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Learning of sustainable infrastructure management through individual and network level

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ABSTRACT

CONTEXT

Engineering employment requires the capacity to work effectively in teams, to communicate effectively both orally and in writing, and to learn effectively. To prepare graduates for employment, they should be provided with a quality assured teaching and learning environment which is conducive to the development of adult learning: i.e., the student accepting responsibility for their own learning and by actively participating in the learning process as individuals and as contributors to teams.

PURPOSE OR GOAL

Course provides an overview of sustainable management of infrastructure both at the individual and network level. It delivers a comprehensive understanding of inspection, durability, and maintenance of structures. The deterioration mechanisms, methods of inspection, interpretation of the data, repair techniques and lifetime analysis of structures. It also discusses sustainable asset management for structures and networks of structures, from design through operation to repair and replacement.

APPROACH OR METHODOLOGY

This module is constructively aligned with the Engineers Australia competencies via a weekly 2-hour lecture, a 2-hour tutorial for project work and a 3-hour scheduled laboratory practical. The assessment plan is designed as a mixed mode. Group work is project-based learning, considering a pedagogy approach for engineering education. The laboratory project delivers a fluent application of engineering techniques, tools, and resources. At last, the individual assessment that tests both the theory based understanding and the engineering principals underpinning the engineering fundamentals applicable to the engineering discipline.

ACTUAL OR ANTICIPATED OUTCOMES

This course will provide knowledge and hands-on experience of: (1) the whole of life cycle of infrastructure systems covering the service, performance, and life expectancy; (2) the technical knowledge of standard deterioration, maintenance and repair techniques; (3) the understanding to be able to integrate technical knowledge with economic constraints and environmental sustainability to develop a management plan for critical infrastructure structures and systems essential for the needs of society; and (4) to be able to function as a professional engineer within the context of the lifecycle management of infrastructure assets.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This module integrates the technical knowledge with economic constraints and environmental sustainability to develop a management plan for critical infrastructure structure and systems essential for the needs of society. The learning outcomes will also be a guide for future technology development that will enhance sustainability.

KEYWORDS

Project-based Learning; sustainability; lifecycle assessment

Introduction

Engineering employment requires the capacity to work effectively in teams, to communicate effectively both orally and in writing, and to learn efficiently. RMIT University has emphasised its vision to enhance student learning outcomes, engagement and improve retention by implementing a student-focused learning approach. To prepare RMIT students for employment as graduates, they will be provided with a quality assured teaching and learning environment which is conducive to the development of adult learning. Adult learning is characterised by the student accepting responsibility for their own learning and by actively participating in the learning process as individuals and as contributors to teams. Adult learning is a hallmark of a professional. It is the process that transform life experience into knowledge and skills (Illeris, 2010). Literature has described adult learning as a lifelong process whereby knowledge is created through the transformation of experience (Illeris, 2010; Kolb, 1984). Furthermore, adult learning tends to be a highly self-directed and independent process (Merriam, 2010). Self-directed learning is a complex phenomenon, involving a range of activities, decision-making strategies, learning experiences and a degree of responsibility for accomplishing learning goals (Beach, 2017). The importance of adult-learning has particularly been influenced by the opportunities digital technologies have offered in recent decades, as adults can have lifelong engagement with various learning opportunities available to them for professional and personal development purposes (Boeren, 2017).

In addition, the school of engineering in RMIT has been implemented a range of project-based learning initiatives in the undergraduate courses (Hall, Palmer, & Bennett, 2012; Palmer & Hall, 2011). Project-based learning has received considerable interest for engineering education (Frank, Lavy, & Elata, 2003; Helfenbein, Nalim, & Rajagopal, 2012; Krishnan & Nalim, 2009; Lima et al., 2017; Mills & Treagust, 2003) since it can transpose the learning process closer to a 'real-world' engineering experience and improve connection to the desired graduate attributes. Students do their own learning, and the lecturer takes on a supporting role to teach students' how to learn' rather than being a 'provider of facts' to passive listeners (Frank et al., 2003). Helle, Tynjälä, and Olkinuora (2006) suggests three different purposes for implementing project-based learning, including the promotion of a "concrete and holistic experience regarding a certain process", "integration of subject material", and "self-regulated deep-level learning". Compared to traditional lectures, the active learning approach with multiple pedagogies including problem-based learning, case studies, tutorized exercises, and debates offer an opportunity to better meet the competencies that involve complex systems and holistic solutions (Segalàs, Mulder, & Ferrer-Balas, 2012). However, restructuring engineering education to incorporate new teaching methods and new concepts to meet sustainable engineering challenges is no easy feat.

