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A Review and Comparison of Associated Schools of Construction (ASC) Capstone Course Content

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A capstone course is the apex of a bachelor's degree. It is an integrative course that embeds professional and business skills and it is based on the application of knowledge to real-world situations. Despite its importance, there is a lack of information about how construction programs organize their capstone offerings and what is included in these offerings. To this point, the present exploratory study surveys construction programs to determine basic course characteristics. To obtain this information, we reviewed 127 ASC-affiliated undergraduate programs in the United States to find that 112 programs had a capstone or capstone-related course. Most programs require only one capstone course, offered for a median of 3 credit hours. Through content analysis of course descriptions, the authors provide the main topics addressed by construction capstones. Main findings suggest oral communication and collaboration as main soft skills covered in capstones; project management, estimating, and scheduling as the top three technical content; and, simulation as the most frequent course format. Findings provide a comprehensive view of how capstones are being offered in construction undergraduate programs in the United States and can be helpful to construction programs' instructors and administrators looking to improve their students' capstone experiences.

Key Words: undergraduate education; capstone course; curriculum; course descriptions; construction management

Introduction

A capstone course is considered the apex of a major's coursework. Students are challenged to demonstrate the knowledge and competencies developed during their undergraduate program. It is often an integrative course, based on knowledge application, but also focusing on professional and business skills. Several disciplines offer capstone experiences – from liberal arts to engineering. Construction is not different and many programs include a capstone course during the senior year. However, in construction, work processes differ depending on the chosen delivery method. For example, the expectations of a construction professional in a design-bid-build arrangement are significantly different than in a design-build arrangement, in which you collaborate with designers from the start of the process. Additionally, the construction industry is a project-based industry, in which graduates collaborate with different teams during the course of a project to create a unique

structure. Therefore, the commercialization of a product developed during a student capstone experience and industry partnerships are limited for construction students. Additionally, given that the cost to actually build a building can be prohibitive, it is unclear how construction programs incorporate real-world challenges related to the construction phase in their courses.

To assist faculty of the Associated Schools of Construction (ASC), the authors have developed an exploratory study about capstone experiences in American construction programs guided by the following research question and sub-questions:

- What are the basic characteristics of construction capstone courses in the United States?
 - How are courses organized in the curriculum (number of courses and credit hours)?
 - Which topics are more frequently taught in this type of course?

Findings are relevant to provide a comprehensive view of how capstones are being offered in construction undergraduate programs in the United States. Additionally, our results can be helpful to construction programs' instructors and administrators looking to improve their students' capstone experiences.

Background Literature

Because capstone courses are not exclusive to construction education, the authors started by exploring literature outside of the construction domain. Then, the authors reviewed previous literature related to capstone courses specific to construction. These previous works comprise mainly of case studies that provide further information about how these integrative courses are utilized within the construction curriculum.

The concept of a capstone course

A capstone course is considered the culmination of a major's coursework (Durel, 1993). Often it is an integrative course, during which students are expected to apply technical knowledge, along with business and interpersonal skills (Hoffman, 2014). A capstone course is not exclusive of technical disciplines, being offered in liberal arts disciplines, such as sociology (Durel, 1993) and business (Sonner, 1999). Since the 1990s, several North-American engineering programs include a capstone course in their plan of studies (McKenzie, Trevisan, Davies & Beyerlein, 2002; Todd, Magleby, Sorensen, Swan & Anthony, 1995). Many engineering capstone courses are project-driven, focusing on the design of a product, though depending on the area, the capstone may focus on research (Todd et al., 1995). Also in engineering, several programs have industry-sponsored projects – something noted by Todd et al. (1995) "not only because of the practical experience gained by the students, but also that it builds the confidence of industry in engineering education" (p. 173).

Hoffman (2014) argues that there should be five experiences in a capstone course: focus on "real world" issues and challenges, integration of technical and soft skills, teamwork; project management techniques, and use of oral and written communication. However, due to the specificities of the construction discipline, some of the structure proposed by Hoffman (2014) is not feasible, such as development, fabrication, and testing, though simulation techniques could be used.

