

The Capstone Course – A New Approach

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The Capstone Course – Proposing a New Approach

The main objective of a capstone course is to enable students to integrate the knowledge gained from pursuing a given degree program. The course should allow the students to incorporate the skills and concepts learned systematically during their four-year stay at the university. A construction capstone course aims to prepare the students to enter the construction and building technology field. Through a case study, we present the development and deployment of a capstone course at University of Massachusetts Amherst. In this course, a request for qualifications is used as a semester-long project and guides course content. The course culminates with a presentation of written and oral outcomes in front of a panel of industry jurors. Lessons learned from this recent experience are presented and prompt some questions for future reflection: First, is what we are teaching in the capstone course enough for construction companies? Second, what are the primary skills that the construction companies are looking for? Third, do our students know how to express their opinions in a meeting, write a report, make a presentation, work in a team, and finally, know about ethics and compliance?

Introduction

Similar to engineering, construction management is about providing better, safer products and services; being trusted, while following clients' expectations and specifications and contemplating the triple constraints (scope, time, and budget) [1]. This translates to completing the project within the planned schedule and budget while keeping the stakeholders satisfied with the final delivery. It is unique within engineering and technology because its focus is on process improvement, and not necessarily on product design.

For years, several construction management programs have included capstone courses in their plan of study [2]. These courses are usually offered in the last semester or semesters of instruction and focus on content integration [3]. However, it is noted that there is much variation in what is included in a capstone course [3], [4]. Several researchers have provided examples of construction capstone courses (see [2], [4] and [5]), and though each program have their specificity, most align in their use of teamwork, project-based learning, and the focus on integration.

In terms of accreditation, both of the accrediting bodies responsible for accrediting construction-related programs in the United States – the Accreditation Board for Engineering and Technology (ABET) and the American Council for Construction Education (ACCE) do not require a capstone course in accredited programs. However, several learning outcomes of ABET and ACCE can be directly matched to capstone courses in construction, especially those related to communication, teamwork, and professional roles and responsibilities of graduates [6], [7]. Therefore, assessment of student learning outcomes specific to accreditation requirements can be facilitated by the use of an integrative capstone experience.

In fact, researchers surveying engineering programs have indicated that engineering capstones usually include several skills that can be easily matched to accreditation criteria [8]. However, we note that most research was focused on overall engineering programs, and not only those focused on construction.

To further explore the capstone concept, we present a case study about the development and deployment of the updated design of a senior capstone course. The main focus of this course, BCT 494BI (Senior Seminar Capstone), was to highlight the attributes desired by construction companies when hiring professionals for the construction management area. Among several attributes we can highlight good communication skills, good client relations, time management, construction project management (including safety, planning, operations and contract interpretation), and understanding of codes, regulations and construction law [9]. The BCT 494BI course is a capstone and required course at the Building and Construction Technology (BCT) program at University of Massachusetts (UMass) Amherst in the United States. The update adds to the current body of knowledge by focusing on hands-on learning, and it was inspired by a guide to the Project Management Body of Knowledge (PMBOK) [10]. The PMOBK guide is widely acknowledged as a respected authority on effective project management practices. It is unique, and it was developed by project managers, for project managers. The present paper can be used by other instructors and administrators looking for references related to capstone teaching. Additionally, individual activities presented here can also be implemented in other areas of the curriculum.

The goals of this paper is to present (1) present the development of a new capstone course approach; (2) detail the activities included in this revised course; and (3) raise discussion points about how to improve capstone course design in construction education. The case study will include a description on the course, its learning outcomes and main activities. Then, instructor's reflections about the two iterations of the course, as well as students' feedback will be presented provide insights that help identify lessons learned and discussion points about the topic. The present paper can be used by other instructors and administrators looking for references related to the teaching of capstone. Additionally, individual activities presented here can also be implemented in other areas of the curriculum.

Course and Program Context

To this point, we will use a case study approach, presenting the development and deployment of the Senior Seminar capstone course. We start our case study with a brief description of the context, including program and university settings. Then, we describe the redesign process, giving special emphasis to the alignment between the goals of the course and the activities developed. We then describe the main topics and activities of the course, including the development and distribution of a Request for Proposals (RFP) to students. Information on group formation, assessment, and deliverables are reported. Then, impressions from the main instructor, who is also an author of this paper, will be reported for the Spring 2020 and Spring 2021 iterations of the course. Students' impressions will be reported by end of the semester course evaluations in the Spring of 2021. No formal student evaluations were captured during the Spring of 2020 due to adaptations for the Covid-19 pandemic. Finally, the paper concludes with lessons learned for future iterations of the course, as well as for other instructors considering implementing similar activities in their courses and further recommendations for other programs and instructors teaching construction capstone courses.

