

Sustainability Content in Construction Curricula

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ABSTRACT

Sustainability concepts and sustainable building practices are integral to construction science, management, and technology degree programs and curricula. The current industry practice often requires projects to consider and implement sustainable approaches and materials. Accreditation agencies, including ABET and ACCE, include sustainable construction or sustainability concepts in their required student learning objectives, emphasizing the subjects' importance in professional practice. There are different approaches to delivering sustainability content in a construction curriculum, including required or elective stand-alone courses, delivering the concepts as part of another construction course, or requiring a non-construction sustainability course from another discipline. This paper reviews the sustainability requirements of construction programs in Texas. As part of this study, the catalog requirements of construction degree programs are examined to determine how sustainability content is delivered. The data is presented using rubrics and numbering system designations, highlighting patterns and trends. A discussion of the differences among the construction science, management, and technology degree designations is included to highlight the accreditation and organizational differences.

INTRODUCTION AND BACKGROUND

Sustainability is emerging as a critical component of design and construction practice. The increasing complexity of projects, technological developments, and evolving professional expectations adds to the challenges of implementation. As a multi-disciplinary and application-oriented discipline, construction has a unique place in this discussion. As a relatively young academic discipline, construction programs show differences in their "origin" stories, and their curricula are often influenced by their development and history, where the programs that originated from architecture or engineering often carry a design-heavy structure, while programs with industrial technology backgrounds include more hands-on applications [1, 2]. Historically, the industry's expectations and influence also played an essential role in shaping educational content, including technical and managerial skills [3-6]. The unique nature of construction practice shapes the educational approaches, which often influence the educational approaches and curriculum development [7-9].

Construction is recognized by multiple accreditation agencies, including the American Council for Construction Education (ACCE) [10] and ABET (under engineering, technology, and applied science categories) [11]. ACCE addresses the sustainability content with a required learning outcome: "SLO 15 - Understand the basic principles of sustainable construction" [12]. ABET student learning outcomes address sustainability in a broader context with "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" and "an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering

solutions in global, economic, environmental, and societal contexts”[13, 14]. Since the required learning outcomes offer flexibility in delivery, different educational approaches have been used to deliver sustainability content, including standalone classes (required or elective) [15-17] and sustainability modules/components in other classes [18-20]. There are funding and grant opportunities, such as the One Planet Mini Grant Program, which encourages the development of structured and core learning outcomes [21]. A micro credentialing program has recently been established, adding to the various teaching and learning opportunities [22]. The literature shows multiple studies examining sustainability as a transversal content rather than a limited focus on subject-specific dedicated courses [23-25]. The majority of these programs and examples are in the design and engineering realm. The sustainability discussion in construction often focuses on materials and specific systems.

To establish a better understanding of the current educational approaches in construction higher education, the natural starting point is a review of the sustainability courses in construction curricula. This paper reviews the sustainability requirements of construction programs in Texas. As part of this study, the catalog requirements of construction degree programs are examined to determine how sustainability content is delivered. The data is presented using rubrics and the common numbering system, highlighting patterns and trends. A discussion of the differences among the construction science, management, and technology degree designations is included to highlight the accreditation and organizational differences.

CLASSIFICATION CODES AND CONSTRUCTION PROGRAM DATA

Texas utilizes the National Center for Education Statistics’ Classification of Instructional Programs (CIP) codes to classify programs (identification of the program type) [26] and categorize each course offered by the program [27]. Texas also maintains a database of higher education programs through the Texas Higher Education Coordinating Board (THECB) [27]. The THECB database was searched for the “construction” keyword in “Community Colleges,” “State Colleges,” “Technical Colleges,” “Public Universities,” “Independent Colleges and Universities of Texas (ICUT),” “For-Profit Colleges & Universities Authorized by Certificate,” and “Other Institutions Authorized by Certificate” categories. Table 1 shows the results of the keyword program search for the bachelor-level [28].

A total of 21 bachelor-level programs are listed in Table 1. The distribution shows 48% in technology (CIP 15), 33% in engineering (CIP 14), 14% in business (CIP 52), and 5% in construction trades (CIP 46). Table 1 also shows a variety of program names, including “management,” “science,” “engineering,” “engineering technology,” or combinations. The “construction management” program title may be linked to technology (CIP 15), engineering (CIP 14), or business (CIP 52) codes, noting the unique nature of construction higher education offerings. Texas Tech University, the University of Texas at Tyler, University of Houston, and University of North Texas list multiple construction degree programs housed under different academic units. Although the program title does not include the word “construction,” Texas State University’s Concrete Industry Management Program is also included in the search results.

