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Enhancing Student Learning through Inter-Disciplinary Capstone Design Projecct

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Abstract

In many universities, capstone project is associated with an advanced course, which focus on the expertise in one concentration area. This limits student learning of interdependency of other disciplines within the major for problem solving. At our program, we formulated a creative way to use the traditional course offering yet provide an opportunity for students to work on an inter-disciplinary project in civil engineering. Students from three concentration areas within civil engineering (structures, construction, and transportation) were offered an opportunity to work together in small groups on an active or proposed project that included components from all three concentration areas. Student groups were provided with drawings and specifications of an actual project that was in the process of being built or recently completed and were required to propose alternate approaches to design and other components of the project. All groups diligently worked on this project in true competition style, to incorporate changes through value engineering, sustainability, energy efficiency, and other modern tools to improve the functionality, or other aspects of the project. Students had opportunity to review actual construction drawings and work in inter-disciplinary teams to incorporate changes. Confidential peer-reviews were used to assess the performance and contribution of each member, and their interaction with other members of the group. Students presented their final project in front of mixed audience that included family members as well as experts in the area during the Capstone Design Conference. Team consisting of faculty and industrial advisory board members evaluated communication skills and technical skills of students during this conference. In addition to enhancing student learning, this approach was also valuable to assess ABET student outcomes that are difficult to assess in the traditional class setting. This paper presents the beneficial effects of such approach to assess ABET student outcomes, and their effectiveness. The success of this approach has encouraged us to broaden the project to include all concentration areas in civil engineering going forward.

Introduction

Engineering education across the United States, predominantly culminate in a capstone design course. This may be offered in the form of a course in one semester, or a sequence of courses offered over two semesters. Capstone courses are also widely used for assessment due to the nature of the course. Many of the capstone projects involve real-world problems. It may also involve multidisciplinary teams. While multidisciplinary projects are easy to achieve in some areas of engineering, it has been a challenge for civil engineering projects. Even working on a project involving multiple concentration areas within civil engineering is a challenge due to the

way courses are offered at many universities (Sirinterlikci 2014, Sheppard et al 2011, Koromyslova et al 2022, Fernandez-Solis 2012, Goldschneider et al 2019, Adams et al 2020, Nemes et al 2011, Su et al 2016, and Dixon et al. 2018). We tried to overcome this by providing opportunity for students from different capstone courses to work together. The next step was to identify a project that consists of all components and provide real-life experience, similar to working in a civil engineering company. The primary objective of this approach was to challenge students to work in multidisciplinary teams and include best practices in the industry while enhancing their technical as well as communication skills. We merged students from three concentration areas of civil engineering (structures, construction, and transportation) to work in a small group or six students. Some of the example projects students worked in the past few years include Building project for a university that includes classroom and laboratory facilities; Building project for a university that includes student services facilities and an auditorium; Indoor sports complex in a local community; and Ash recycling facility for a local township. A sample project along with the scope the required guidelines provided below:

Scope of a Sample Project

The assigned project is a Center for Innovation and Collaboration at a local university. This new center is currently in the process of being revised, since the bidding on the project exceeded the expected project cost significantly. The drawings that are posted online are for the original proposed project. Geotechnical reports and specifications associated with bid documents are also posted online. The objective is to work as a team to design critical components, planning and estimating including cost estimate, and to address transportation needs of the university due to this new addition. You have the flexibility to incorporate innovative ideas that will add value to the building. While bringing down the cost of the project is encouraged, it will be one of the many factors that should be considered to make this project functional and efficient.

Group Formation

Each group normally consisted of two people. The recommendation was to have at least one member in each concentration areas. The group leader was responsible to coordinate the tasks and to make sure they are completed on time. It was also the responsibility of the group leader to regularly organize meetings and report any personnel issues.

Project Requirement

- An interim report (one per group) along with the progress of your project is due mid semester. This short report (3 – 5 pages) should highlight your proposed recommendation along with the status of your project. Follow the guidelines provided by the technical writing experts from the Learning Center during writing workshop.
- A bound copy of the final report is due at the end of the semester. It should include final report along with detailed work. There is no limit on the number of pages. Please make sure your report is legible and contain all the details and drawings.

- One of the main components of the project is to consider value engineering, sustainability, energy efficiency, and other modern tools to improve the functionality, or other aspects of the proposed project. Make sure to include all the options that were considered and the justification for the proposed changes/improvements.

Expectations:

There are two components for the project: Required component; and value engineering component. All groups must perform the same tasks (analysis and design of critical members) under the required component. Value engineering should include proposed changes to improve the functionality or other aspects of the proposed project. It is extremely important that you are prepared to justify these improvements during your oral presentation.

The structural design process involves identifying critical members and designing them to meet the latest code requirements.