This paper presents a final year infrastructure management course that provides an introduction to the management of infrastructure, both at the individual and network level. It provides background knowledge on the inspection, durability, and maintenance of structures. The deterioration mechanisms, methods of inspection, interpretation of the data, repair techniques and lifetime analysis of structures. It also provides details of asset management for structures and networks of structures, from design though operation to repair and replacement. The implementation of adult learning together with project-based learning encourages students with an active learning experience that aims to simulate a "real-world" engineering experience. The specific responsibilities of students as adult learners in respect of this subject are: effective and honest participation as a responsible member of a learning team; effective contribution to the learning of peers in a climate of mutual respect and to question each other and the academic staff when uncertain; complete all pre-reading and preparatory work prior to the class for which it will be used; effectively utilise the academic resources provided (consultation time, library etc); on-time submission of all work for assessment; develop understanding from the laboratory sessions and lectures, using them to help make links between theory and practice; manage time to facilitate efficient study and maximise learning, as far as reasonably possible.

Context

Course Overview

CIVE1173 is a final-year course in the Bachelor of Engineering (Honours) program in the Civil and Infrastructure Engineering discipline at School of Engineering, RMIT University. There are approximately 350 students enrolled annually. This is 12-week, 3 credit-point course giving 38.5 hours face-to-face teaching that comprises 2-hour lectures for 12 weeks; 2-hour tutorials for 5 weeks; 1.5-hour field visit; and 3-hour Laboratory practical session. The aim of this course is to provide an overview of the management of infrastructure both at the individual and network level. It provides a comprehensive understanding of the inspection, durability, and maintenance of structures. The deterioration mechanisms, methods of inspection, interpretation of the data, repair techniques and lifetime analysis of structures. It also discusses sustainable asset management for structures and networks of structures, from design though operation to repair and replacement. The course contributes to development of the RMIT engineering program by considering five main learning outcomes, namely: comprehensive, theory based understanding of the underpinning natural and physical engineering fundamentals applicable to the engineering discipline; in-depth understanding of specialist bodies of knowledge within the engineering discipline; understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the civil engineering discipline; fluent application of engineering techniques, tools and resources; and application of systematic approach to the conduct and management of engineering projects.

The course is organised by project-based learning approach. Students also gain skills in using a field visit and supplement their knowledge via lectures from industry speakers, including experts in design durability and assessment and ex-RMIT students who have progressed from the course to working in the industry, group-projects and individual examination. Assessments for the course are as listed in Table 1. At the successful completion of this course, students will be able to achieve: the whole of life cycle of infrastructure systems covering the service, performance, and life expectancy; the technical knowledge of standard deterioration, maintenance and repair techniques; the understanding to be able to integrate technical knowledge with economic constraints and environmental sustainability in order to develop a management plan for critical infrastructure structures and systems essential for the needs of society; and be function as a professional engineer within the context of the lifecycle management of infrastructure assets.

Table 1: Course assessments

Assessment Item	Description of Task	Weighting	Arrangement
Problem-solving Project	Lifecycle Repair Strategy	25 %	Group work
Laboratory-based learning Project	Non-destructive testing	25 %	Group work
Final Examination	Management of a structure over the operational lifetime	50 %	Individual work

Group Project

The task for student is to work in groups of five to design a lifecycle repair strategy for St Kilda pier which is an iconic part of Melbourne and one of the most popular tourism destinations. The site investigation of St Kilda pier allows students to observe and identify the durability issues at the pier and related information, Fig. 1. This task has been further developed with input from an ex-student who worked on the assessment of the structure and provided data to increase the industry relevance of the project and enhance the student learning experience, knowledge and employability, This task facilitates students' application of theoretical engineering knowledge, skills and techniques gained from lectures to identify real word engineering issues and define complex problems in a variety of contexts.

Each student group needs to identify the optimal repair strategy for the pier based on the results of a site investigation. The repair strategy is split into two sections, namely the concrete slabs of the pier deck and the substructure encompassing the reinforced concrete crossheads and piles. Initially, the visual defects present on the deck slabs are identify and recorded in the field visit. Detailed information related to these defects is provided in classroom. This is supplemented by inspection data supplied for the substructure. Once all the information has been obtained including designs, inspections and, test data, the future strategy can be decided. This depends on the design life, the results, the costs and budget, Fig. 2, each group being given a unique set of data. Students need to identify appropriate repair techniques for concrete slabs and substructure and quantify the total extent of each type of defect for the reinforced concrete elements. The students then undertake a lifecycle analysis of the various repair option to identify the optimal repair strategy given the repair costs and effective lifetimes for the various repair options.