Capstone experiences in construction education

There are several published conference proceedings on capstones for construction education. Many

of them stress the use of teamwork, industry participation, integration of topics, soft skills, and simulations (Arnold, 2010; Cecere, 2002; Jenkins et al., 2002; Luo & Hyatt, 2020; McIntyre, 2002; Mills & Beliveau, 1999; Sharma & Sriraman, 2012)

One of the first mentions to capstones describes a vertical integration experience at Virginia Tech (Mills & Beliveau, 1999). In their experience, Mills and Beliveau (1999) report the integration of lower-level courses to emphasize leadership and people management skills in senior students. The simulation works with sophomore and junior students acting as subcontractors to senior students during a project simulation throughout a semester.

Teamwork was frequently mentioned in capstone-related previous literature (Cecere, 2002; Jenkins et al., 2002; McIntyre, 2002; Sharma & Sriraman, 2012), however, the reported size of student teams varied. Sometimes groups consisted of students from different Architecture, Engineering, and Construction (AEC) disciplines, as outlined at North Dakota State University (McIntyre, 2002).

In terms of project scope, most capstone courses use a simulation approach. This can sometimes mean answering a request for proposals (Cecere, 2002; Sharma & Sriraman, 2012), a request for qualifications (Jones & Mezo, 2014), a contract (Jenkins et al., 2002), or a problem posed to students (McIntyre, 2002).

Duration of courses varied from one semester (Jenkins et al., 2002; Jones & Mezo, 2014; McIntyre, 2002) to two semesters (Cecere, 2002; Luo & Hyatt, 2020). In some cases, programs have different commitments for capstones in each semester, such as the case presented by Cecere (2002), in which a two-semester capstone is divided into one preparation semester (1 credit hour course) and one development semester (3 credit hour course).

Soft skills, such as teamwork, leadership, and communications are often mentioned as integrated into the capstone and real-world situations. Deliverables typically include written reports and an oral presentation. For examples, see Cecere (2002), Jenkins et al. (2002), Sharma and Sriraman (2012), and Jones and Mezo (2014). However, while some programs choose to emphasize company management skills, such as marketing (for example see Cecere, 2002), others are more interested in construction project management skills (for example, see Jenkins et al., 2002).

Industry involvement is high in this type of course, ranging from guest lectures and judging (Jenkins et al., 2002) to mentorship and coaching opportunities, such as in Sharma and Sriraman (2012) and Jones and Mezo (2014). Still focused on industry engagement, but using a different approach, Arnold (2010) presents a capstone focused on students' review of an ongoing commercial, residential, or civil / infrastructure project. In their case, the capstone course is delivered in two semesters, and students are required to provide their own version of some technical documents for construction, as well as a comparative analysis with the real project. Industry participation is essential for this mode of delivery and can sometimes be a challenge, given that projects can greatly vary in size and complexity.

Most recently, Lee and Kim (2020) provide a framework for the development of a capstone course. To do this, they have reviewed current construction capstone syllabi and course descriptions from eight institutions, surveyed industry professionals, organized course topics and learning outcomes. They conclude with their recommendations on how to deliver the capstone course at Central Connecticut State University, which includes using industry coaches and student teams answering a request for proposals.

Methodology

The present study used a review of existing data as the methodological to answer the posed research questions. Our population is 4-year undergraduate programs in construction in the United States. Our sample population are programs affiliated with the Associated Schools of Construction (ASC) regions 1 through 7, that are located in the United States, and have a program that includes ‘construction’ or ‘building’ in the major name. Construction concentrations within other courses, such as civil engineering, were also not considered in this study. This resulted in the analysis of 127 undergraduate programs of 121 educational institutions being included in the analyzed sample.

The most recent (fall 2021) program of studies and course descriptions were obtained online in each of the programs’ institutions and tabulated for analysis in Excel. Information collected included institution name, program name, course or courses names and prefixes, ideal semester (when available), and course description. Descriptive statistics on the frequency of programs with capstone courses, the number of programs with more than one capstone course, and average credits in a capstone course were collected.

