Tokomaru Bay Wharf and Heritage Buildings Restoration Design: Innovating a Holistic Final Year Civil Design Project

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Introduction

"Art without engineering is dreaming; Engineering without art is calculating"

– Steven K. Roberts

Engineers solve complex societal problems. To solve the increasingly complicated problems faced by society today, engineering students require more than technical training, they also require training in creative thinking and problem solving. The Washington Accord, an international standard for engineering accreditation, has developed a list of 12 graduate attributes that define the characteristics of an engineering graduate to be successful in professional practice (International Engineering Alliance, 2014). Only the first attribute, WA1, focuses on engineering knowledge, the application of mathematics, science, and engineering principles to solve problems. Four attributes focus on the analysis (WA2), design (WA3), and investigation (WA4), where students use their engineering knowledge to creatively design, analyse, and solve new problems after thorough investigation using the appropriate technical tools and resources (WA5). The remaining attributes emphasis a set of professional skills beyond technical knowledge and problem solving, including engagement with society (WA6), the environment (WA7), ethics (WA8), teamwork (WA9), communication (WA10), project management (WA11) and lifelong learning (WA12). Despite the variety of graduate attributes, the majority of engineering curriculum focuses on the transfer of engineering knowledge to the student and has limited focus on creative thinking, problem solving, design, or any of the professional attributes required for successful engineers.

Engineering programs must readjust curriculum to focus on educating and training future engineers in critical thinking and design in addition to technical knowledge. This will enable students to be better equipped to work with complexity and uncertainty to solve unique engineering problems without a predetermined solution (International Engineering Alliance, 2014). True engineers do more than calculations; they work with communities to solve unique challenges and problems. Figuiredo (2008) states that engineers work across multiple dimensions; they are sociologists, scientists, designers, and crafters. Traditional engineering pedagogy that focuses on lectures and dissemination of engineering fundamentals does little to foster the development of innovative problem solvers that can work within and across all dimensions of society. In 2003, Mill and Treagust identified several critical issues in engineering education. These issues included: programs that were content driven and too focused on engineering science without proper integration into practice, deficiency of sufficient design experiences, lack of communication skills and teamwork, and an absence of awareness of social, environmental, economical, and legal issues important to engineering practice (Mills & Treagust, 2003). Unfortunately, many of these issues still exist 16 years later. To improve the delivery of engineering programs, students need an early introduction to societal and engineering problems. Providing students with opportunities to observe the behaviour of engineering systems and how the systems work in a societal system from the first year of an engineering program will strengthen students' ability to acquire engineering knowledge as well as improve their experiences with the other Washington Accord graduate attributes (Dyer, 2019). To future proof engineering graduates, it is necessary to modify current teaching methods and course curricula to include greater amounts of project- or problem-based learning, foster environments for creative thinking and design, and better integrate social, environmental, economic, and legal constraints into project briefs.

Currently, the new University of Waikato Civil Engineering programme is focusing on creating new courses that integrate design and problem solving with technical competencies in an effort to prepare graduates to work on large-scale multidisciplinary projects. This year, for the final year capstone course, students are working with a community on a real-life large-scale design project. The project requires the students to examine the specific societal constraints of the community, and use their technical engineering skills to develop solutions to a complex problem.

Tokomaru Bay Wharf and Heritage Buildings

In line with Washington Accord Graduate Attributes (WA3, WA6, WA7, WA9, WA10), the Tokomaru Bay capstone project comprises an open-ended project-based design that addresses the broader aims of solving a complex infrastructure scheme with significant social, cultural, economic, and environmental issues. As such, the course created an environment for transdisciplinary thinking by bringing in experts from fields outside of engineering structured around a holistic learning framework illustrated in Figure 1. The learning framework was supported by a pedagogy that required three learning steps involving a) making observations and measurements, b) making reflections, and c) critiquing proposed solutions to the community and tutoring staff. Site visits to the project area help solidify the magnitude and scale of the project for the students. Students work in teams to create a conceptual design for the restoration of the Tokomaru Bay Wharf and Heritage Buildings.

