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SINGLE CAPSTONE OR MULTIPLE CORNERSTONES? DISTRIBUTED MODEL OF CAPSTONE SUBJECTS IN CONSTRUCTION EDUCATION

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Capstone experiences provide critical opportunities for undergraduate students to integrate and apply the skills and knowledge they have previously developed in their degree or program. Commonly, this involves students engaging in learning experiences that involve real-world issues and which in turn enhance the student experience and employability skills. The research on capstone experiences in the construction management education literature indicates a need to develop customized delivery models that addresses the specific requirements of construction industry and education providers. This paper aims to showcase an innovative model of distributed delivery for multiple capstones (cornerstones) in a construction management program. The case study described in this paper realized an improvement in capstone design and practice-based learning by incrementally enhancing a student's knowledge of construction project management skills. The model of multiple capstones discussed here is applicable to diverse disciplines, including construction engineering and management programs.

Keywords: Construction engineering and management, Distributed capstones, Global learning by design, Pedagogy, Project-based learning, Student-centered learning.

1 INTRODUCTION

Construction education has been known for its innovation in delivering industry-ready graduates who meet diverse industry demands. Part of this success is the result of using practice-based education in construction management programs. Capstone subjects, for instance, offer a range of experiences that lie outside the purview of traditional construction management subjects. Capstone courses are important in development of skills that are required by construction industry and core competencies stipulated by industry's professional institutions (McIntyre 2002, Arashpour *et al.* 2012).

A wide range of pedagogical philosophies have been utilized in developing and delivering final-year capstones. Active learning, project-based learning, and work-based learning are three prevalent approaches used for this purpose (MacDonald and Mills 2013, Arashpour *et al.* 2013b). Traditionally, the capstone subject is embedded in the final year to conclude the academic experience. Despite the success of final-year capstone subjects in numerous curriculum areas, there have been criticisms in the construction education domain about associated issues such as heavy workload for senior students and limited student-practitioner interactions (Kift *et al.* 2013, Arashpour *et al.* 2015a). Very few studies have explored the potential of using an alternative model to final-year capstone experiences in order to develop a tailored pedagogical approach for construction education.

The aim of this paper is to showcase a distributed model of capstone subjects (cornerstones) and describe the lessons learned from implementation of the model in the construction management program in the authors' university. In this distributed model, rather than having one capstone course towards the end of the degree program, students engage in a capstone subject across 3 year levels. In order to examine the efficacy and applicability of a cornerstone approach to capstones, this paper provides a review of pedagogical literature relating to the design and implementation of capstones. The authors also examine the challenges inherent in integrating final-year capstones into curriculum. Finally, the lessons learned as part of delivery process are discussed.