Finally, course descriptions were analyzed in two rounds using a qualitative approach. In the present case, the qualitative approach is particularly helpful to allow for comparisons between courses and identify themes that are common across capstone courses (Patton, 2014). The first utilized descriptive coding to summarize the information contained in course descriptions. Then, a thematic analysis was performed on the initial first-round codes, following the recommendation of Saldaña (2021). Two of the authors coded the dataset, and all discrepancies were resolved using a consensus approach. Results from the thematic analysis include the frequency of themes found on the data as well as a brief explanation of the major themes found in course descriptions.

Results

Construction and construction-related programs came from 45 unique American states. Some states had more programs and academic institutions reviewed than others, such as California and Texas, each with 10 institutions surveyed for the present research. The states of Hawaii, Maine, Maryland, New Jersey, South Dakota, and the District of Columbia did not have institutions surveyed in the present research. We also note that 100 of the 127 programs surveyed were named “construction management” or included both the words “construction” and “management” in their names.

Of the 127 programs surveyed, only 15 programs did not have any course that could be identified as capstone by the researchers. Six programs had courses with descriptions that could not be directly identified as a capstone; but after thorough consideration, the researchers deemed them to include at least one course compatible with a capstone course, and they were included in the present research. And 106 programs had courses that could be clearly identified as having some sort of capstone experience.

A total of 138 courses were identified as being capstones. In the vast majority of programs (n=95), only one capstone course was required of students; in fourteen programs, two capstone courses were required; and only in three programs, three courses were required. Additionally, three institutions offered more than one option that could be considered a capstone, among them, Texas A&M offered 5 different capstone course options. In terms of credit hours, the identified capstones ranged from 1 to 6 credit hours (note that these include quarter-based courses), with a median of 3 credit hours.

Figure 1 summarizes the process of identifying programs with capstone courses, the number of courses per program, and the range and median credit hours for capstone courses identified in the present research.

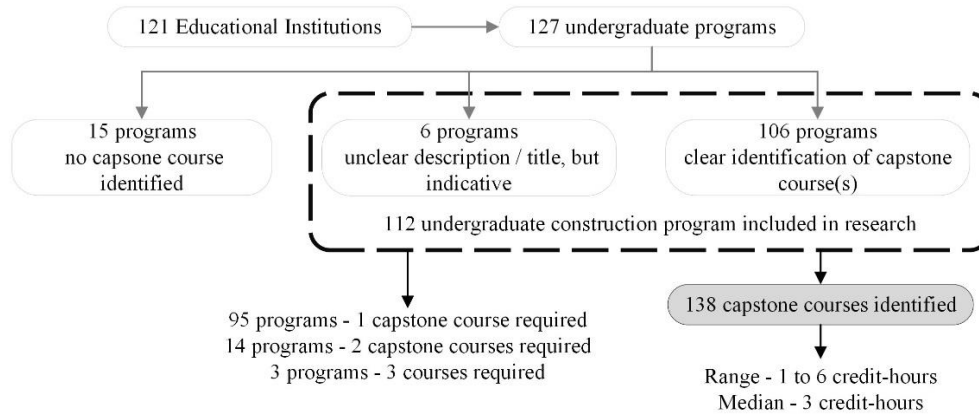


Figure 1. Summary of surveyed programs and identified courses

Additionally, the authors performed a qualitative analysis of course titles and descriptions. For course descriptions, 78 of the 138 courses included the word "capstone" in their course titles, followed by 30 courses named "Senior Design," "Senior Project" or similarly, 21 included titles that related to construction or project management, three mentioned the integration of project, and design and construction. Six courses included names that differed from the others analyzed, and included general titles (such as "senior seminar"), or related to specific sectors (such as commercial, capital projects, or residential), but did not mention management or capstone, and one mentioned a thesis.