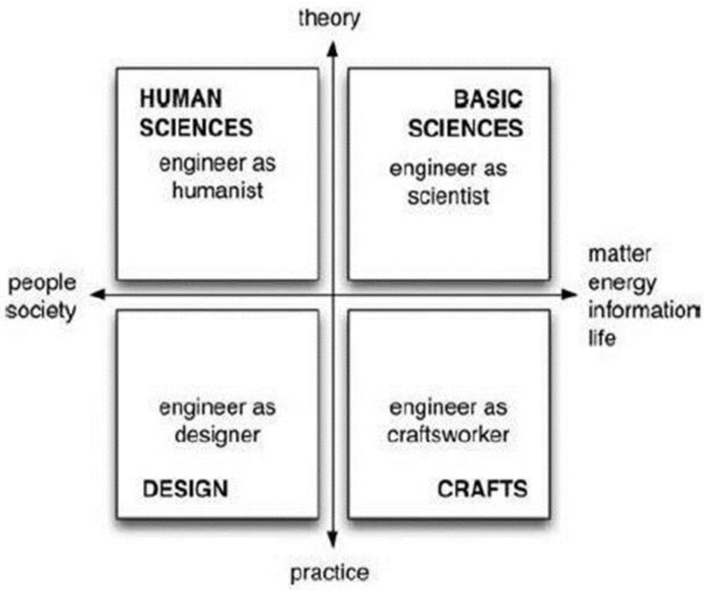

Figure 1: **Trans-disciplinary framework for Tokomura Bay Capstone Project, after Figueiredo (2008) and Dyer et al (2016).**

Tokomaru Bay is located on the East Cape of the North Island of New Zealand. The area played a historically significant role in the Freezing Works in New. Zealand. The Tokomaru Bay Freezing Works, Wharf, and Shipping Building contributed to the local economy, provided jobs, and enabled East Cape farmers a better way to sell surplus stocks of meat and wool. However, once the freezing works closed in 1952, the associated buildings and wharf begin deteriorate. (Heritage Trust New Zealand, 2019a).

The current wharf, constructed out of reinforced concrete and timber, completed in 1940 replaced a previous wharf structure. The wharf provided docking for large shipping vessels and had a small railway to carry cargo from the freezing works directly to docked ships. The closure of the freezing works in the 1950s meant the wharf was no longer required. Currently, the wharf is used by locals for fishing (Heritage New Zealand, 2019b).

The heritage buildings and wharf have significant structural deficiencies from gradual decay and deterioration in the years since the freezing works closed. Many of the freezing works buildings have suffered full or partial collapse. Some structures, such as the shipping company building, Figure 2, have not collapsed but still have significant structural defects and as an unreinforced masonry building are prone to collapse under earthquake loads. The wharf piles have significant corrosion. Many of the piles have steel rebar exposed where the concrete has cracked and fallen away. The timber section of the wharf has partially collapsed due to a lack of structural integrity, Figure 3.

Figure 2: Tokomaru Bay Shipping Company heritage building, another focal point for the project

Figure 3: Deteriorated condition of the Tokomaru Bay Wharf

Tokomaru Bay is part of a network of four wharves in the Tairawhiti, East Cape Region of New Zealand. All four of the wharves are in various states of disrepair, with some of the wharves having deteriorated beyond repair. However, to the local communities, the wharves are more than a physical presence; they are significant assets to the community. The wharves have forged the communities' identities, adding to each community's identity through the associated history and culture, and service as places of unity. A business case prepared by the Gisborne District Council estimates the total cost for rehabilitating the four wharves to be over $6Million NZD. The largest expense is the refurbishment of the wharf at Tokomaru Bay. For the investment to worthwhile, the rehabilitation must also include efforts for increasing tourism and economic growth in the region (Cook, 2019).

The Tokomaru Bay Heritage Trust has established a list of priority for the restoration of the wharf and heritage buildings. Students were required to consider these priorities as part of their design process. The list of restoration priorities provided by the heritage trust are:

- Restore the wharf's concrete piles and the wharf's wooden section
- Restore the NZ shipping company building
- Construct walkways around the freezing works' ruins (Tokomaru Bay Heritage Trust).

Delivered Program Evaluation

The final year capstone project spans over two semesters involving 300 study hours. During the first semester, students worked in teams to develop a conceptual design for the restoration of the Tokomaru Bay Wharf and Heritage buildings. The conceptual designs were required to match the Tokomaru Bay community's needs and incorporate aspects of urban design and architectural. In the second semester, students completed a detailed structural analysis and design of their projects. This paper focuses on the first semester of the course.