The Senior Seminar is a senior course (3 credits) offered only during the Spring semester in the student's last semester, and known as the BCT major Capstone Course. It is a large class offer

only during the Spring semester with approximately 80 students per iteration. This class is primarily be conducted as a seminar, and usually meets on Mondays and Wednesdays for 75 minutes per day. The class covers project management techniques related to construction business organization, project delivery methods, cost control, time management, quality control, labor, bidding, contracts, ethics, risk management, etc. Students must complete a group-based semester-long comprehensive project in this course that responds to an RFP and leads to a written and oral presentation in front of a panel of industry jurors. Assignments included in this course relate to estimating, scheduling, logistics, safety, benchmarking, quality, sustainability, etc.

The course was redesigned during Spring of 2020 to prepare the students to enter the construction and building technology field as a hands-on course. As mentioned previously, the students must work in a group (8 students) to respond to an RFP of a real-world scenario. Usually, the real projects used during the course are already built, and the students can check them using Google Maps. The projects used in this course were obtained in previous student competitions, professional organizations or, publicly available information.

The main goals of BCT 494BI Senior Seminar course are to:

1. Demonstrate understanding of depth and breadth of knowledge required for a BCT degree.
2. Work collaboratively in a team environment on comprehensive projects.
3. Communicate effectively through writing and presentations.
4. Develop leadership skills for business and management.
5. Understand and appreciate the necessity of working with the entire project delivery team.
6. Practice problem solving and decision-making skills in construction including evaluation of associated risks.
7. Utilize skills and knowledge acquired from the general education curriculum.

Course deliverables span a range from business and technical documents. From a business perspective, students make up a fictitious company and define organizational roles. Team members also are given fictitious project roles and should provide an adequate resume for the project to be pursued. Technical deliverables include a complete cost estimate for the pursued project (including general conditions, insurances, bonds, permitting, contingencies and fees), schedule (including pre-construction, construction, and close-out phases), detailed safety plan, logistics plan, schedule of values, and cash flow. Students are also expected to provide schedule updates, record meeting minutes, and provide a professionally formatted deliverable that includes a cover letter specific to their assigned clients.

Course (Update) Development - Main Topics and Activities

The original course already had the necessary breadth expected for a capstone course. However, updates were made to emphasize active learning. The update's main focus was (1) the structure of the Request for Proposals (RFP) deliverables and (2) the inclusion of a new hands-on scheduling activity learning using interlocking blocks (such as Lego blocks). Given that previous research and empirical evidence suggest improvement of students' engagement with active learning activities [11], the instructor decided to focus on the two aforementioned activities.

Usually, traditional lectures have low student engagement [11]. Based on this evidence and in the professional industry experience of one of the authors, the instructor decided to break away from traditional training and move to a more activity learning experience using Lego blocks to help with planning. The students can construct, deconstruct and reconstruct using creative thinking that requires breaking the existing pattern to discover another. Deconstructing helps the students break their preconceptions and see the same thing from a whole new perspective. As a deliverable of the Lego blocks active learning, the students have to develop a logistic plan, work attack plan, and build a mockup of their projects.

The RFP is the semester-long group project which guides the course topics through the weeks. It is organized in five phases (Project Management Processes Groups) as Initiation, Planning, Executing, Monitoring and controlling, and Closing. An RFP is a formal document compiled by the client organization that describes characteristics and requirements for a product or a service that the organization wants to procure. The deliverables requested during this course are related to preparing an RFP in the same way the construction companies do. The RFP must describe the project, its goals, and the organization sponsoring it and outline the bidding process and contract terms. For these reasons, all the deliverables requested during the course are related to preparing and answering a client's RFP. Some essential areas must be considered: Cover, Letter, Executive Summary, Detailed strategy that meets the RFP objectives (Scope), Project recommendations, company information, Risks, Budget, Schedule, Quality, Closing, etc.

Additionally, during the RFP development, students may hire or consult their professor or BCT Faculty's advice to assist them to develop their proposal. However, groups that choose to hire a consultant would have to pay thirty pieces of LEGO per consultancy hour. Groups could also contact alumni at no cost to assist in proposal development.

