How Service Learning Can be Offered as Capstone

Ali Shafaat
Lyles School of Civil Engineering
Purdue University
West Lafayette, IN
ashafaat@purdue.edu

Behzad Esmaeili
Durham School of Architecture Engineering and Construction
University of Nebraska-Lincoln
Lincoln, NE
besmaeili2@unl.edu

Farshid Marbouti
Charles W. Davidson College of Engineering
San Jose State University
San Jose, CA
farshid.marbouti@sjsu.edu

Brandon Fulk
Division of Construction Engineering and Management
Purdue University
West Lafayette, IN
fulk@purdue.edu

***Abstract*— The capstone design course is a senior level course in large number of civil engineering and construction programs. This course bridges the gap between education and industry by emphasizing project-based learning, asking students to accomplish open-ended project planning and system design. This study aims to investigate the potential of incorporating service learning into capstone courses in Civil Engineering, Construction Engineering, and Construction Management curricula. To accomplish this objective, a questionnaire is designed and will be distributed among alumni of Purdue University as well as Durham School of Architecture Engineering and Construction. The questionnaire is asking about the main learning objectives of the current capstone courses, objectives that can be better covered by a service learning project, and the most practical, efficient, and systematic way to incorporate service learning into capstone courses. The results of this study can be used to successfully incorporate service learning as a more advanced authentic performance task into the capstone senior design course and increase the student's experience with real-world issues, and enhance required skills such as project management, project planning, and cost analysis and estimation.**

Keywords—Capstone Design; Service Learning; Construction Engineering; Construction Management; Backward Design

I. Introduction

In this paper, the term "capstone" refers to a senior-level design course in which students learn to apply their engineering skills to a real world problem. Real-world problem solving is acknowledged by the Accreditation Board for Engineering and Technology (ABET) as a means to evaluate and enhance engineering programs [1]. In a senior design class, the learning occurs based on the social constructivism theory. According to this theory, learning is a collaborative and social process in which students' existing knowledge plays an important role [2]. Instructors mainly help students to construct knowledge by making experiences and improve their existing knowledge. Service learning exposes students to more real-world problems and encourages them to collaborate with others, thus reinforce the learning process. This study aims to investigate the potential of incorporating service learning into capstone courses in Civil Engineering, Construction Engineering, and Construction Management curricula. This study also investigates at the potential changes in the current capstone course in the construction division at Purdue University as well as Durham School of Architecture Engineering and Construction. This is a part of the constant and ongoing educational reform and commitment to engineering excellence.

II. Background

In this section, first we describe capstone courses in construction engineering and management. Then after a brief introduction to service learning, backward course design for construction capstone course is discussed.

A. Capstone

A capstone courses goal is to prepare the students for work by experiencing real life problems that:

- Cover materials students have learned
- Help students learn by doing
- Increase self-learning
- Develop a system view of the construction industry
- Enhance students' soft skills
- Advance students' design skills by working on wicked problems

A capstone design course requires senior-level students to apply knowledge gained from previous coursework and work experiences such as internships in accomplishing an open ended design task. It is the hope that the capstone design facilitates the student's transition from an academic to an industrial environment [3]. Coursework in the area of Construction Engineering, according to the National Science and Technology Council [4] should cover the entire life cycle of a project. Therefore, senior students should understand initial planning and programming, design, site construction, occupancy and maintenance, condition assessment, retrofit and renovation or removal. However, engineering courses mainly use well-defined problems to train students. Although these problems may be complicated, it is expected that when students understand the approach and its execution, the solution can be found almost automatically [5]. On the other hand, problems in the

real world are dynamic in nature and are characterized by both model and data uncertainties. Therefore, problem solvers should deal with challenges like incomplete information, changes in parameters, and insufficient data [6]. Construction educators were aware of this gap for a long time and tried to address it by technological problem solving situated in real-life contexts [7].

Filling the gap between the industry needs and graduated students' competencies consequently increases employment records. As a mismatch is identified as the main factor behind graduates' unemployment and employer dissatisfaction in the construction industry. Wu, Feng, Pienaar and Zhong [8] recently studied the construction education gap in Australia by running a survey for 32 reported gaps and found that the most significant gaps are related to problem solving in real-life contexts through teamwork and communication. To address this educational gap, universities typically offer a capstone course to diminish the gap between knowledge and skills.