During the first semester, students engaged focus on design concepts, enforcing the idea that technical skills and numerical calculations are only a small part of the overall project. Designs and analyses are better when students understand how their technical capabilities fit into the overall scope of large projects. The project-based course used site visits, weekly workshops and design journals to navigate students through the open-ended project. The outcome for the first part of the project was a conceptual design report and a poster presentation to the community. Students were evaluated based on their conceptual designs, integration of urban and community planning, and interaction with the local and regional community.

Site Visit and Stakeholder Engagement

The semester started with a site visit to Tokomaru Bay. This visit provided allowed students to see the site and meet with members of the community. As part of the visit, students meet with Tokomaru Bay Heritage Trust (Tokomaru Bay Heritage Trust) and were provided with a list of priorities for the project. The Heritage Trust provided the students with copies of the original wharf building plans, documents covering previous work done to restore the area, and the community's plans for the restoration.

While in Tokomaru Bay, students walked the project around area to assess of the project scale, evaluate the current conditions of the wharf and surrounding heritage buildings, and get general dimensions for their designs. Further, students learned some of the local history, and the significance of the area, the heritage buildings, and the wharf to New Zealand. Physically visiting the site and meeting with the community solidified the reality of the project.

Interactive Workshops

The first semester of the course had a series of interactive workshops delivered by a transdisciplinary teaching team covering a mix of technical and non-technical topics; Table 1 contains a list of all the workshop topics. Early workshops focused on developing community and people-centric designs and required students to consider the historical nature of the area, the current condition of the built environment, and needs and wants of the local community for the restoration. The non-engineering topics of urban design, architecture, and risk analysis introduced students to problem-solving skills outside the typical engineering skillset. This enabled students to think beyond a textbook solution and forced them to come up with solutions to a complex problems with multiple community and economical constraints. Later workshops covered detailed technical topics specific to the historic wharf restoration not covered in previous courses.

Each workshop targeted the development of different Washington Accord Graduate Attributes. While many of the workshops enhanced technical skills or engineering knowledge, they also developed skills in communication, teamwork, and assessing societal problems. All workshops had direct integration with design and problem solving and forced students to think in the realm of a designer to incorporate multidisciplinary approaches to their conceptual designs.

Urban Design

This workshop covered the basics of urban design. The workshop focused on training students to plan and design communities based on people and not on buildings. Students mapped land use over time in the Tokomaru Bay community to get a sense of the morphological changes and learned how to distinguish desire lines in a community to create conceptual maps based on paths, edges, districts, nodes, and landmarks (Lynch, 1976).

Architectural Restoration

This workshop covered the basics of architectural restoration and introduced students to different types of restoration practices for historic buildings, various government regulations governing restoration, and material selection for restoration. Different approaches to architectural restoration including authenticity, recognisability, reversibility, and compatibility were covered and students worked on incorporating some of these approaches into their conceptual designs.

Risk and Resilience

This workshop introduced hazard and risk analysis techniques. Students considered the different types of hazards that could occur in the region, both natural and human made. After identifying hazards, students determined the impacts of the hazards on the built environment and practised using risk analysis tools such as fault trees, event trees, and failure modes and effects analysis to quantify the consequences of the risk to the region. The final conceptual designs incorporates the risk factors to improve the overall community resilience.

GIS and Mapping

During this workshop, students received an overview of GIS. They used GIS to create different maps of the Tokomaru Bay area and to visualise how the land use has changed over time.

