Development and Implementation of a Final Year Civil Engineering Capstone Project – Successes, Lessons Learned, and Path Forward

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1 Introduction and Overview of the Capstone Project

This paper covers the development and implementation of a final year Civil Engineering Capstone Project at the University of Auckland, New Zealand. The Capstone project is based on a Civil Engineering design office experience, and allows students to experience authentic involvement with a real-world, open-ended project. Students integrate their technical knowledge by working in teams to deliver an engineering design report and presentation that must achieve real, coordinated outcomes targeted for a non-specialist client. The Capstone design project is selected each year with the help of local engineering practitioners with the goal of allowing students to work on a challenging civil engineering project. The ideal project is:

1. Local (i.e. students can visit the site in person and observe the design problems which need to be solved),
2. Currently in progress (i.e. final details of the selected solution are not yet constructed), and
3. Interdisciplinary to a degree that requires substantial problem-solving input from each specialisation within Civil Engineering (e.g. Construction, Environmental, Geotechnical, Transportation, Structural, and Water).

Students manage their own design teams of 7 to 10 individuals (depending on course enrolment numbers, which have ranged from 220 in 2018 to 240 in 2019 and are expected to increase to 260 in 2020), taking advantage of available resources to develop unique solutions to the design project (a single design project is assigned to the course, and each group develops their own solution). A short series of lectures and a site visit are included in the first weeks of the one-semester course, but student learning primarily takes place during Design Office sessions, where students work in teams on their design with the support of specialist academic staff and consulting engineers. Each team acts as a group of consulting engineers undertaking an open ended preliminary investigation and design with the assistance of technical specialist advisors and a staff member as their nominal client.

The course structure is roughly based on the deliverables and project milestones associated with a typical consulting engineering project at the scheme assessment or preliminary design level, progressing from authoring a proposal for engineering services in response to a client project brief, through to final verbal presentations and a report on the team's final design. The challenge from an instructional standpoint is taking this design process, which often takes many months (or years) for a professional engineering organisation to implement, and compressing it into a 12-week course during the second semester of the academic year which can be completed by teams of final year engineering students used to solving well-defined and technically detailed problems. Jonassen (2014) appropriately states "*Engineering students think like students, not engineers, challenging instructors to clarify and simplify the content they are distributing. If students are to learn to think like engineers, they must be challenged to solve authentic, complex problems.*" The

remainder of this paper covers the specifics of how the Capstone concept has been implemented at the University of Auckland, including the course structure, timeline, team formation process, deliverables, and assessment. There is an emphasis on lessons learned and qualitative points for future improvement, based on academic staff and coordinator interactions with students in their teams through the semester, weekly meetings of academic staff, course evaluations undertaken by each team, and from feedback provided in final team interviews.

2 Course Development during Semester 1: Project Selection, Team Formation, and Optional CADD Tutorials

2.1 Capstone Project Selection with Industry

Identifying a suitable project for the Capstone project which is local, currently in progress, and requires substantial problem-solving input from each specialisation within Civil Engineering involves a good deal of coordination between academic staff and industry, and an industry partner who is willing to share background project information and reports with students. Additionally, the academic staff involved in the course need time to review the project information along with any existing design documents, and agree upon the most appropriate deliverables for the course. This process begins early in Semester 1 due to the time and logistics involved. Because the project selection process involves identifying and coordinating with industry partners, and the evaluation of a practical engineering project in real time, academic staff with recent industry experience and/or those with industry contacts are extremely valuable to the Capstone project. In past years, a highway realignment project over a stream and a shared path along a coastline have been selected in association with the consulting engineers at GHD in Auckland. At the time of this writing, the project for the 2020 implementation of the Capstone course has not been selected.