B. Service Learning

Jacoby [8] defined service-learning "as a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities for reflection designed to address desired learning outcomes." Purdue University has a multidisciplinary service learning program called Engineering Projects in Community Service (EPICS), which has been replicated in several other institutes. In this program, student teams design products and processes to meet the needs of local and global communities. The project teams identify the needs with a community partner. This structure provides students with authentic experiences and gives them the opportunity to develop competencies to deal with real-word problems. This feature is especially important to civil engineering-based projects. For instance, in the 2011-2012 academic year, more than 20 percent of 600 students in EPICS were engaged in projects with a civil engineering focus. One of the main goals of the capstone course is to merge with the EPICS program and provide leadership opportunities for construction students in addition to the real-world problem solving experiences. Recently efforts to implement service learning in engineering courses have increased [e.g. 9-14] Despite the advantages of this implementation the course objectives may not be aligned with service learning [15 and 16] and the alignment can be challenging [17]. Engineers without Borders (EWB) and EPICS are two established avenues for incorporating service learning into engineering schools.

Several scholars [e.g., 10,14, 17-20] proposed service learning projects as helpful tools to introduce civil and environmental engineering students to the open-ended nature of engineering and promote a systems approach to engineering problem solving.

C. Course Design Process

The content of the capstone course is arranged according to backward design principles [21]. Backward design is based on first identifying the desired outcomes, then determining the acceptable evidence that the goals have been achieved, and finally planning for the learning experience. According to this method, the course designer identifies what the students should learn from the course, what evidence will demonstrate that learning has occurred, and finally how to plan for the learning to happen.

The concepts are arranged according to enduring understanding, items that are important to know, and items that are good to be familiar with. The terminology comes from the Wiggins and McTighe [21], who stated, "Enduring understanding refers to the big ideas, the important understandings, that we want students to 'get inside of and retain after they've forgotten many of the details." Enduring understandings are proven useful knowledge that students take away from the course far after the end of the course. They help students to make inferences and find patterns when they are dealing with the course concepts in the future. Enduring understandings are best stated as propositions and starts with phrase like: "Students should understand ..." [22] followed by an essential question such as "how" or "why". The enduring understanding is built on the students' prior knowledge and experience, and future courses can use these concepts as what students' know before taking those courses. As mentioned before, however, for senior design courses the list can be too long and impossible to be covered in one semester.

The determination and, more importantly, prioritization of the beneficial concepts can be done by using established guidelines such as ABET criteria [1], literature such as studies focused on construction capstone courses in civil engineering departments [e.g., 23-26] and surveys conducted to find which pieces of knowledge and skills the students learned were most useful during their careers. For re-designing the capstone course, data gathered from a questionnaire were used.

III. Research Question

This study aims to test applicability of incorporating a service learning project in the capstone course for senior students in Civil Engineering, Construction Engineering, and Construction Management programs would increase the students' performance after graduation or not. To address this overarching goal, the following questions need to be answered:

1. What are the main learning objectives for capstone courses in Civil Engineering, Construction Engineering, and Construction Management programs? What are the priorities for each objective?
2. Which objectives can be better covered by a service learning project in capstone courses?

And finally as the main outcome of this study:

3. What will be the most practical, efficient, and systematic way to incorporate service learning into capstone courses?

IV. Design of Study

This research tries to advance content, pedagogy, and assessment strategies of capstone senior design course by adding service learning components. This addition would be based on the student's prior knowledge and the required skills in early career period. To do so, two questionnaires are being prepared and approved by IRB. The first questionnaire will be sent to the recently employed alumni of the CEM program (2015-2010) and the other one for the employers who are active in the construction industry and have hired

CEM program alumni. The Employers will be questioned for the most useful learning objectives of the course for newly hired employees during their early professional experience. The result of these surveys will help the researchers to prioritize the learning objectives for a capstone course.