Table 1. Construction Program Inventory at Bachelor Level [28]

INSTITUTION	PROGRAM NAME	CIP CODE (2-DIGIT)
Collin County Community College District	Construction Management	52 – Business
East Texas A&M University	Construction Engineering	14 – Engineering
Lamar University	Construction Management	14 – Engineering
Prairie View A&M University	Construction Science	15 – Technology
Sam Houston State University	Construction Management	15 – Technology
Stephen F. Austin State University	Construction Management	52 – Business
Tarleton State University	Construction Science and Management	15 – Technology
Texas A&M University	Construction Science	15 – Technology
Texas State University	Concrete Industry Management	15 – Technology
Texas State University	Construction Science and Management	15 – Technology
Texas Tech University	Construction Engineering	14 – Engineering
Texas Tech University	Construction Engineering Technology	15 – Technology
The University of Texas at Arlington	Construction Management	14 – Engineering
The University of Texas at El Paso	Construction Engineering and Management	14 – Engineering
The University of Texas at San Antonio	Construction Science and Management	46 – Construction Trades
The University of Texas at Tyler	Construction Engineering	14 – Engineering
The University of Texas at Tyler	Construction Management	52 – Business
University of Houston	Construction Engineering	14 – Engineering
University of Houston	Construction Management	15 – Technology
University of North Texas	Construction Engineering Technology	15 – Technology
University of North Texas	Construction Management	15 – Technology

SUSTAINABILITY COURSE REQUIREMENTS AND OFFERINGS

The latest online academic catalogs are reviewed for each program in Table 1 to identify the MEP systems course requirements associated with the degrees. Table 2 presents the results of the catalog review, including the professional accreditation and degree names. Table 3 includes the course descriptions as noted in the university catalogs. Texas Tech University’s Construction Engineering Technology Program is a newly developed (revived) program that does not appear in the university catalog and has no degree or curriculum requirements. Tables 2 and 3 include information for the remaining 20 construction programs.

As listed in Table 2, 14 out of 20 (70%) programs have a course with a sustainability designation. These include required courses with “sustainable” or “sustainability” in the title/content, elective courses with sustainability in the title/content, and required courses that include sustainability content in the course description but do not have “sustainability” in the title.

Table 2. Sustainability Course Requirements for Four-Year Construction Programs

INSTITUTION	PROFESSIONAL ACCREDITATION AND DEGREE NAME	SUSTAINABILITY COURSE REQUIREMENT
Collin County Community College District	ACCE Candidate Program - BAS in Construction Management	ABSC 3410 - Applied Building Science
East Texas A&M University	ABET Engineering - BS in Construction Engineering	-
Lamar University	ACCE - BS in Construction Management	CMGT 4380 - Sustainable Built Environment and Society ****
Prairie View A&M University	ACCE - BS in Construction Science	ARCH 3346 - Sustainable Building
Sam Houston State University	ABET Applied and Natural Science - BS in Construction Management	-
Stephen F. Austin State University	ACCE Candidate Program - BS Construction Management	INDS 4310 - Sustainable Issues
Tarleton State University	ACCE Candidate Program - BS in Construction Science and Management	-
Texas A&M University	ACCE - BS in Construction Science	COSC 303 - High Performance Residential Building **** COSC 411 - Seminar in Design and Construction Executive Leadership ****
Texas State University	ATMAE – BS in Concrete Industry Management	CIM 4360 - Sustainability Management for the Concrete Industry
Texas State University	ACCE - BS in Construction Science and Management	CSM 4313 - Architecture II - Technology in Construction
Texas Tech University	ABET Engineering - BS in Construction Engineering	CONE 3304 - Sustainable Building Design and Construction
The University of Texas at Arlington	ABET Applied and Natural Science - BS in Construction Management	CM 4357 - Sustainable Construction Practices
The University of Texas at El Paso	ABET Engineering/Applied and Natural Science - BS in Construction Engineering and Management	CE 1301 - Civil Engineering Fundamentals
The University of Texas at San Antonio	ACCE - BS in Construction Science and Management	CSM 4613 - Sustainable Building Practice
The University of Texas at Tyler	NA (New Program) - BS in Construction Engineering	CMGT 4325 - Sustainable Construction
The University of Texas at Tyler	ABET Applied and Natural Science - BS in Construction Management	CMGT 4325 - Sustainable Construction
University of Houston	ABET Engineering - BS in Construction Engineering	CNE 4326 - Smart and Sustainable Urban Infrastructure
University of Houston	ACCE - BS in Construction Management	-
University of North Texas	ABET Technology - BSET in Construction Engineering Technology	-
University of North Texas	ACCE - BS in Construction Management	-