2.2 Team Formation and Initial Communications to Students

About halfway through Semester 1, students are given a brief overview of the Capstone project and begin forming themselves into teams using a specific software application with the guidance of Capstone course coordinators. In the Capstone Project, students generally work in teams of nine (with a few exceptions depending on the total enrolment). Experience from a trial year and two years of large classes in the Capstone course has shown that with six major specialisations within Civil Engineering, a team of nine works well. Teams of eight are workable, but if a student withdraws from a team of eight, the remaining students typically struggle to complete the required work. Similarly, on teams of 10 or more, non-contributing group members may become more significant and team management issues may become more prevalent. With teams of nine, a class of about 260 students can be split into roughly 29 groups, which allows the 13 Capstone academic staff to mentor two to three groups each.

Before team formation begins, students are informed that the overall Capstone Project goal is to work together on a project, integrating all their skills in a team setting to solve a complex problem with competing constraints. They are told that the project involves real technical design with

supporting documentation to a "scheme assessment" or "preliminary design" level where costs can be estimated to about plus or minus 20%. Emphasis is also placed on the idea that the Capstone project is not a final design project which would be assessed on detailed design calculations.

The objective of team formation is to form teams of nine that all include a range of skills within Civil Engineering and cover the full range of capabilities needed for the Capstone Design Project. The steps in team formation are summarised below:

1. Students first use the team formation software application to provide information to each other that will include relevant course background, information about their intentions and expectations from the project. It allows students to note the capabilities they have from work and other experience to be contributed to the project and team. Students select their top three specialisations within Civil Engineering, their preferred team role (e.g. Team Leader, Subgroup Leader, Team Contributor). Students are also told that their completed coursework and reported work experience should be consistent with their selections.
2. Students then add themselves to teams and review the range of capabilities and experience for each member in the team and confirm that team members cover the needed skills and share the same learning objectives. Student teams will ideally have at least one person who has their first choice for each of following six specialisations, and preferably not more than two first choices in any specialisation (Management & Construction / Geotechnical / Transportation & Pavements / Hydrology & Water / Structures / Environmental & Resource Management). Students are also provided with the following warning: "*Selecting friends who do not have the right skills or the same project outlook can result in adding pressure to the team and testing friendships. It is best if you choose a team with some people you know but with the correct set of capabilities.*"
3. After students form themselves into teams, Capstone course coordinators review the team selections to verify that the teams represent a reasonable balance of capabilities and experience, and that the teams as formed by students appear to be capable of delivering the project. If teams with deficiencies are noted, coordinators have the ability to manually adjust teams after consultation with students, although in general students have done a good job of forming their own teams and intervention has not been required.

After two years of full-scale Capstone Project implementation with class sizes of 220 and 240, team dynamics in the course have generally been observed to be very positive and students have reported that the team selection process generally works well. Because students have some input in selecting their own teams, they tend to be more motivated to make them work. In future versions of the course, the software application for team formation will continue to be refined.

2.3 Optional CAD Software Tutorials

At the University of Auckland, Engineering students are introduced to Mechanical CAD drawing in their first year. However, because there is no formal Civil CAD taught in the core curriculum, and the Capstone Project deliverables involve some basic engineering drawings and schematics,

students with little or no CAD experience are given the opportunity to attend a one-day introductory tutorial session about halfway through Semester 1. This training session is provided for up to two students per team. In early versions of the Capstone course, the tutorial session was run during Semester 2, but student feedback indicated that it would be more valuable in Semester 1 because CAD skills are required relatively early in the course. If student teams have two or more competent CAD users, they are advised that there is no need for any of their team members to attend the tutorial sessions. If student teams have only one experienced CAD user, they are advised that it is strongly recommend that two additional team members attend the training.