After defining and ranking the learning objectives, the course content will be established using backward design methodology. At this stage the ability of service learning in covering the enduring understanding topics will be evaluated. In this study, to determine whether service learning addresses the needs for developing enduring understanding, a capstone course will be studied. The students who will be exposed to the service learning components in their class will be evaluated using pre-tests, post-tests, and interviews. The pre-tests and post-tests will target their level of knowledge about the course objectives before and after the class, their motivation, and the use of resources for accomplishing the assignments. In the designed evaluations, other related areas such as motivation, commitment, and use of resources also will be tackled. The pre-tests, post-tests, interviews, and observations will answer the second and third questions of this study.

A. Sample

This study is designed surveys based on the body of knowledge to collect subject matter experts' opinions. Earlier alumni surveys had up to 75% response rate. So the expectations will be 60 completed surveys from both CEM and Durham school alumni who graduated from the programs between 2010 and 2015. The target for the industry survey is up to 100 individuals who are in charge of hiring the construction engineers. These individuals work at different sections, branches, and areas of companies active in the construction industry.

Regarding the capstone class, the expected class for next fall, will have more than 20 students. Four of these students have already experienced service learning through the EPICS program at Purdue.

B. Capstone Courses

The followings are the capstone structures at Purdue University and University of Nebraska:

- Capstone at Purdue University

According to the construction engineering and management plan of study at Purdue, "Construction Project Practice" is a senior level course. This course typically offered in the fall. The two pre-requisites of the course are CEM 291 (summer internship and CEM 302, practical application for construction engineering). The class includes both lecture and laboratory components. Normally lecture time is two hours, split into two fifty minute classes. Laboratory takes place after the lectures for two hours and fifty minutes, during which students are supposed to work in teams on their projects and assignments. Students receive instructions and guidance from the instruction team during the lab time. The course is developed based on a bidding process simulation. Students are asked to prepare bidding packages and present them to the class.

- Capstone at University of Nebraska

At university of Nebraska, CNST 489 - Senior Construction Project is a course equivalent to capstone at Purdue University. In this course, which is offered in springs, students practice execution of a construction project involving conceptual design and location, estimating, bidding, site layout, construction organization, planning and scheduling, cost control, records management, and project completion and documentation. The following courses are prerequisite for the senior construction project: CNST 378 - Construction Planning, Scheduling, and Controls; CNST 379 - Construction Estimating II; CNST 420 - Professional Practice and Ethics; CNST 476 - Project Budgets and Controls; and CNST 480 - Productivity and Human Factors in Construction.

V. Implementation and Next Steps

This study tries to rank the knowledge and skills such as project management, planning, cost analysis and estimating, human resource, safety, means and methods, or technology-oriented to be addressed in capstone courses accordingly. Then the study evaluates the potential of incorporating service learning ability to into the senior design course to increase the students' experience with real-world issues to enhance their project management, project planning and cost analysis and estimation skills. It will investigate the logistics of including service learning component into the construction engineering students' overall learning process.

References

[1] ABET. Criteria for Accrediting Engineering Programs. Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, 2015, Baltimore, MD. Worldwide web address: http://www.abet.org

[2] Ben-Ari, M. Constructivism in computer science education. *Journal of Computers in Mathematics and Science Teaching*, 2001, *20*(1), 45-73.

[3]Parker, J., Midkiff, C., & Kavanaugh, S. Capstone senior design at the University of Alabama. *In Frontiers in Education Conference Proceedings,* 1996,Vol. 1, pp. 258-262. IEEE.

[4] National Science and Technology Council.. "*Rationale and preliminary plan for federal research for construction and building*." Subcommittee on Construction and Building, 1994 ,Civilian Industrial Technology Committee,

[5] Van Nederveen, G. A., Soons, F. A. M., Suddle, S. I., & De Ridder, H. Simple, Complex, Innovative: Design Education at Civil Engineering. In IASDR 2011: *Proceedings of 4th World Conference on Design Research" Diversity and Unity*", Delft, The Netherlands, 31 October-4 November 2011. TU Delft & IASDR.

[6] Ruud, C. O., & Deleveaux, V. JDeveloping and conducting an industry based capstone design course. *In Frontiers in Education Conference Proceedings.* . 1997. Vol. 2, pp. 644-647. IEEE.

[7] Hill, A. M., Problem solving in real-life contexts: An alternative for design in technology education. *International journal of technology and design education*,1998, *8*(3), 203-220.