The RFP activity was chosen to cover and establish a strong foundation for the students and prepare them to join the environmental construction industry. This is because an RFP is a comprehensive document which includes all the requirements and needs of a project; it also guides companies in terms of expected deliverables and selection procedures. Additionally, requests for proposals in the construction industry require that companies form teams of professionals capable of understanding owners' requirements and expectations, as well as coordinating technical work. The response usually culminates with teams providing provide clients with a comprehensible written document, which is usually followed by an oral presentation.

In the first two weeks of the semester, BCT students have classes about Introduction to Project Management. In these two weeks, the topics presented include:

1. Definition of a Project
2. Definition of a Project Management
3. Definition of Project Planning, Monitoring, and Control
4. Project Constraints
5. Organizational Structures and their Influence on Projects
6. Project Management Roles and Responsibilities
7. Planning Life Cycle Key Documentation

8. Project Delivery Method - EPC

9. Knowledge areas of the PMBOK.

After these introduction weeks, usually, the students must create ten teams with eight people and decide who the project manager will be. Students are not assigned a group, but rather self-select to join or form a group. Icebreakers' activities help in the creation of these groups.

After each team is formed, they receive a unique real-world project that contains all the drawings and specifications. It is in this stage that students are presented with the active learning scheduling activity using lego blocks. They use the LEGO blocks to plan the execution of the construction activities. In the Project Planning with LEGO, all the team members must take an active role in the process. Project Planning is everyone's responsibility, and it takes the whole team to synergize to meet each milestone. LEGO in Project Planning is a technique where the students will learn how to use the LEGO blocks to follow through a series of structural exercises. They simulate typical construction activities and manage the activities with project management best practices. The LEGO activity is developed throughout the semester, and the professor works together with all the groups as a coach, providing immediate feedback and discussing the new approaches/ideas. Finally, each team must plan the project and build it based on their understanding as a team, as the conclusions are discussed, agreed upon, and understood by all.

During the planning phase development, some advantages of using the LEGO blocks were realized. We can mention this, such as a better understanding of the logistic plan, construction sequence, interferences and planning, final deliverables phase by phase, teamwork, communication, problem-solving, and creative thinking. In addition, through the use of LEGO, students are forced to think outside the box and consequently have a more significant interaction as a team.

Once roles and expectations are understood by all project members, the RFP process starts. This process guides professionals towards creating a final proposal. And an effectively developed RFP process facilitates project management activities post-award. For this reason, the teams have partial deliverables based on the Project Management Book of Knowledge (PMBOK) project's phases: Initiating, Planning, Execution, Monitoring and Controlling, and Close-Out). Eight major deliverables are included in the course and are outlined in table 1.

At the end of the semester, the students must present the RFP in front of a panel of industry jurors from national and international construction companies, professors from the department, invited professors from several universities besides professional consultants. Each team has 20 minutes to presenting and the jurors have 10 minutes for questions and answers (Q/A) and final comments. During Spring 2021 due to the COVID pandemic, presentations were held virtually on Zoom.

Table 1 – RFP Process Assignments

Deliverable (Week Points)	Content	Observations
Initiating (1 2)	<ul style="list-style-type: none"> • Name of the construction company, bio and logo • Project Manager Name; Organizational Chart and Roles and Responsibilities • Cover Letter addressed to the client • Actual Resume for each team member • Meeting Meetings signed by all team members; Kickoff Meeting Agenda; Kickoff Meeting Minutes signed by all team members • Project Charter (with inputs/tools, techniques/outputs) • Stakeholders Matrix 	Initial project phase. Team formation and company creation.
Planning and Logistics (6 15)	<ul style="list-style-type: none"> • Logistic Plan • Create a Work Breakdown Structure - WBS • Develop Schedule (Plan Schedule Management, Define and Sequence Activities, Estimate Activity Durations • Plan Cost Management; Cost (estimate); Budget • Plan Quality Management 	Planning Phase. Define and refine project objectives to plan and select the best way to attain these objectives.
Planning (8 6)	<ul style="list-style-type: none"> • Plan Communications Management • Plan Risk Management (List of Risks; Qualitative Risk Analysis; Quantitative Risk Analysis; Plan Risk Response) 	Planning Phase. Identify potential problems before they occur, or, in the case of opportunities, leverage them to cause them to occur.
Execution (10 3)	<ul style="list-style-type: none"> • Direct and Manage Project Work • Manage Quality • Manage Communications • Implement Risk Response • Manage Stakeholder Engagement 	Execution Phase. To set the teams in place to get the work done efficiently and effectively.
Monitoring and Controlling (11 3)	<ul style="list-style-type: none"> • Monitor and Control Project Work • Control Schedule, Costs, Quality • Manage and Monitor Stakeholder Engagement • Monitor Risks 	Monitoring and Controlling Phase. Check the overall performance of the project and makes changes if necessary.
Closeout (12 1)	<ul style="list-style-type: none"> • Close Project 	Closing Phase. Ensuring the customer has accepted all final phase or project deliverables.
Peer Evaluation (16 15)	<ul style="list-style-type: none"> • Team members evaluation • Project Manager evaluation 	
Final Deliverables (16 55)	<ul style="list-style-type: none"> • Final Binder (printed) • Final Presentation (PowerPoint file) • Final presentation of written and oral outcomes in front of a panel of industry jurors. 	