In 2018 and 2019, the CAD tutorials were run by a Graduate Teaching Assistant and covered the use of AutoCAD and ran for approximately seven hours (including coffee and lunch breaks). The content included an overview of AutoCAD and how to install student versions, set up a basic AutoCAD drawing, edit an existing layout plan, draw a road alignment, draw simple concept cross sections of roads and bridges, draw longitudinal sections for roads and bridges, draw retaining walls, and included a demo of another software/BIM package with simple hands-on edits and viewing. Students were encouraged to attend the tutorial as both useful background for the Capstone Project and for future employment. Students who fully participate in the tutorials are given a letter to certify their attendance.

3 Course Implementation during Semester 2: Project Intro to Final Report in 12 Weeks

This section covers the structure and timeline of the course during Semester 2, which runs over 12 teaching weeks in the second semester of the academic year. The course involves approximately 220-260 students and 13 academic staff, which consist of two experts from each of the six major specialisations within Civil engineering (e.g. Construction, Environmental, Geotechnical, Transportation, Structural, and Water) and two course coordinators who function as the client (one coordinator also serves as a specialist expert). Each academic staff member also serves as a mentor to two or three groups of students, which allows them to monitor the team's overall progress and interactions and provide mild intervention as necessary (mentors are not meant to serve as project managers or take an active role in the team's design process but confirm students are aware of progress and undertaking adequate management themselves).

3.1 Project Introduction and Overview (Week 1)

In the course syllabus on the first day of class, the students are welcomed to the Capstone Project and given a Course Overview document which is a key reference point for the project deliverables and schedules. They are told that they are to take control and work as a team and develop a feasible design proposal for the Capstone Project that year. Students are advised that the project will be a preliminary design which will require near final alignment and near final sizing, but will not require detailed design. The goal of student teams should be to design each component of the project to a level of detail that will allow a reasonable construction cost estimate to be developed, and for their client to make informed decisions about how to move the project forward to detailed design and construction.

The students are told that the project is happening in real time using data from on-site investigations, and that project has a range of possible solutions and conflicting constraints. Within their team, they will allocate specific roles for each team member, but all students will need to be familiar with all aspects of the project, design process, and the team "design office" procedures. Teams are told they will visit the site, evaluate all the information provided, consider options and propose a viable design solution. Appropriate technical validation supported by calculations will be required, but detailed calculations are not the focus of what will be evaluated. Teams are told to focus on the development of a concise report which integrates each of the technical sub-disciplines into a cohesive, client-focused report summarising the key aspects of their proposed solution. Students are introduced to the two course coordinators and 12 specialist technical advisors, along with the primary industry contributors for the semester.

3.2 Due Dates and Assessment Weighting for Formal Deliverables

On the first day of class, student teams are informed of the due dates for formal course deliverables, summarised in Table 1 for reference (further details of specific deliverables and assessments thereof are covered in subsequent sections). It is also emphasised to students that in addition to their Capstone deliverables, there will be many competing constraints on their time at the end of the semester (especially related to their Final Year Research Projects), and that making substantial progress at the beginning of the semester is imperative.

3.3 Classroom Lectures, Design Office Sessions, and Learning Approach

The timeline of classroom lectures, design office sessions, and tutorial hours is summarised in Table 2, with additional discussion of student expectations following. Students in the course are advised to expect 6 hours of briefing lectures, a 2 hour design office each week for 10 weeks, 4 hours of supplementary class support, 4 hour site visit, and 100 hours of work on assignments, analysis, report and presentation preparation (includes 16 hours in the assigned design office), 2 hours of team presentations and interviews.

Students are expected to attend all lectures and to be aware of all presented content even if they are focussed on one sub-discipline. The course is intended to be a simulation of a design office experience, working in a team on a specific open ended project that must achieve real coordinated outcomes. Students will largely self-direct their learning based on previous coursework and extend their technical knowledge specific to the project and apply it to their design. Students will manage their team and take advantage of the available resources including specialist staff and consulting engineers. Students are encouraged to make use of the technical advisors available. Students are to seek their help and make specific requests for all aspects of the project. There will be some casual advice provided, but it is the students' responsibility to seek the information they need to make progress.