Table 1: Workshop topics and targeted Washington Accord graduate attributes

Week	Workshop	Washington Accord Graduate Attributes
1	First site visit	**WA4** Investigation **WA6** Engineer and society **WA7** Environment
2	Brainstorming design concepts Team development	**WA9** Individual and teamwork **WA10** Communication **WA4** Investigation
3	Urban design	**WA3** Design/development of solutions **WA6** Engineer and society
4	Architectural restoration	**WA3** Design/development of solutions **WA6** Engineer and society
5	Risk and resilience	**WA1** Engineering knowledge **WA5** Modern tool use **WA6** Engineer and society
6	GIS and mapping	**WA5** Modern tool use
7	Conceptual design	**WA2** Problem analysis **WA3** Design/development of solutions
8	Conceptual design development	**WA2** Problem analysis **WA3** Design/development of solutions **WA9** Teamwork
9	Wave loading	**WA1** Engineering knowledge
10	Concrete repair	**WA1** Engineering knowledge
12	Reports and conceptual designs posters due	**WA9** Teamwork **WA10** Communications
13	Second site visit and presenting conceptual designs to the community	**WA6** Engineer and society **WA9** Teamwork **WA10** Communication

Conceptual Design Development

Conceptual design development covered two workshops. During these workshops, students learned about different design shapes and styles and how to match the design to the area. Through a range of small activities, students developed design ideas for different small-scale projects and discussed how the background, education, and interests of the designer influence ideas and designs. The workshop also covered how to select appropriate structural materials for the project based on economic constraints, customer interest, and design requirements.

Wave loading

This technical workshop covered the basic principle for assessing wave loads on marine structures. Wave loading is particularly important for the assessment and design of wharves. During the workshop, students worked on calculating the wave loading on a wharf pile.

Concrete Repair

This workshop covered specifics on the assessment and repair of marine concrete structures. The reinforced concrete sections of the wharf have significantly deteriorated over time. Rebar in the piles are exposed and corroded. The workshop focused on determining the remaining strength of damaged concrete and different methods of repair to strengthen the piles.

Design Journals

Throughout the semester, students maintained design journals that track their design progress. Design Journals are intended to be a way for students to organise thoughts as their designs developed and as a place to keep track of all of the information related to the project (Dyer, 2017). The journals include design sketches, ideas for the project, notes on the history, resources, maps, workshop activities.

Conceptual Design Report

At the end of the semester, students assimilated all of the information from the site visit, workshops, their design journals, and their individual studies to create conceptual designs for the restoration of the wharf and nearby structures. The conceptual designs were included in a comprehensive report covering some of the topics addressed in the workshops. The topics from the engineering specific workshops were not included in this report as the technical details and calculations will be included in the second report at the end of the semester. Topics and weighing for the first report are:

- History, background, building and area usage, current conditions (11%)
- Place Making and Mapping (22%)
- Architecture (22%)
- Risk and Resilience (22%)
- Conceptual design (11%)
- Conclusion and way forward (12%)

Presentations to Community

To conclude the first semester activities, students participated in a second site visit to Tokomaru Bay. The primary purpose of this visit was to present the conceptual designs to the Tokomaru Bay Heritage Trust and the local community. Students held a poster session open to the community. Posters displayed the conceptual designs and other features from the design report. Engagement with the community was positive during this trip and students received valuable feedback on their initial designs. The students' final designs will incorporate the community feedback and additional community ideas.

This site visit also provided an additional opportunity for students to visit the area. Students conducted building surveys to assess the current condition of the buildings, performed basic non-destructive testing of the concrete in the wharf to assess residual strength, and obtained measurements of key buildings. The results from these assessments provide some of the technical data required as the students go forward with their technical designs and calculations.

Course Evaluation

During the first semester of this capstone project, students created conceptual designs for a large-scale engineering project. While the final designs for this project are still on going, the course has had favourable results in terms of student work to date and the community's response. By the end of the first semesters, the students created comprehensive assessments of the urban and architectural environment and all correctly identified the risks and vulnerabilities of the community and project. The students' initial reports were initially weak in the development of their conceptual designs and plans for the community. Work in the second semester had focused on further defining the conceptual designs to enable a better basis for the detailed engineering calculations. In future iterations of the course, better communication from the teaching staff and clear expectations for the conceptual design will be used to help students create better conceptual designs. Further, the weighting of the final report put less emphasise on the conceptual design which lead to students placing less focus on the end design. Future versions of this course will adjust the final weightings to put more emphasis on the development of the conceptual design support by the other factors.

Conclusions

The fourth-year civil engineering capstone project at the University of Waikato requires students to engage in a real-life design project, engage directly with a local community to understand the specific societal, economical, and environmental impacts of the project and create final designs that show technical mastery and competency in problem analysis, design, teamwork, and community engagement.

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