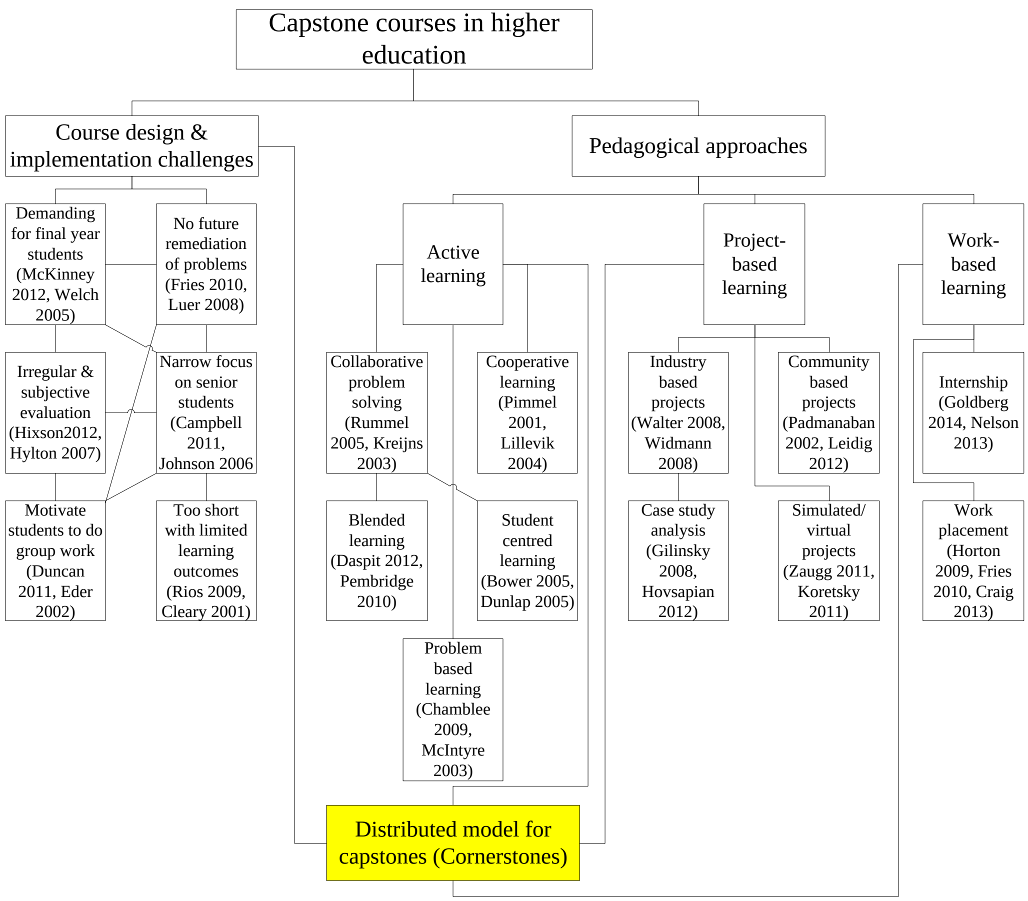

Figure 1. Pedagogical approaches used in capstone experiences and potential challenges.

2 THEORETICAL BACKGROUND

Previous research in higher education literature has shown that integration of capstone courses into a program or degree enhances the structure of a program and supports students to synthesize their prior learning and knowledge (Goldberg 2012, Arashpour *et al.* 2013a). This section of the paper, presents existing ways of integrating capstones into the curriculum that have been identified in the literature.

There are variety of paradigms in the higher education literature that support the design and implementation of capstone subjects. These pedagogical paradigms along with potential challenges have been illustrated in Figure 1.

3 DESIGNING AND IMPLEMENTING THE DISTRIBUTED MODEL OF CAPSTONE SUBJECTS: INTRODUCING THE CORNERSTONES

3.1 The Context

In order to address the challenges in developing and delivering final-year capstones, a new distributed model of capstones was implemented in the context of a Construction Management program at the authors' university. Rather than placing one capstone subject at the end of the degree program, three capstones (cornerstones) are embedded at each year level. Construction Planning and Design (CPD) subjects are offered at the second, third and fourth year of the program. CPD1 (BUIL1245), CPD2 (BUIL1256) and CPD3 (BUIL1262) are embedded in second semesters in order to reinforce the student learning over the four courses in the first semester in the related year level. The three capstone courses (cornerstones) are designed to incrementally build up knowledge as year level advances and are in line with Blooms Taxonomy and requirements of Australian Qualifications Framework (Arashpour *et al.* 2014b). Figure 2 illustrates the distributed model of cornerstones used in the Construction Management program.