Table 1. Due Dates and Assessment Weighting for Formal Course Deliverables.

Due Date(s)	Deliverable	% of Final Mark	Location
Friday Week 2	Project Site Visit	--	Project Site
Friday Week 3	Technical Scope and Project Proposal	10	Submitted electronically
Friday Week 6	Presentation and Q&A	15[1]	Design Office room
Friday Week 6	"40% Design" Report		Submitted electronically
Friday Week 10	Preliminary Report	5	Submitted electronically
Thursday Week 12	Final Report	60[2]	Submitted electronically -AND- Hardcopy delivered
Friday Week 12	Presentation and Team Interview	10[1,2]	Presentation Venue. Some teams present in Week 12 and the remainder present in Week 13 *(Initial Exam week)*
Tuesday Week 13			

Notes:
[1] Presentations include an individual score that contributes 5% towards the final mark.
[2] The final report includes technical appendices with individual contributions noted. Student marks include an individual proportional weighting based on the appendices to which they contributed. The final report is additionally modified by a peer assessment factor which could reduce an individual student's share of the marks. The team interview evaluates students' overall understanding of the project and confirms the validity of the peer assessment.

Table 2. Timeline of Lectures, Tutorials, and Design Office Sessions.

Lecture Room	Time	Purpose
Lecture Hall	Tuesdays (1 hour sessions)	Lectures and Tutorial Sessions
Lecture Hall	Friday Week 1 (1 hour)	Special Week 1 Lecture
Lecture Hall	Friday Week 3 (1 hour)	Special Week 3 Lecture
Tutorial Rooms (Six Total)	Fridays (2 hour sessions)	Design Office Sessions

It is expected that the "Design Office" sessions will be attended as an employee obligation; otherwise, students should provide appropriate notification and make alternative arrangements with their team leader. The various components of the project are very interdependent, requiring

close coordination and communication between team members from various sub-disciplines. Subgroups and individuals need to make progress outside of the "Design Office" time, with the "Design Office" sessions serving as a weekly opportunity for a formal team meeting and collaborative work. Students are advised that the project outcomes will be largely assessed based on the submission of a team report. This will include individual and team components of the mark and will include a peer assessment factor. The processes and performance of the team as noted in the course outline will be evaluated in all the assessments and also in observed roles that are undertaken.

3.4 Week 3 Assessment: Technical Scope and Project Proposal (10% of Final Mark)

3.4.1 Weeks 1 & 2 – Preparation for Week 3 submission

In their initial preparation for the technical scope and project proposal submission, students are advised to update their individual CV content based on what they submitted for Team Formation prior to the start of the semester, but more focussed on what evidence they would want to give a client about their capabilities. Example CV's from industry are provided as guidelines for students. During this time, the team is to make a preliminary evaluation of the technical and support material provided for the project and determine the amount of work they can accomplish in each of the technical areas. Teams are to assign a team leader and collectively agree on the roles all team members will undertake to complete the minimum tasks required for the final Report. Students are advised that these roles may change or evolve with time, but need to be proposed for the most effective performance of the team to the best of their initial project understanding.

3.4.2 Week 2 – Site Visit

On Friday of Week 2, a site visit is coordinated to allow all students, staff, and industry participants (as available) to view the project site in person in advance of their proposal submission. Students are advised that for the site visit, it is strongly recommended that they bring cameras/phones with plenty of memory space, and bring a clipboard, notebook, or some other means of taking notes. They are also advised that when they are walking the site and discussing with teammates, it is very easy to get caught up in the moment and forget to document items of interest in the form of photos or notes, so they should take care to document their observations contemporaneously in such a fashion that they will still make sense weeks or months from now. During the final reports and presentations, photographs and sketches created by students during or soon after the site visit have often formed the basis for their final designs.