Figure 1: Site Investigation of St Kilda Pier, Melbourne (a) St Kilda pier, (b) Salt crystallization, (c) Surface cracks and (d) corrosion of steel

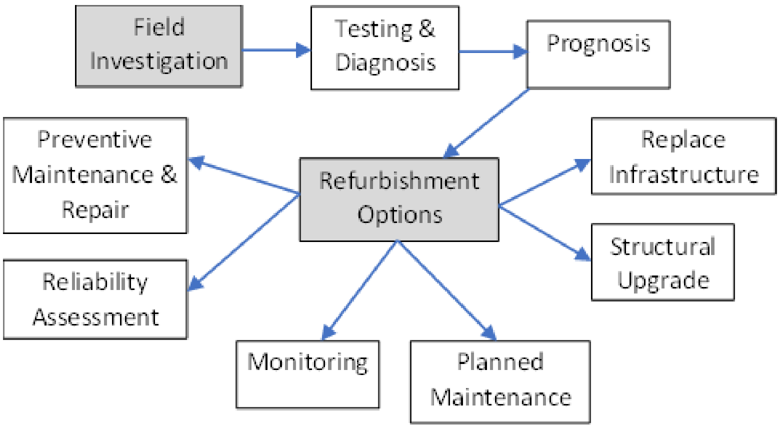

Figure 2: Lifecycle modelling

Laboratory practical

Non-destructive testing (NDT) techniques are effective in testing components for defects without damaging the component. NDT techniques such as Ultrasonic Testing, Resistivity, Schmidt Hammer, Half Cell Potentials and Linear Polarization Resistance are commonly applied NDT techniques applied for the condition assessment of structures. Each of these techniques uses different principles to investigate the material for defects. The geometry, physical and material properties of the component being tested are important factors in the applicability of a technique. The laboratory task for students is to work in groups of five to use five NDT equipment as shown in Fig. 3 and compares them in terms of characteristics and applicability to concrete composites. Each student group needs to acquire experimental data using NDT equipment and submit a detailed laboratory report interpreting their data and the fundamental principles underpinning the equipment utilized. The marks are allocated for the accuracy, presentation, and discussion of test results.