- The project should be designed in accordance with the latest IBC, ASCE 7, ACI 318 and/or AISC, in addition to compliance with specific owner's requirements.
- Please select the appropriate type of roofing and flooring system and arrange the column location for the project. The proposed construction is 2-story steel-frame building with cast-in-place concrete foundation walls, with metal stud and metal panel exterior walls. Note: You have the flexibility to make changes to any of these components including construction type.
- The design process involves design of roof and floor slab, truss/beams/girders, columns, masonry walls, and foundations. Research for the appropriate roofing system and identify the loads to be used and their combination. Perform structural analysis to obtain the critical member forces, moments, axial loads, and shear. Make sure that the deflection requirements are satisfied. It is highly encouraged to use computer software and design aids to perform structural analysis. Structural design criteria, including loads used in this project is presented in drawing S101. However, you are required to confirm these with the design codes. Note: You are not permitted to use loads less than that recommended by the design code.
- Design the roof slab, all critical trusses or beams/girders based on your proposal. Note: You have the flexibility to change the roofing system.
- Design the floor slab for the first floor, all critical trusses or beams/girders based on your proposal. Note: You have the flexibility to change the roofing system. There is no need to design the floor slab for the lower floor.
- Design the stairs that connects from lower level to first floor. Note: You have the flexibility to change the material, method of construction for your stairs design.
- Calculate the allowable safe bearing capacity of soil based on geotechnical report. Design all critical columns and foundations. Provide detailed calculations for the analysis and design of critical components.
- For suggested changes/improvements, design the members needed to justify your recommendation.

The construction estimating process involves pre-bidding steps. The main divisions that will be concentrated for this project are Divisions 3, 4, and 5. Further divisions that will be needed will be discussed in class. The estimating process will be conducted on the original building and the project addition. The following are the steps to produce a thorough estimating process for these two:

- Create checklists of each division used. Each item should have a detailed description included.
- Perform a quantity take-off for each item on the checklist. This step should include detailed units and measurements. Any assumptions made should also be included.
- Include detailed cost estimates for all resources: material, labor, and equipment.
- Include detailed summary division and total cost estimates. This will be a part of your bid package and will include any material taxes, overhead, profit, bonds, permits, and any other fees or mark-ups.
- The scheduling process will include two Gantt Charts:
    - The first Gantt chart will include the progress schedule. This schedule is to be started at day one of the capstone design and should include the group's schedule of progress. This will include start and end milestones, work breakdowns, important dates and deadlines, events, and progress days.
    - The second Gantt chart will include the activities and durations of the project addition design and construction. This bar chart should include a work breakdown structure, list of activities, durations of each activity, and their relationships.

- The addition to the project should include some LEED design aspects. This will be done in two parts:
    - Use the new construction for LEED design checklist to mark all the items that will be used on the addition to obtain a certain LEED credential. The total of points at the end of the checklist should determine the score and level of LEED new construction.
    - Explanation of why and where LEED was used in the addition design should be written in the report.

- The value engineering process should be used on the design addition only. This will include worksheets of alternative methods, designs, materials, and etc. The items that will be used in the value engineering process will be evaluated based on function, cost, and life cycle.
- The following software programs can be used throughout the construction design process to complete all the necessary items listed above: Microsoft tools (Excel, Word, PPT), AutoCAD, Revit, PlanGrid, RSMeans on-line, P6 – Primavera, and PDF.

The transportation component involves determining the impact of the new facility in terms of traffic and transportation. This project would also involve analyzing and forecasting the traffic and transportation around the campus as a whole. The following are some of the components of the project,

- Determine the parking space requirement for the facility according to local body code. Study the existing parking supply and design new parking lots if required.

- Design a driveway from the facility to the adjoining roadway as per the National Cooperative Highway Research Program (NCHRP) guidelines.
- Forecast traffic around the campus as a whole.
- Conduct a warrant analysis for intersections around the campus and suggest recommendations to improve traffic operations if needed.
- Determine the Level of Service (LOS) on the roadways around the campus using Highway Capacity Manual (HCM) procedure as well as using Highway Capacity Software (HCS).
- Determine the reduction in design life (if any) of the pavement of the roadways around the campus due to increase in traffic. Use the Guide for Design of Pavement Structures by American Association of State Highway and Transportation Officials (AASHTO) to determine the design life of pavement.

Oral Presentation

Teams should prepare their presentation with the idea that they are addressing a committee that consists of faculty members and industrial advisory board members with different technical expertise. The presentation should convince the committee of the technical adequacy of their design and merits of their proposed changes/improvements. It is your responsibility to make sure that each member of your group will have adequate (equal) time for presentation. Each individual member of your group will be evaluated for presentation and the grade is based on individual performance, not group performance.

Table 1. Rubric for Evaluation of Student Presentations

Evaluation of Presentation	Rating Scale									
	1	2	3	4	5	6	7	8	9	10
Organization										
Visual Aids										
Technical content										
Conclusion / Justification										
Communication										
Time management										
Teamwork										

Final Report

The final report is the culmination of the group's activities in capstone design. It must stand on its own merits as a document being submitted to an engineering committee who will review the technical adequacy of the project. It must address all the requirements of the project and must conform to the specifications. The report should explain the alternate approaches that were considered and justify the approach selected. Spreadsheets and computer outputs, if any, should be accompanied by simple calculations. Please make changes to your proposal as needed and include it in your final report. It is important to pay attention to the quality as well as quantity.