3.4.3 Week 3 – Submission

On Friday of Week 3, student teams submit a technical scope and project proposal analogous to what a team of consulting engineers would submit to a client soliciting bids for an engineering design project. Required items for this submission include:

1) A document that overviews the Scope of the project and what tasks will be required to complete the report. This document should include an overview of who will undertake each task in order to deliver a concise, well targeted, and technically sound final report. It should also include who is going to take what leadership/management roles within the team, a simple work timeline, and a table showing the time allocations to a maximum of 100 hours per person, to be charged at $170 NZD per hour.
2) A well-formatted CV for each team member, two sides of A4 maximum (about 1 page pure text) including what capabilities they have developed from relevant courses, and other relevant experiences or special skills.
3) A bullet point list of the key drawings, illustrations, photographs and tables the team proposes for the body your final report (there will be additional content in technical appendices). Students are required to note what key resources (e.g. design manuals, software analysis packages, etc.) they plan to use beyond what is provided in the course information.
4) A covering proposal letter to "the client" in response to the Request for Proposal (RFP). The letter should concisely explain what student teams understand to be the key objectives of the project, the work they are going to undertake, the general overview of what will be provided in the final report, and the final price to undertake the work. (Two A4 pages maximum in formal letter layout.) This is a well-structured, non-technical explanatory summary of the work product that student teams propose to deliver to the client – not a sales pitch for their services.

There needs to be adequate detail in this document for the staff and review panel to consider if the team's proposed work plan is adequate for a high quality output, or to give feedback or indicate where it is over-ambitious or lacking in detail. Students are advised that because they will be expected to keep timesheets, time allocations at this stage should be as realistic as possible (it is also noted that it is generally better to overestimate your time allocation at the pricing stage). The document is submitted electronically in the form of a single compiled PDF file.

3.4.4 Successes and Lessons Learned

The logistics of conducting a site visit with about 240 students, 13 academic staff, and potentially industry and public participants can be daunting. Although the site visit involves a large coordination effort, student feedback, personal experience, and published research (e.g. Swan et al. 2014) indicates that the site visit is a critical component of the Capstone experience. The benefits of the site visit on the development of students' practical problem solving skills are difficult to replace, and students have consistently reported that the site visit was a crucial element in them transitioning from viewing engineering projects as real-life problems which require practicality, compromise, and engineering judgment rather than abstract theoretical exercises which have a perfect solution.

General staff experience over the past two years indicates that student proposals tend to be somewhat over-scoped (i.e. too much is promised for the given time allocation) and relatively

vague (i.e. not enough specifics on scope are provided to objectively evaluate when a task is done). Some of this may be inevitable when dealing with teams who have relatively little practical experience scoping and budgeting engineering design projects, but there may be opportunities for improved direction from lecturers regarding proposal writing. In future versions of the course, more elements of how to write a project proposal may be introduced, although the first weeks of the course are typically crowded with introductory material.

3.5 Week 6 Assessment: Team Presentation / Q&A, "40% Design" Report (15% of Final Mark)

3.5.1 Weeks 3 to 6 – Preparation

Students are advised that over these three weeks, the provided technical and support documents should be thoroughly reviewed for the project data relevant to your proposed solution. The data should be fully evaluated and a detailed programme of work confirmed within the team. Where additional information is required, students need to identify how (or if) they can obtain that information, what additional skills they need to learn, and make early information requests to the client for additional information.

Preliminary work plans for how the team will approach the design alternatives should be developed and integrated. Key decisions for each aspect should be mapped so that dependencies are clear and are anticipated (e.g. where geotechnical decisions could impact the structural engineering, or where hydrology could change alignment etc.). Each member should be progressing the design of their individual components, with special consideration given to how they will be integrated into the overall structure of the final report.