Five emerging themes were generated based on the analysis of the course descriptions: process, assessment, technical content, soft skills, and course format. Explanation and further analysis of each code are included in the following paragraphs.

The *integration* code captures the format of the course. The authors were mainly interested in the integrative nature of the course. Therefore, subnodes were created for explicit and implicit mentions to integration. If a course description included the word "integrate," or a similarly stemmed word, it was coded as "explicit integration". And a course description was coded as "implicit integration" if a course mentioned three or more technical aspects (such as scheduling, estimating, and cost control) or if it mentioned the use of previous knowledge, such as "Utilization of student's previous coursework to creatively..." Courses that did not include any of the two were coded as "unclear integration." A course could not have more than one integration subnode. As a result, most courses were deemed to have an implicit integration element (n=90), while the number of courses that clearly mentioned integration was only 26. Few courses (n=22) were identified as having an unclear integration component, meaning some course descriptions were vague to describe how the capstone integrates previous content, such as the following description "Application of team design concepts to the capstone project." More information in the description could help authors to understand how contents are integrated into capstone courses.

The code *assessment* was created to capture how students were assessed in the courses. It is noted by the authors that the descriptions for 85 courses did not have a clear reference to assessment methods. The 53 descriptions that did mention assessment aspects, were then further analyzed on types of

assessment. One course description could have more than one type of assessment. Of those 53 courses, the majority (n=45) included an oral presentation, while 28 include a specific mention of written reports or documents. It was also interesting to note that 18 courses clearly mentioned industry participation in oral presentations or in evaluating students' work.

Following, the authors analyzed mentions of *technical content* in course descriptions. Similarly to assessment, not all courses included mentions to technical contents (n=97). One course description could have more than one technical content. The subnodes help to understand which technical topics are being integrated into construction capstones and results are presented in Table 1. As expected, technical topics mainly include project management procedures, estimating, and scheduling. Interestingly, the fourth topic mentioned is design, and further investigation could explore what type of design are construction students performing.

Table 1

Technical content embedded in course descriptions

Rank	Content	Frequency (n=97)	Rank	Content	Frequency (n=97)
1	Project Management	72	7	Documentation	15
2	Estimating	58	8	Bidding	12
3	Scheduling	56	8	Plans and Specifications	12
4	Design	27	9	Cost Control	11
5	Safety	21		Others ¹	43
6	Contracts	17			

¹ includes sustainability, quality assurance and control, site logistics, company management, risk management, financing and accounting, closeout procedures, computer applications, legal and insurance, and building systems

Mentions to the use of *soft skills* in the courses were also analyzed as a node. Because capstones usually integrate professional and social skills, such as communications, subnodes were created to evaluate which soft skills are being integrated into capstone courses. As expected, several courses (85 out of 138) had a mention to one of the following soft skills: oral communication (n=51), teamwork and collaboration (n=43), written communication (n=30), communication skills in general (not specifying if written or oral) (n=12), leadership (n=10), ethics (n=9) and networking (n=1). Course description could have more than one soft skill subnode and Table 2 presents the findings for this subnode.

Table 2

Soft skills embedded in course descriptions

Rank	Soft Skill	Frequency (n=85)
1	Oral Communication	51
2	Teamwork and collaboration	43
3	Written communication	30
4	Communication skills in general	12
5	Leadership	10
6	Ethics	9
7	Networking	1

Finally, a code related to *the course format* was created. This node captures how the course is taught, and subnodes include case studies, simulations, industry sponsorship, competitions, or third-party exam. Again, some courses (n=39) were not coded in *course format* because they did not have a clear mention of instructional strategies used for teaching, such as the ones previously mentioned. Most of the courses only had one specified format, but 19 of them could be identified with two different formats. Of the 99 courses descriptions that contained information that suggested the format of the course, the overwhelming majority (n=89) indicate they use a simulation approach. Industry sponsorship was also mentioned in 13 course descriptions. In this case, industry sponsorship was considered different than just industry review but also included participating during the course by providing construction scenarios or projects. Five courses mentioned the use of competitions, such as participating in the Associated General Contractors (AGC) competitions. Four courses mentioned the use of case studies, and one course mentioned a seminar format. Though not directly associated with course format, six course descriptions mentioned requiring students to take a third-party certification such as the Associate Construction (AC) exam, from the American Institute of Contractors (AIC) and were included in this subnode because it may guide decisions related to course format. Table 3 presents the results.