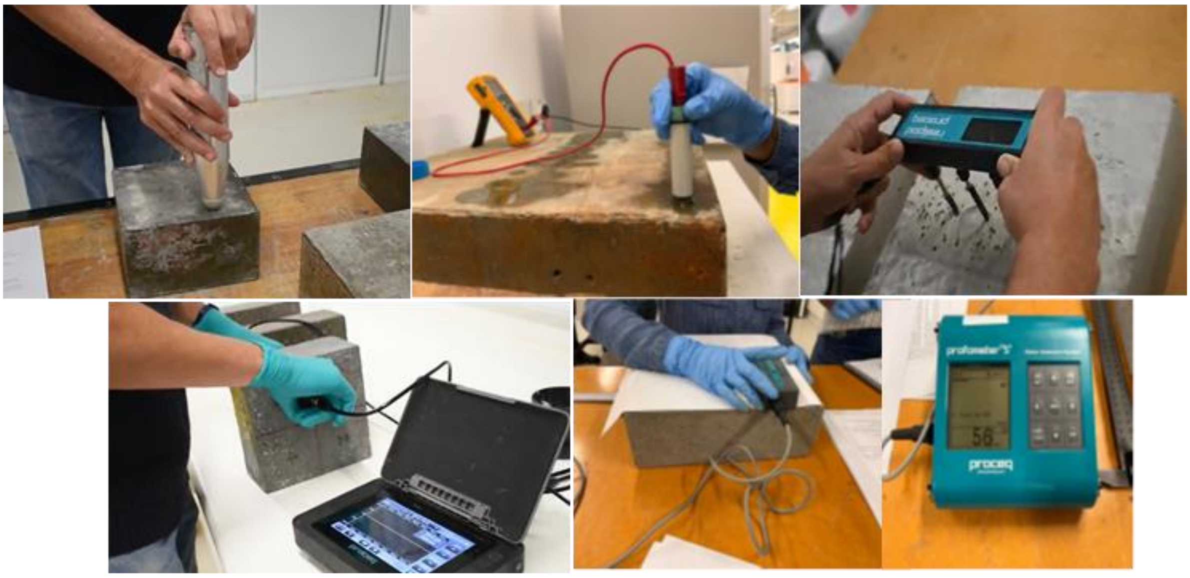

Figure 3: Laboratory practical using non-destructive testing (NDT) techniques

Individual Final Examination – Durability Plan

The final examination is to undertake an individual assessment of the management of a structure over the operational lifetime of the structure. The final examination requires the preparation of a technical report of a durability plan for the specified structure situated in the specified environment to ensure that the structure operates as designed for the specified lifetime of the structure and considering the requirements and risks associated with each phase of the structure lifetime. The structure will be a combination of mass concrete, reinforced concrete, steel and wooden elements It will have a specified design life of 50 to 100 years and be in a specified location which can include exposure to a marine, industrial or buried environment and could be in an arid, tropical or sub-tropical environment. It should operate over the design life period with no major rehabilitation however with normal maintenance and repairs. It should be designed to avoid initiation of corrosion in the reinforcing steel during the design life. The durability plan shall cover the different stages of the structure; design phase, construction phase and operation phase. Students should refer to all material in the lecture notes, tutorials and use any standards, advice documents etc that are appropriate. Students should submit a technical report providing a clear and detailed explanation for the rationale used to select the tests, standards, deterioration mechanisms, models and risks identified and discussed. The specific tasks to be covered in each Phase are defined separately. Under the design phase, testing to determine environmental exposure, identification of appropriate standards and exposure categories, deterioration mechanisms, models employed to ensure the design life is achieved and, material specification (selection of concrete type, cove, steel type, any coatings or other protective measures and design of elements to reduce durability problems) are assessed. The tasks in construction phase consists of quality assurance (that should be employed to ensure structure satisfies the design specification) and deterioration mechanisms (that can occur during construction). Finally, appropriate NDT, monitoring techniques and appropriate repair/rehabilitation options should be covered under the operation phase to ensure the lifetime is achieved of the respective structure.

Discussion

This course covers a comprehensive understanding of the inspection, durability and maintenance of structures by implementing a project-based learning approach. Throughout the course students learn how to apply scientific and engineering principles to real-life engineering problems. For instance, NDT of concrete which are facilitated through laboratory sessions in this course, is more common in the construction industry due to the requirement of verification of the properties of common construction materials. Therefore, the practical experience for a final year undergraduates student is a vital opportunity in terms of their early-stage career as a civil engineer mainly in construction industry. Students are facilitated to learn how to address complex problems and develop innovative solutions that are beneficial to an organisation and the wider community. As a graduate of this course, students will be highly sought-after by industry for their skills in engineering, decision making, problem solving, leadership, project management, teamwork and communication.
Furthermore, students will also gain practical involvement through group assessment and activities (in NDT laboratory sessions) lead to develop their social skills, teamwork, time management and decision making through group discussion. They undertake various team roles, work effectively within a team, and utilise effective teamwork skills in order to achieve learning goals during the laboratory sessions and group project. Students are able to apply interpersonal skills to interact and collaborate to improve outcomes. Students of the group should plan and manage the task, manage their time, and should be able to deliver the assessment which meet international standards and encompass best practice. The individual assessment directs students to evaluate and use recognized engineering methods to identify potential solutions to independently and collaboratively resolve complicated engineering problems and realise solutions.

This course is currently being delivered for undergraduate students in one of the Hong Kong TAFE Civil Engineering programme. The core of the core is similar however, lecture notes, assignments, group projects are restructured according to the construction condition of the respective country and based on the civil engineering environment. Moreover, this course aligns with the Advanced Materials and Manufacturing in Australian Government’s National Science and Research Priority, specifically addressing the practical research challenge of “Knowledge of Australia's comparative advantages, constraints and capacity to meet current and emerging global and domestic demand” by introducing sustainable manufacturing methods for green materials. The course is enabling students to gain UN sustainable development goals while addressing the resource recovery challenge and its management, by integrating solutions with the infrastructure boom created by increasing population and urbanisation.

Conclusion

The main aim of the project-based learning in this undergraduate course is to engage the engineering students in learning. Successful implementation of the project-based learning in this course on environmental sustainability to develop a management plan for critical infrastructure is well discussed. The learning outcomes will also be a guide for future technology development that will enhance sustainability. Students obtain knowledge and hands-on experience of the whole of life cycle of infrastructure systems, the technical knowledge and the understanding to be able to integrate technical knowledge with economic constraints and environmental sustainability. Moreover, students are beneficial and able to function as a professional engineer within the context of the lifecycle management of infrastructure assets by actively participating the course.

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