3.5.2 Week 6 – Submission

On Friday of Week 6, roughly half the team (usually four people from a team of nine) present on their design progress and anticipated outcomes to a panel of academic staff and industry volunteers as available, using PowerPoint or similar presentation software. Following the presentation (maximum time of 15 minutes), the panel provides feedback and engages in a question and answer session with the entire team for about 15 minutes following the presentation. The presentation assessment includes a team mark and an individual mark for presenters; the weighting of the individual mark is 5% of the overall course mark. Students who do not present in Week 6 receive their individual presentation mark during the final presentations in Week 12. The Week 6 presentation is to include:

1. An overview of:
    a. The project;
    b. The social, political and environmental context; and
    c. The technical work proposed
2. A progress report on the technical work and issues faced

3. Near final details on approximately 40% of the final report content and two technical appendices
4. A forward-looking update on:
    a. What is going to be achieved by final report submission;
    b. The time/budget spent compared to the proposed timeline; and
    c. An evaluation of the roles being undertaken and their effectiveness

Additionally in Week 6, students submit a "40% Design" report electronically as a single PDF file for evaluation and feedback (analogous to an early draft report provided to a client on a typical consulting engineering project). Students are advised that at the "40% Design" stage, the overall structure of the team's design report and proposed solutions should be taking shape, and a few simple, preliminary calculations to determine feasibility of proposed solutions should be near complete. The main purpose of the "40% Design" report is to provide the client with a document to supplement the Week 6 presentation which allows them a chance to evaluate and provide feedback on the project plans in big picture terms. Students are advised that most of the report will be 40% complete with the two most advanced technical sub-disciplines providing indicative technical detail at the "80% Design" stage. All the technical aspects of the team solutions can be refined during the preparation of the preliminary report.

3.5.3 Successes and Lessons Learned

The "40% Design" Report deliverable was introduced for the 2019 version of the course, after it was observed in 2018 (when only the presentation was required) that students had made very little progress by Week 6 and generally seemed to lack an understanding of how much work remained to deliver the final product. Initial reactions to the introduction of the "40% Design" report were extremely positive from both students (who appreciated the external pressure to complete more work at an earlier stage in the semester) and staff (who appreciated the ability to get a sense of which teams were doing well and which may need intervention to keep their projects on track).

General staff experience indicates that on the Week 6 presentation and "40% Design" report, because initial team formation is focused on students' abilities relative to the specialisations within Civil Engineering, students have had a tendency to structure their deliverables more in terms of sub-disciplines (e.g. transport, structures, geotechnical, etc.) than in terms of client objectives (e.g. end goals of project, construction costs, stakeholder considerations, etc.). For future versions of the course, increased emphasis on structuring reports in terms of client concerns rather than team member specialisations will be provided earlier in the semester. In the 2019 course, a lecture on client-focussed report writing was delivered during the second half of the semester which incorporated staff experiences, contrasted the goals of an engineering design report with the goals a final year research report (which the students are also writing during Semester 2), and incorporated general pointers from Kmiec and Longo (2017) and Write Limited (2017). Following the lecture, staff observed a notable increase in report quality; the lecture may be moved earlier for future versions of the course so that students are exposed to the material prior to the Week 6 submission.

3.6 Week 10 Assessment: Preliminary Report (5% of Final Mark)

3.6.1 Weeks 7, 8, and 10 – Preparation

During these three weeks (Week 9 is not available for work due to a week-long Faculty of Engineering activity involving all fourth-year students), students are advised that all the technical work should be completed, with photographs, diagrams, tables and drawings near complete. The structure of the report should be final and all the background data evaluation and introductory work should be completed. The body of the report should include a number of clear illustrations to quickly orient the reader to the team's key design decisions. These illustrations need to make the concepts clear to the client, but do not need to be technical drawings.