Table 3

Capstone course format

Rank	Soft Skill	Frequency (n=99)
1	Simulation	89
2	Industry sponsorship	13
3	Third-party exams	6
4	Competitions	5
5	Case studies	4
6	Seminar	1

Discussion

Our results indicate that most of the ASC-affiliated construction programs have a capstone (or capstone similar) course in their plan of study, which is aligned with information from Todd et al. (1995) for engineering programs. Opposed to engineering (McKenzie et al., 2004), most construction programs have only one course dedicated to the capstone.

Additionally, communication (including oral, written, and general) was mentioned in several courses, along with teamwork and collaboration, project management, and technical content. These areas were identified by Hoffman (2014) as key experiences for capstone courses. Echoing previous literature on construction capstone education, many mentioned grouping students in teams (Cecere, 2002; Jenkins et al., 2002; McIntyre, 2002; Sharma & Sriraman, 2012).

Engagement with industry varied in course descriptions. There were multiple references to industry presentations, which is in accordance with previous research reviewed (Jenkins et al., 2002). Fewer course descriptions mentioned industry sponsorship, which can include a closer partnership between capstone instructors and industry. This partnership was highlighted in previous research to provide opportunities for mentorship and coaching (Sharma & Sriraman, 2012; Jones & Mezo). Finally, similarly to previous case studies published in construction capstone undergraduate education (see

Cecere, 2002; Jenkins et al., 2002; Jones & Mezo, 2014; McIntyre, 2002; Sharma & Sriraman, 2012), an overwhelming majority of courses included a simulation component, which could be simulating a response for a request for proposals, or simulating how to solve construction problems on a construction project.

Conclusions

The present paper presented an analysis of undergraduate ASC-affiliated construction programs' course information. The authors identified 112 of 127 programs that had a capstone or capstone-related experience in their programs and were included in the present research. A total of 138 courses were identified as capstone or capstone-related, given that some programs had more than one option for capstone or had capstone in more than one semester or quarter. Most programs only required one capstone course of their students and that course was usually 3 credit hours.

The authors also analyzed the course descriptions qualitatively concerning integration, assessment, technical content, soft skills, and course format. The majority of identified courses had an implicit mention of integration. Also, many courses did not have a mention to assessment, but when that was included, many mentioned an oral presentation. Oral communication was also the most frequent soft skill mentioned in course descriptions, followed by teamwork and collaboration. For technical content, the top three components included were project management, estimating, and scheduling. For course format, the overwhelming majority of courses use a simulation approach, with a few indicating industry sponsorship of projects.

We note that our analysis is limited to the course names, descriptions, and information available online at the institutions' websites. We also note that, because not all courses were clearly identified as capstones, the authors decided on the inclusion or exclusion of courses on their analysis based on their experience and knowledge. Two of the authors revised and coded independently half of the courses each while reviewing and commenting on the other half, to include inter-rater reliability and minimize biases. Even though limitations apply to the present paper, it provides a current initial state of the practice in terms of capstone courses in construction programs in the United States.

Further studies could survey the ASC-affiliated institutions for further information about their capstone offerings, such as common assessment types, mode of delivery, engagement with industry, and scope of work. Doing so would provide a comparative analysis between industry needs for recent graduates and capstone simulations. Additionally, more in-depth case studies of current construction capstones can provide further guidance about how these courses are taught in different regions of the United States. A common understanding of the role and scope of a capstone course can provide a unified framework that construction programs. This can strengthen the use of such courses for the demonstration of students' mastery in the integration and application of construction topics, and their readiness to graduate.

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