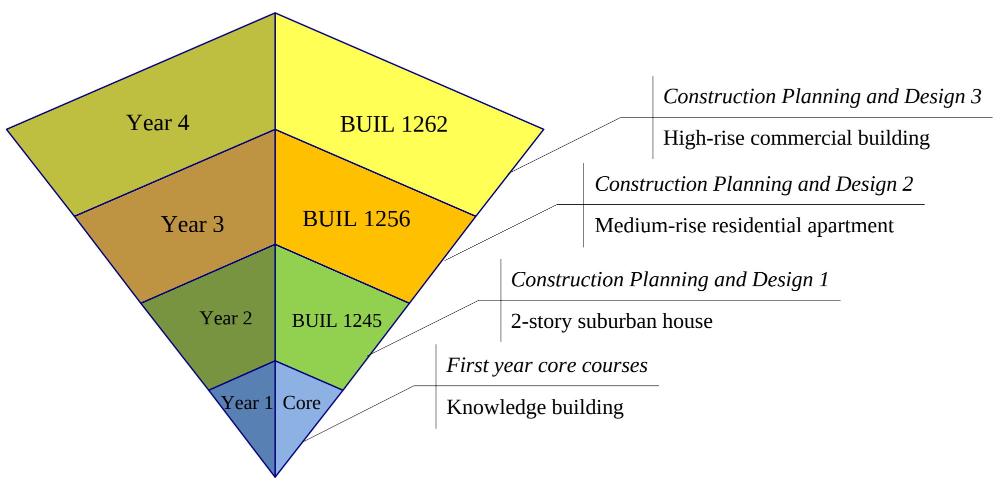

Figure 2. Distributed model of cornerstones in the construction management program.

3.2 Incremental Knowledge Building in Cornerstone Courses

In the construction Planning and Design (CPD) courses, students analyze and discuss how construction techniques, measurement, estimating and process planning apply to industry specific problem-based scenarios.

Table 1. Learning outcomes and benefits of cornerstones in the studied construction management program.

Course	Learning outcomes
Construction planning and design 1	Estimate and plan the construction of a building
	Describe the processes and technologies of construction
	Utilise production planning methods using project documentation
	Discuss how building systems interface and are constructed
Construction planning and design 2	Determine and apply complex construction management theory to the professional practice and/or further study
	Professionally communicate to a range of audiences, demonstrating in depth knowledge of the discipline and of the needs of diverse construction management stakeholders
	Apply logical critical and creative thinking to analyse, synthesise and apply theoretical knowledge and technical skills to formulate evidenced based solutions to industry problems or issues
	Collaborate effectively with others and demonstrate intellectual independence and autonomy to solve problems and/or address industry issues or imperatives
Construction planning and design 3	Integrate and apply specialised construction management skills to a current construction project
	Develop solutions to identified problems using conflict resolution skills, relevant policy and regulatory frameworks including OH & S
	Apply theoretical specialised knowledge to address problem based case studies in construction management
	Undertake independent research and apply analytical skills to produce tender submissions
	Lead and contribute to professional discussions

This scenario is a two-story suburban house in the second-year cornerstone. In third year and fourth year, a medium-rise residential apartment with basement and a high-rise commercial building is analyzed respectively. The expected learning outcomes of the three courses are presented in Table 1.

Appropriate class activities and assessment tasks have been designed for cornerstones that are proportional to the complexity level of the courses. For example, in Construction Planning and Design 2, all building documentations for a medium-rise development are given to students. As the construction literature suggest, these educational problems include but are not limited to low production rates (AbouRizk *et al.* 2001, Lee *et al.* 2013), variability and uncertainty in processes (Arashpour, Wakefield *et al.* 2013c), waste in construction (Chan *et al.* 2015), and quality problems and rework (Arashpour *et al.* 2014a). The final report for the capstone project over 12 weeks looks like the diary of a construction manager.

4 CONCLUSIONS

By addressing the challenges in developing and delivering capstone subjects, the case study described in this manuscript realized an improvement in the current state of practice-based learning in construction education. As a result, several lessons were learned from implementing the distributed model of cornerstones, including the following:

- Using multiple cornerstones at different year levels in the construction management program helped students to reinforce their learning over the course of study by overcoming the forgetting curve.
- Harnessing the distributed model of capstones in curriculum design facilitates delivering cutting-edge and innovative construction education. Several instances of interaction with industry mentors benefitted students in understanding contemporary issues of the construction industry.
- Initially more time and resources were used to set up multiple cornerstones. However, after this developing stage, the delivery stage was smooth with both students and academic staff realizing time savings.
- Despite the overwhelming success of onshore cornerstone delivery, some challenges were observed in offshore delivery. It was found necessary to coordinate lecturing staff and develop localised project-based scenarios in order to ensure quality learning outcomes in offshore delivery.
- Using internet-based tools in developing course content for blended delivery developed the online learning capacity for both students and staff. This improvement facilitated the processes of knowledge sharing and also showcasing students' works.
- Working on real-world project scenarios in cornerstones enhanced the student knowledge of construction project management skills. These skills are closely linked to the core competencies stipulated by construction industry's professional institutions such as RICS, CIOB, and AIB.

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