3.6.2 Week 10 – Submission

On Friday of Week 10, the team is to submit a Preliminary Report, analogous to a "90% Draft" submitted on a typical engineering design project. This report is to include:

1. A single page summary of the team's progress to date and what remains to be done;
2. A Table of Contents for the Report (page numbers not needed) which should include all headings/subheadings to clearly indicate the full report structure;
3. A fully formatted draft of several sections of the final report body, including introductory material and key tables/diagrams/drawings; and
4. One complete sub-discipline appendix of the final report

The Preliminary Report is submitted electronically a single compiled PDF file. This preliminary report receives rapid preliminary feedback in Week 11 to help with students' efforts in bringing together the final report.

3.6.3 Successes and Lessons Learned

Staff and student experience over the past two years has been mixed on the preliminary report. Because feedback turnaround times are very short and involve 13 academic staff quickly providing qualitative input on a relatively high page count, students have complained about inconsistency or lack of clarity in feedback, or mixed messages from different academic staff on the level of detail required for final design. Some improvements were made in this regard between 2018 and 2019 by increasing the time that staff have to provide feedback to students and providing additional staff guidance on how to assess reports consistently, but there is still room for improvement in the assessment of the preliminary report. In future versions of the course, the process for quickly providing feedback and assessment on this preliminary report will be revisited and adjusted for improved clarity and consistency.

3.7 Week 12 Assessment: Final Report (60% of Final Mark)

3.7.1 Weeks 11 and 12 – Preparation

During these two weeks, all technical work should be complete and the team should focus their efforts on bringing their work together into a concise, well-structured report which allows the client to easily understand the key objectives, conclusions, and results of the team's design process. The report should not include dense technical discussion or detailed calculations; technical details of the project's design approach are to be compiled into technical appendices which would be suitable for a specialist reviewer to quickly check that the proposed design solutions are fundamentally and technically sound.

3.7.2 Week 12 – Submission

The Week 12 submission, the final team report, is to be well structured and well formatted with adequate white space, submitted in both electronic form (as a single compiled PDF file) and one hardcopy. Minimum requirements and contents for the final report are:

1. Bound, A4 pages, 10-pt minimum font size. Use an appropriately sized comb binding (or similar). Students are advised to not leave report binding and assembly until the last minute, and that the professionalism and quality of their final product will be adversely affected if it is hastily assembled and bound.
2. Formal cover page
3. List of authors
4. Executive Summary (2 pages)
5. Table of Contents
6. Major sections and subsections clearly identified. In total, the report should contain about 20-30 pages of concise, well-written text, diagrams, and tables. Emphasis should be placed on organisation, structure, and clarity rather than attempting to maximise the amount of information provided.
7. Technical drawings, formal illustrations, and/or site photographs
8. References – Technical references with any formal referencing system. Technical appendices may contain their own lists of references.
9. Appendix A – Team Management Details, including:
    a. Time summary for personnel and consulting cost compared with price
    b. Typical timesheet
    c. Meeting minutes for a typical meeting
    d. CV's of all Team members (appropriate to the project)
    e. List of each authors written contributions and team roles undertaken, including a roughly 200-word statement on the team structure and way of working
10. Appendix B – List of files and supplementary documents which do not form part of the final report
11. Appendices C (and more) – Technical Appendices: each appendix should represent one major sub-discipline, and should contain the major technical details supplementing the report, along with summary calculations and the relevant details of more highly technical

calculations. Technical appendices should be well structured and organised, and should provide a deeper technical background to the key aspects of the project. As with the report, the emphasis in technical appendices should be on organisation, structure, and clarity, rather than attempting to generate as much information as possible. The technical appendices should be less than approximately 60 pages total with no more than 20 pages in any individual appendix.

12. Electronic Compendium – Where technical work has involved substantive calculations, data sets or support material that would be too extensive or repetitive for the Appendices this may be optionally submitted electronically as a PDF file. It should be one document which is a compilation of each clearly designated sub-discipline that requires compendium additions. Students are advised that the Electronic Compendium will not be specifically marked and only viewed as needed for further confirmation of points in the appendices.