**** Designated Elective

Table 3. Catalog Descriptions of the Sustainability Courses

INSTITUTION	SUSTAINABILITY COURSE REQUIREMENT	CATALOG DESCRIPTION
Collin County Community College District	ABSC 3410 - Applied Building Science	A study of the integration of factors that cause a building to be a working system, including; engineering, architecture, materials, climate and environmental factors. The purpose of building science is to provide predictive capability to optimize the performance and sustainability of a building, understand or prevent building failures, and guide the design and use of new materials, techniques, and technologies.
Lamar University	CMGT 4380 - Sustainable Built Environment and Society ****	Introduction to the concept of sustainability and understanding of its impact on the environment and society. Covers fundamentals of sustainable technologies and practices for development and operation of built environment, including buildings and infrastructure. It addresses energy-efficient design and construction, as well as sustainable use of natural resources and renewable energy. It also introduces the USGBC LEED Certificate Program and economic analysis of sustainable practices.
Prairie View A&M University	ARCH 3346 - Sustainable Building	Issues facing the design and construction industries in creating and maintaining high performance green buildings. Sustainable building projects will be analyzed, green building rating systems of USGBC's LEED system and the DOE's Energy Star program will be studied and researched and presentation of benchmark sustainable case study projects will be accomplished.
Stephen F. Austin State University	INDS 4310 - Sustainable Issues	In-depth study of environmental impact from construction components and materials used in building systems. Application of codes utilized in interiors.
Texas A&M University	COSC 303 - High Performance Residential Building ****	Exploration into the concepts of homebuilding operations using green building methods, tools to reach consumers, organizational and operational theories and market driven green building solutions; alignment with ICC 700 National Green Building Standard; operations of publicly traded and private production homebuilders and best practices; application for the professional designation of Certified Green Professional (CGP) given by the National Association of Home Builders (NAHB) upon completion.
Texas A&M University	COSC 411 - Seminar in Design and Construction Executive Leadership ****	Promotes an understanding of leadership and builds the capacity to understand and meet the challenges involved in developing and leading ethical and sustainable organizations in today's economy; examination of theory, conceptualizing, reflection and application; share experiences in everyday life and learn to predict outcomes based on theoretical models.

INSTITUTION	SUSTAINABILITY COURSE REQUIREMENT	CATALOG DESCRIPTION
Texas State University	CIM 4360 - Sustainability Management for the Concrete Industry	This course explores the principles and practices of sustainability management tailored specifically for the concrete industry. With the growing emphasis on environmental responsibility and resource efficiency, this course equips students with the knowledge and skills necessary to navigate the complex landscape of sustainability within the concrete sector.
Texas State University	CSM 4313 - Architecture II - Technology in Construction	This course prepares students to create individual and group commercial projects which include plans, elevations, sections, details, and 3D drawings utilizing 3D building information modeling (BIM) and other current technologies used in the industry. Structural, mechanical, electrical, plumbing, accessibility, and sustainable building issues are discussed
Texas Tech University	CONE 3304 - Sustainable Building Design and Construction	Techniques and methods of sustainable construction and design. Addresses the importance of team effort among owners, developers, architects, engineers, and contractors.
The University of Texas at Arlington	CM 4357 - Sustainable Construction Practices	Ethics and application of environmental sustainability practice in building construction. Introduction to U.S. Green Building Council LEED program standards, methods, and procedures as applied to construction documents interpretation and construction.
The University of Texas at El Paso	CE 1301 - Civil Engineering Fundamentals	Principles used in the analysis, design, construction and maintenance of civil engineering infrastructure systems. Concepts of sustainability and environmental impact, civil engineering as a profession and expectations of ethical behavior.
The University of Texas at San Antonio	CSM 4613 - Sustainable Building Practice	Ethics and application of environmental sustainability practice in building construction. Introduction to U.S. Green Building Council LEED program standards, methods, and procedures as applied to construction documents interpretation and construction.
The University of Texas at Tyler	CMGT 4325 - Sustainable Construction	Exploration of cutting edge technology used in sustainable construction of residential and commercial structures. Introduction to the requirements for LEED, Energy Star and the NAHB Green Program rating systems used for evaluating sustainability
University of Houston	CNE 4326 - Smart and Sustainable Urban Infrastructure	Students learn about smart cities within the context of management of urban infrastructures. Students are equipped with the knowledge and skills to help build the sustainable smart cities of the future through digital technologies, big data, smart mobility, renewable energy, low-energy buildings and neighborhoods, and sustainable urban best practices.