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Instructor Impressions

Spring 2020 was the first time the instructor taught the course using the described format. After one semester of working together with the students, the primary impression was that the students needed to have proper training and learning mainly about writing, presenting, working in a team, etc. Other author impressions are given below.

1. It was clear that the students had to work hard to achieve the final deliverables and prepare the binder and the final presentation.
2. The instructor realized that some topics were challenging, such as developing the logistics plan, reading the plans, especially MEP, Steel structure, drainage plans, etc.
3. Regarding Risk Management Analysis, the instructor's impression was that during the first time the course was offered, the students didn't understand how complex and vital it is to perform and analyze the risks inherent to the construction/execution phase before moving to the job site.
4. Using the PMI framework works proportional to the students' better understanding of what must be considered to prepare an RFP, execute the project, and archive the goals planned in the feasibility phase.

During the second iteration of the course in this format (Spring 2021), it was clear that the students had improved considerably from the first day of the semester until the final presentation day, especially regarding reading plans, development of the work attacks, and logistics. Unfortunately, in Spring 2021, the classes were virtual due to a pandemic by Zoom. Therefore, a considerable difference was observed between the first and the second time the course was offered, mainly in the written and presenting ways.

Students' Feedback (Spring 2021)

In addition to feedback obtained from students during course interaction, formal anonymous course feedback was also obtained in the spring of 2021. Formal course feedback did not occur in Spring 2020 for the entire university, due to the switch to online learning and the COVID-19 pandemic. Table 2 summarizes the course evaluations for Spring 2021. Results show that the course is well accepted by students and that there is a strong emphasis on teamwork.

In addition to rating scale questions, students were asked to list the most valuable things they have learned in the course. This was an optional question and 22 students provided their perceptions. Answers are summarized in table 3. Results from the open-ended questions also

indicate that learning focused on teamwork and collaboration, followed by skills on how to put a bid proposal together and on presentation skills.

Table 2 – Course Evaluation, Spring 2021 (n=67)

Topic	Score (1 – worst to 5 – best)
Expectations and Participation	4.3
I felt supported to learn in this course	4.5
I Knew the content was critical to learn in this course	4.4
I felt engaged in this course	4.4
I had multiple opportunities to interact with other students	4.8
Overall, how much do you feel you have learned in this course	4.5
What is your overall rating of this course	4.5

Table 3 – Course evaluation (open-ended) – most valuable learned experience, Spring 2021 (n=22)

Topic	Frequency
Team Collaboration	13
Bid proposal	11
Presentation Skills	11
Real-world skills/project	10
Time Management	4
Technical Skills (scheduling, estimating, analyzing documents)	4
Other	4

Lessons Learned and Future Recommendations

This paper presents a case study about the capstone senior course at the University of Massachusetts in the United States in the BCT program. Usually, it is taken by the BCT students in their last year during the Spring semester before graduation. This class is primarily be conducted as a seminar. The students have to complete a group-based semester-long comprehensive project that responds to an RFP based on a real-world scenario and leads to a presentation of written and oral outcomes in front of a panel of industry jurors.

During the semester, the students have the opportunity to solve technical problems by applying the skills and concepts learned systematically during their four-year stay at the university. As a result of having taught this course for two semesters (Spring 2020 and Spring 2021), the main lessons learned and recommendations for further research are presented below.

- Spring 2020, where we had a presential course, it was possible to observe that the active learning with Lego blocks had 100% participation of the students. Using the Lego blocks, classroom time was better spent giving students options to work with concepts over and over, in a variety of ways, and with opportunities for immediate feedback from the professor, allowing that the acquired knowledge could take hold in their minds. As a lesson learned, the students could better understand the logistics plan and work attack plan. Unfortunately, during Spring 2021, it was impossible to use Lego blocks for active learning remotely because the students lived in different cities. The classes were virtual.