3.7.3 Successes and Lessons Learned

Experience over the past two years has been very positive with the Final Reports. Both academic staff and industry practitioners involved with the course have commented on the high quality of output achieved by most groups in the course, and student teams have a great sense of accomplishment when delivering a well-structured and attractive report which represents the culmination of their engineering degree. Reports submitted in 2019 were generally of a higher quality than those submitted in 2018, as more guidance was provided by lecturers on the specific elements of a quality report and the students achieved more work earlier due to the introduction of the "40% Design" report deliverable in Week 6. Staff also generally noted an improvement in writing quality over the course of the semester, consistent with the observations discussed in Fries et al. (2017). In future versions of the course, guidance on the Final Report will likely remain similar, potentially with the lecture on client-focussed report writing moving into the first half of the semester.

3.8 Week 12 or 13 Assessment: Presentation and Team Interview (10%)

On either Friday of Week 12 or Tuesday of Week 13 (some teams present in Week 12, the remainder in Week 13), the four or five team members who did not present in Week 6 deliver a 15 minute presentation, followed by a 30 minute interview to be conducted with all team members. Prior to this presentation, each team member is asked to submit a confidential peer evaluation to measure the relative contributions of each team member. The main purpose of the presentation and team interview is to summarise the key project outcomes, to evaluate what they have learned as part of the Capstone project, and for advisors to get a sense of team dynamics and individual contributions to supplement the peer evaluations.

At the end of the formal verbal assessment students are asked for feedback on the course. This has been rewarding with students quickly understanding the relevance of the learning but additionally giving very specific suggestions for improvement.

3.8.1 Successes and Lessons Learned

Similar to the Final Report, the feedback from staff, students, and industry on the Final Presentations has been very positive. Students have generally responded well to challenging questions about their projects and have shown a good grasp of the overall flow of an engineering design project, the context of their roles as individuals on a project team, and the role of an engineering design report on a project as a whole. In future versions of the course, the basic format of the final presentations will likely remain similar, with incremental improvements related to logistics and staff scheduling on the day being the main point for improvement.

4 Conclusions and Path Forward

This paper has summarised the course structure and lessons learned from the first years of a final year Civil Engineering Capstone Project at the University of Auckland, New Zealand. The Capstone Project incorporates many of the features of an open-ended, industry-affiliated project as described in Dutson et al. (1997) and has implemented them for a large class size of approximately 220 to 260 (or more) students, with generally good results and positive feedback from students, staff, and industry. Through the incorporation of real-world, open-ended problems, student interaction with industry practitioners working on similar projects, and an emphasis on a higher level understanding of the project context and goals, the University of Auckland Capstone Project incorporates several of the aspects Naylor (2016) has identified as key to increasing the relevance of tertiary engineering studies in New Zealand.

After being involved as an industry contributor in the first years of the Capstone Project at the University of Auckland, Sean Dowdall (Business Group Leader – Infrastructure Technology Delivery at GHD) provided the following commentary on the value of the course:

> "*Many of our summer students and new graduates have communicated with me in regard to the value they have gained from this multidisciplinary project, explaining that they have gained skills they can apply in the workplace. Key attributes we look for in our potential graduates and employees is confidence, interpersonal skills and the ability to collaborate, which in the past has been very difficult to teach. This project has enabled students to interact on a professional level with lecturers and industry professionals and to develop these skills, and we are extremely proud of this course that the Engineering Faculty team have created.*"

As the Capstone Project moves into 2020 and beyond, the course will continue to evolve and be refined based on experiences, feedback, and observations. Procedures for obtaining additional quantitative student feedback may also be introduced. The basic framework of the course has been demonstrated to provide a rewarding experience for the students, academic staff, and industry practitioners involved. Although challenges still exist (e.g. maintaining consistency across large numbers of students and staff, the need to select a new project each year, etc.) the course is well-positioned to build on its successes helping to prepare engineering students for the realities of functioning as effective problem solvers in a rapidly changing world.

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