**** Designated Elective

The following observations can be noted from Tables 2 and 3:

- The course requirements range from 1 to 3 credit hours.
- 12 out of 14 courses (86%) are required courses, while two programs list sustainability course content in designated elective courses.
- 71% of the courses are at the 400/4000 level, while 21% are at the 300/3000 level. One required course (7%) is at the introductory 100/1000 level. 93% of the courses are offered at the upper level of the construction programs.
- 29% of the courses include sustainability content as a part of other construction classes. Building construction classes with content on materials and methods appear to be the most common course selection for the sustainability discussion.
- 43% percent of the courses specifically refer to the United States Green Building Council's Leadership in Energy and Environmental Design (LEED) Program. An additional 21% refer to other programs, including the National Association of Home Builders' (NAHB) Green Program and the Environmental Protection Agency's Energy Star Program.
- There are examples of industry/sector-specific course offerings, including the Texas State University's "Sustainability Management for the Concrete Industry" and Texas A&M University's "High Performance Residential Building."
- The University of Texas at El Paso's "Civil Engineering Fundamentals" course appears to be the only lower-level introductory course that contains sustainability in the course description.

Overall, the programs accredited by ACCE and ABET (Engineering, Technology, and Applied and Natural Science) show similar trends in course requirements and content.

SUMMARY AND CONCLUSIONS

This paper aims to provide an organized review of the sustainability course requirements of the construction programs in Texas. The review shows the diversity of program names, program CIP designations, and individual course offerings, illustrating the multi-disciplinary and unique nature of construction education. Although the ACCE and ABET accreditation standards include specific references to sustainability, the accreditation process applies to the entire curriculum of a degree program. It is assessed mainly by the learning outcomes rather than the individual course offerings.

The information and data presented in this paper are collected from the publicly available university catalogs based on construction-related CIP designations. This is a limitation of the study, as the frequency of catalog updates and their implementation may directly affect the observations presented in this paper. Similarly, limited catalog descriptions do not provide an opportunity to review the delivery and assessment of the content or the emphasis on the course offerings.

As a part of the discussion, the following issues must be noted:

- 70% of the construction programs have a dedicated sustainability course in their curriculum. 86% of these courses are required, while 14% offers elective options. Since accreditation standards, such as ACCE student learning outcome 15, require sustainability, it is reasonable to assume that all programs include sustainability content in some form, including learning modules in other construction courses. Materials and methods courses offer a convenient platform for such modules, as the overall course content could seamlessly integrate sustainability discussions. As noted in their publicly available program assessment documents, one of the construction programs that does not have a dedicated sustainability course utilizes two materials and methods courses to assess sustainability outcomes.
- Two of the programs appear to utilize courses taught by non-construction programs as a part of their curriculum. For example, architecture and interior design course rubrics are listed in Tables 2 and 3 as required courses for the construction degree. Considering the influence of the historical development of construction programs and various organizational structures within the academic institutions, this is not a surprising observation.
- 43% of the courses refer specifically to the USGBC's LEED Program, while an additional 21% mention other programs, including the NAHB Green Program and Energy Star. It is also important to note that the words "certification" or "credential" are not mentioned in the course descriptions, although some of the course content may be used to prepare for these opportunities.
- None of the courses listed in Tables 2 and 3 has a specific laboratory component for the sustainability applications. There are examples of "project-based" courses in other engineering and science disciplines that include a laboratory component. However, design-oriented courses may offer a better environment for such applications.
- In the context of required sustainability courses, there is no significant difference between the construction engineering/technology programs and the construction management/science programs.
- Although the course descriptions and requirements outline the overall expectations in a particular topic and student learning outcome, the effective delivery of the topic is very much dependent on and influenced by the instructor's experience and expertise.

A limited curriculum and catalog review is not a perfect tool for detailing the status of construction education in a sustainability context; however, it provides insight into how the curricula and programs are structured. A broader topical content comparison may provide a further understanding of the programs.

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