examples	Limited technical information, Outdated, Price	N.A.
Schaufelberger, J., Construction Equipment Management, 1st Edition, Prentice Hall	Industry experience, clear and concise,	Lack of learning resources, Limited focus	N.A.
Construction Equipment and Methods: Planning, Innovation, Safety, 1st Edition, Wiley	Up-to-date information, Real-world examples	Limited depth of information, hard to understand technical language	N.A.
CONE 360 Soils and Foundations (& Lab)			
Liu, Cheng, and Jack Evett. Soils and Foundations. 2013.	Instructor guide with worked assignment problems, good examples		Adopted fully with supplemental labs
Dickenson, S. E., et al. Soils in Construction. 2003. Bowker, https://doi.org/10.1604/9780130489173.		Too advanced, not enough examples	
Das, Braja M. Principles of Geotechnical Engineering. 2018.	Instructor guide with worked assignment problems, newer editions have even better online resources	>$200 for all resources	would have also been a good text
Gunaratne, Manjriker, editor. The Foundation Engineering Handbook. 2013.		Assumes a soils mechanics class has been taken prior, too advanced	
Other Resources: Several labs (Grain Size Distribution including hydrometer, Atterberg limits, compaction, permeability), with lab procedures written by the instructor following ASTM			
CONE 410 Project Scheduling			
Newitt, Jay S. Construction scheduling: principles and practices. Second Edition, Pearson Higher Ed, 2011	Comprehensive coverage, Real-world examples, Clear and concise language	Limited learning and instructor resources	Adopted as main textbook
Hinze, Jimmie W. Construction planning and scheduling. Fourth Edition, Pearson Higher Ed, 2011	Comprehensive coverage, rich in examples and learning resources	Technical language difficult to understand for undergrad students	Example problems used to supplement the other textbook
CONE 415 Project Management and Engineering Administration			
Gould, Frederick E., and Nancy Eleanor Joyce. Construction project management. Fourth Edition, Prentice Hall, 2009.	Comprehensive coverage, clear and concise language	Limited learning resources for students and instructors, some outdated information	Chapters 1-8, 11-12

Fisk, Edward R., and Wayne D. Reynolds. Construction project administration. Tenth Edition, Pearson Higher Ed, 2011.	Updated information, Real-world examples	Limited focus, Complexity, limited learning and instructor resources	Chapters 10 and 16
Walesh, Stuart G. Engineering your future: The professional practice of engineering. Third Edition, J. Wiley & Sons, 2012.	Provides a good overview of engineering projects and role of different stakeholders. The accounting section explains what is required for a PM to understand project financial reports.	The focus is more on Eng. Consulting firms rather than construction sector.	Chapter 10- Accounting
Kerzner, Harold. "Project Management Case Studies. Third Edition, John Willey & Sons." (2005)	Includes real world case studies with the description of the project and each case has a few questions to engage students in the class discussions,	Takes lots of time to cover each case, and the price is high to make it required.	Some of the case studies used for class discussions
CONE 440 Construction Methods and Temporary Structural Design			
Ratay, Robert. Temporary Structures in Construction, Third Edition. 2012.	Good variety of topics covered	Too advanced, not enough examples, no instructor guide	Ch 3 construction and environmental loads
Souder, Christopher. Temporary Structure Design. 2014.	Variety of examples (just too simplified)	Not engineering science based (requirement), too few types of temp structures covered, no instructor guide	
Other Resources: (6-10) targeted construction site visits with the specialty sub-contractor after learning about the temporary structure in class; Various manufacturers handbooks, online manufacturer material			
CONE 450 Facilities Operations and Maintenance (BIM)			
The Facility Management Handbook, Fourth Edition, Kathy O. Roper and Richard P. Payant, 2014, ISBN-13: 978-0-8144-3215-0	Includes the fundamental information about Facility Operation and Management and its process	Very expensive for the limited use it has for students. Provides very detailed information about FM which was beyond scope of the course.	Sections 1, 2, 4, 7 and 8.

BIM Handbook, 3rd Edition, Chuck Eastman, Paul Teicholz, Rafael Sacks, Kathleen Liston, 2018, ISBN- 13: 978-1119287537	Provides a robust foundation about BIM, useful for students, not only in this course but also for their future careers	Very lengthy chapters, covers other topics which are out of scope of this course	Chapters 1, 3, 6 and 10.
Increasing Autodesk Revit Productivity for BIM Projects: A practical guide to using Revit workflows to improve productivity and efficiency in BIM project. Fabio Roberti, Decio Ferreira ISBN-13 : 978-1800566804 (Not adopted)	Directly related to Autodesk Revit which is the software used in this course	Very technical and deep knowledge required to understand some chapters and would not fit into the scope of this course	Not adopted
Other Resources: Knowledge Network Forum for Autodesk users and Autodesk tutorial links			
CONE 460 Mechanical and Electrical Systems			
Mechanical and Electrical Systems in Architectural, Engineering, and Construction. Fifth Edition, 2010, Joseph B. Wujek and Frank R. Dagostino, Prentice Hall, ISBN-13: 978-0-13-500004-5	The flow of Mechanical and Electrical Systems in Buildings; The number of example problems and end of chapter problems are extensive.	Some of the pictures are outdated, but still relevant to what they are showing.	The textbook aligned with the developed course objectives.
Mechanical and Electrical Systems in Buildings, Sixth Edition, 2019, Richard R. Janis and William K.Y. Tao, Pearson, ISBN-13: 978-0-13-470118-9	The additional materials available from the authors/Pearson to support pictures/tables/problem solutions for lesson development were key in the decision. The updated version in 2019 further strengthened the case to use it.		
CONE 470 Practicum in Construction Engineering			
No Text book is used for this service course. The students were provided with the safety guidelines and other required texts.			