- It was possible to realize during the semester that the students need to have deep knowledge about reading Construction Plans. The instructor presented this general situation to other professors at the end of the semester, and it was suggested to focus more on the reading plans in their specific courses. This action contributed significantly to the student's progress after the course was offered for the second time.
- The idea to include LEGO, Risk Analysis Management and the PMI framework helped students understand how complex it is to prepare an RFP, archive the project's objectives and satisfy the stakeholders.
- After introducing the Lego blocks to plan the construction activities, all the team members noticed greater participation during the planning process. As a result, all participants who faced the responsibility for the planning phase were better engaged. Thus, it was realized that Project Planning is everyone's responsibility. As a result, the instructor realized that the students could better understand the logistics plan and work attack plan.
- Risk is an inherently challenging aspect of the construction industry. Therefore, academic institutions need to adjust and/or offer courses to deal with risk appropriately. In this case study, it was necessary to teach the main concepts about Risk Management Analysis in the four major areas, Financial, Time, Design, and Quality, in a previous course, BCT 353 Construction Project Management, to cover and prepare the students for the capstone course.
- Finally, having construction management professors, national and international professionals from the construction industry as judges and evaluators made students take their presentations more seriously. After their presentations, the judges provide specific feedback.

Students' feedback on the course indicates that they appreciated the experience. However, several areas of improvement are identified. Mostly they relate to aligning the content of teaching and the RFP simulation with what construction companies are looking for in graduates. Furthermore, our experience prompts questions about Construction Capstone Courses in general for future reflections: First, is what we are teaching in the capstone course enough for construction companies? Second, what are the primary skills that the construction companies are looking for? Third, do our students know how to express their opinions in a meeting, write a report, make a presentation, work in a team, and finally, know about ethics and compliance?

Further studies could explore an updated analysis of key competencies (from industry and academics) used in capstone simulations; and a broad study on construction students' writing and soft skills perceptions and performance. Both studies could help guide improvements in instruction, specifically at the capstone levels, and prepare students for success in the construction industry.

References

- [1] Hoffman, H. F. (2014). Engineering and the capstone course. In *The engineering capstone course* (pp. 1-5). Springer, Cham.
- [2] Lee, N., & Kim, S. J. (2020, October). A Systematic Course Design Approach to Guide the Development of a Construction Engineering and Management Capstone Course. In *2020*

Annual Conference Northeast Section (ASEE-NE) (pp. 1-5). IEEE.

[3] Debs, L., Romero Moraes, F., & Benhart, B. (2022). A Review and Comparison of Associated Schools of Construction (ASC) Capstone Course Content. In *2022 ASC 58th Annual Schools of Construction International Conference* (pp. 577-585).

[4] Cecere, J. (2002, June). Capstone course in construction management. In *2002 ASEE Annual Conference* (pp. 7-278).

[5] McIntyre, C. (2002, November). Problem-based learning as applied to the construction and engineering capstone course at North Dakota State University. In *32nd Annual Frontiers in Education* (Vol. 2, pp. F2D-F2D). IEEE.

[6] Accreditation Board for Engineering and Technology (ABET) (2020), 2021 - 2022 criteria for accrediting engineering programs. <https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022/>

[7] American Council for Construction Education (ACCE) (2020) Document 103 – Standards and Criteria for the Accreditation of Construction Education Programs. Retrieved from: https://683b8d30-e51d-49ba-9440-a5669f44051b.usrfiles.com/ugd/683b8d_2714ae361f2f41e9b7eb7c7dcb69a160.pdf

[8] McKenzie, L. J., Trevisan, M. S., Davis, D. C., & Beyerlein, S. W. (2004, June). Capstone design courses and assessment: A national study. In *Proceedings of the 2004 American Society of Engineering Education Annual Conference & Exposition* (pp. 1-14).

[9] Ahmed, S. M., Yaris, C., Farooqui, R. U., & Saqib, M. (2014). Key attributes and skills for curriculum improvement for undergraduate construction management programs. *International Journal of Construction Education and Research*, 10(4), 240-254.

[10] Project Management Institute (PMI) (2017). *A Guide to the Project Management Body of Knowledge (PMBOK)*. 6th edition Project Management Institute, Inc.

[11] Prince, M. (2004). Does active learning work? A review of the research. *Journal of engineering education*, 93(3), 223-231.