[8] Wu, P., Feng, Y., Pienaar, J., & Zhong, Y.,Educational Attainment and Job Requirements: Exploring the Gaps for Construction Graduates in Australia from an Industry Point of View. 2015, *Journal of Professional Issues in Engineering Education and Practice*, 06015001.

[9] Jacoby, B. Service-Learning in Higher Education: Concepts and Practices. 1996. The Jossey-Bass Higher and Adult Education Series. Jossey-Bass Publishers, 350 Sansome St., San Francisco, CA 94104.

[10] Padmanabhan, G., and Katti, D., "Using community-based projects in civil engineering capstone courses", *J. of Professional Issues in Engineering Education and Practice*, 2002, 128(1), 12-18.

[11] Mehta, Y., and Sukumaran, B., "Integrating service learning in engineering clinics", *Int. J. for Service Learning in Engineering*, 2007, 2(1), 32-43.

[12] Zhang, X., Gartner, N., Gunes, O., and Ting, J. M., "Integrating servicelearning projects into civil engineering courses", *International Journal for Service Learning in Engineering*, 2007, 2(1), 44-66.

[13] Duffy, J., Barrington, L., West, C., Heredia, M., and Barry, C., "ServiceLearning Integrated throughout a College of Engineering (SLICE)," *Advances in Engineering Education*, 2011, Summer Issue.

[14] Hayden, N. J., Rizzo, D. M., Dewoolkar, M., Neumann, M. D., Lathem, S., and Sadek, A., "Incorporating a systems approach into civil and environmental engineering curricula: effect on course redesign, and student and faculty attitudes*", Advances in Engineering Education*, 2011, Summer Issue.

[15] Sigmon, R. L., Serving to Learn, Learning to Serve: Linking Service with Learning, 1994, Council of Independent Colleges, Washington D.C.

[16] Bielefeldt, A. R., Dewoolkar, M. M., Caves, K. M., Berdanier, B. W., and Paterson, K. G., "Diverse models for incorporating service projects into engineering capstone design courses", *Int. J. of Engineering Education*, 2011, 27(6), 1206-1220.

[17] Dewoolkar, M., Lens, J., and Hayden, N., Service-Learning Design Projects to Enhance Geotechnical Engineering Education. *GeoCongress 2012*: pp. 1283-1292

[18] Dewoolkar, M. M., George, L. A., Hayden, N. J., and Neumann, M., "Handson undergraduate geotechnical engineering modules in the context of effective learning pedagogies, ABET outcomes, and curricular reform", *J. of Professional Issues in Engineering Education and Practice*, 2009, 135 (4) 161-175.

[19] Dewoolkar, M. M., George, L. A., Hayden, N. J., and Rizzo, D. M. "Vertical integration of service-learning into civil and environmental engineering curricula", *Int. J. of Engineering Education*, 2009, 56(6), 1257-1269.

[20] Jeffers, Ann E., Paul A. Beata, and Beverly Strassmann. "Qualitative Assessment of the Learning Outcomes of an International Service Learning Project in Civil Engineering." *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship* 10, no. 1 2015: 38-58.

[21] Wiggins, G. P., & McTighe, J., 2005. Understanding by design. Ascd.

[22] Hansen, E. J., Idea-based learning: A course design process to promote conceptual understanding. 2012, tylus Publishing, LLC.

[23] Hanna, A. S., & Sullivan, K. T., Bridging the gap between academics and practice: a capstone design experience. Journal of *Professional Issues in Engineering Education and Practice*, 2005, 131(1), 59-62.

[24] Batie, D. L., & Morton, D., Development and Implementation of an Industry Accelerated Construction Management Capstone Course. InProceedings of the 2008 *ASEE Southeast Section Conference*.

[25] Jenkins, S. R., Pocock, J. B., Zuraski, P. D., Meade, R. B., Mitchell, Z. W., & Farrington, J. J., Capstone course in an integrated engineering curriculum. *Journal of Professional Issues in Engineering Education and Practice*, 2002, 128(2), 75-82.

[26] Elzarka, H., Suckarieh, G., & Uwakweh, B., Redesigning the Senior Construction Management Capstone Courses at the University of Cincinnati. *In ASC Proceedings of the 38th Annual Conference* 2002,(pp. 25-32).