Only bound reports will be accepted. Loose sheets or 3-ring binders are not acceptable. Your project will be graded for:

- Technical Content
- Quality of Work
- Innovative Approach
- Cost Savings or Other Benefits
- Energy Efficiency Initiatives

Peer-review Process

In addition to the above, there will be a confidential peer evaluation from your group members. Since this is a group project, you will be evaluated for individual contribution, meeting deadlines, quality of work, providing and receiving feedbacks, and ability to work independently. Peer-review will be kept confidential and will not be revealed to you or other members of your group.

Table 2. Peer-review of Performance

Performance Evaluation	Rating Scale				
	1	2	3	4	5
Showing up for meetings					
Meeting assignment deadlines					
Quality of work					
Providing/Receiving feedback					
Ability to work independently					

Outcome assessment

Data collection for ABET accreditation

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. 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 economical factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions

7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Student Survey

In addition to direct assessment of student performance, students also completed two surveys: One survey was to evaluate the effectiveness of the presentation by invited speakers to enhance learning and professional development; and the second survey was to understand the effectiveness of the capstone project on various aspects to enhance student learning.

Table 3. Student Survey of Presentation by Invited Speakers

Presentation by Invited Speakers provided:	Rating Scale				
	1	2	3	4	5
Management and business concepts in the industry					
Knowledge of public policy					
Investigate and analyze information related to contemporary issues					
Impact of profession on societal and environmental issues					
Importance of ethics and other legal issues					
An opportunity for networking					
Importance of professional licensure					

Table 4. Student Survey of Presentation by Invited Speakers

Design project completed in this course helped me to:	Rating Scale				
	1	2	3	4	5
Identify an appropriate engineering method for problem solving					
Identify and use appropriate computer software for problem solving					
Develop a design strategy to meet desired needs					
Function as a team member					
Strategize the solution process and weigh alternative approaches					
Demonstrate technical writing ability					
Deliver oral presentations					
Explain and discuss technical issues					
Develop leadership skills					

Summary and Conclusion

Capstone project was offered in a creative way to use the traditional course offering yet provide an opportunity for students to work on an inter-disciplinary project in civil engineering. This provided a unique opportunity for students from three concentration areas within civil engineering (structures, construction, and transportation) to work together in small groups on an active or proposed project that included components from all three concentration areas. The approach used is similar to what students expect once they start their professional career. Based on the response received from students and industrial advisory board members who evaluated student performance, the approach was very effective in enhancing student learning. The success of this approach has encouraged us to broaden the project to include all concentration areas in civil engineering going forward.

References

Sirinterlikci, A. (2014, June), Interdisciplinary Capstone Projects Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana. 10.18260/1-2—20691

Sheppard, K. G., & Nastasi, J. A., & Hole, E., & Russell, P. L. (2011, June), SE CAPSTONE: Implementing a Systems Engineering Framework for Multidisciplinary Capstone Design Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC. 10.18260/1-2—18937

Koromyslova, E., & Shannon, C., & Lovrien, P., & Barnett, B., & Steinlicht, C. (2022, August), Multidisciplinary Capstone Design Experiences: Students' Perspective Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. https://peer.asee.org/40745

Fernandez-Solis, J. L. (2012, June), Building Construction: Interdisciplinary Capstone Projects Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. 10.18260/1-2—21035

Goldschneider, B., & Pitterson, N. P. (2019, June), Interdisciplinary Collaboration in Capstone Courses Paper presented at 2019 ASEE Annual Conference & Exposition, Tampa, Florida. 10.18260/1-2—31912

Adams, J. C., & Pirrotta, N., & Michmerhuizen, M., & Holmes, P. M., & Oostema, P., & Kastner, B. (2020, June), Crayowulf: A Multidisciplinary Capstone Project Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual Online. 10.18260/1-2—34342

Nemes, J. A., & Hochstedt, K. S., & Brannon, M. L., & Kisenwether, E. C., & Capuro, R. M., & Bilen, S. G. (2011, June), SE CAPSTONE: Introduction of Systems Engineering into an Undergraduate Multidisciplinary Capstone Course Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC. 10.18260/1-2—18936

Su, J., & Nie, Z., & Wang, J., & Lin, Y. (2016, June), Lessons Learned from Multidisciplinary Senior Capstone Design Projects Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.25553

Dixon, W., & Neal, N., & Yanik, P. (2018, August), An Interdisciplinary Capstone Project in Assistive Robotics Paper presented at 2018 ASEE Conferences - Conference for Industry and Education Collaboration / San Antonio proceedings, San Antonio. https://strategy.asee.org/31349