Delivering an Effective Balance of Soft and Technical Skills within Project-Based Engineering Courses

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Daniel Konings
Department of Mechanical & Electrical Engineering
Massey University
Auckland, New Zealand
d.konings@massey.ac.nz

Mathew Legg
Department of Mechanical & Electrical Engineering
Massey University
Auckland, New Zealand
m.legg@massey.ac.nz

***Abstract*—As technology advances exponentially, the requirements of engineering graduates are everchanging as they are developed to meet the needs of the 21st Century industry. To ensure graduates meet evolving industry requirements, university educators need to teach in a way that stays relevant to industry, while maintaining the quality of graduates. Project-based learning offers an effective solution as the projects can evolve based on industry needs, while maintaining consistent learning objectives that ensure equity of outcomes. This paper focusses on the effective delivery of project-based courses for engineering students. Paper structure is discussed, with a pathway given for varied soft-skills implementation. Examples are given from two undergraduate courses, showing the progression of soft/technical skills implementation. Mitigation strategies for teaching project-based courses within a COVID-19 lockdown setting are given, with ongoing challenges discussed.**

Keywords—project-based learning (PBL), industry skills, engineering education, soft skills, covid-19

I. Introduction

The Washington Accord (WA) is a multi-lateral agreement between bodies responsible for accrediting tertiary-level engineering programs within their respective jurisdictions, to assist in the mobility of professional engineers. The original signatories included USA, Canada, Ireland, UK, Australia and New Zealand. Fourteen other jurisdictions have since joined. The accord provides a framework for the mutual recognition of "*accredited engineering degree programs. It also establishes and benchmarks the standard for professional engineering education across those bodies*" [1]. The accord outlines 8 knowledge profiles and 12 attributes that graduates must have been taught/be familiar with for any degree program to attain and maintain their Washington Accord status. The accord outlines 4 graduate attributes (WA9-WA12) that require graduates to have gained the 'soft' skills of: individual autonomy, effective teamwork, oral communication, written communication, project management, finance, and a preparation for lifelong learning [1]. In 2010, Engineering New Zealand (ENZ) prepared a report to "*develop a coherent national plan for ensuring that the right numbers of the right types of [engineering] graduates are produced to meet New Zealand's needs*" [2]. Through consultation with industry and tertiary providers, several key outcomes arose which included: "*There is a need for professional engineering graduates who are 'rounded' and not just technical boffins – many of the existing graduates do not have strong 'soft' skills. Graduates entering industry have technical knowledge that is largely theoretical, and industry needs to invest considerably to close off the knowledge gap between principles as taught and codified knowledge as used in industry*" [2]. Unfortunately, this is not an isolated assessment, with multiple studies showing that engineering graduates do not meet industry [3-6] or program accreditation expectations [7].

Engineers currently make up only 3% of New Zealand's workforce, however they contribute 5% of New Zealand's GDP. Engineering positions produce on average $213,000 of GDP per employee, nearly twice the amount of an average New Zealand worker [8]. Considering the devastating impact COVID-19 has had on the New Zealand economy, the government has committed an additional $334m funding to increase tertiary enrollments, and $141m to support high quality tertiary/trades education [9]. This includes targeted funding for civil, electrical and mechanical engineering which have been identified as crucial employment growth areas in aid of New Zealand's COVID-19 recovery effort. This becomes more important considering New Zealand is not currently producing enough engineering graduates to support local industry [2], with an additional 500 engineering graduates required each year [10]. New Zealand has a clear need for graduates that can efficiently learn new skills (WA12), and quickly provide a net benefit to New Zealand's industry without requiring an extensive multi-year post-tertiary industry induction.

A. Contribution

The authors believe that delivering both individual and group project-based learning (PBL) courses can assist students in attaining an effective balance of soft and technical skills, resulting in increased industry-readiness. By providing projects with clearly defined deliverables and an open-ended development pathway, Massey University provides an explicit focus on developing the following soft skills: spatial skills [11], teamwork, oral/written communication, conflict resolution, time management/meeting deadlines, autonomy, goal orientation, problem solving, creativity and innovation, continuous learning, attention to detail, flexibility, decision-making, leadership [12], cultural awareness, environmental consideration and ethical awareness among others. Project-based learning has been around for several decades; however, the literature focus has primarily been on implementing it in the final year(s) of a degree program [13-15]. This paper outlines the implementation of a project spine within an undergraduate engineering program and offers the following contributions:

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- Provides a framework for implementing project-based learning within all stages of an undergraduate engineering program.
- Outlines the balance between soft/technical skills within a 4-year project-based spine, with examples given from 1st and 3rd year undergraduate papers.
- Provides an example of changes made to project-based papers to allow them to continue operating remotely through the ongoing COVID-19 pandemic, and discusses the ongoing challenges faced by project-based courses.

The rest of the paper is organized as follows: section II outlines related literature, section III provides an overview of the degree structure at Massey University, section IV provides a course overview, section V outlines the impact COVID-19 has had on courses, section VI outlines ongoing challenges, section VII provides the results of a student survey and section VIII concludes the paper.

II. Related Works

Belski [16] and Lappalainen [3] outlined an increased industry desire for "creative" engineering graduates, with higher levels of emotional intelligence. Belski noted that standard engineering education has not been able to appropriately develop this competency. They believe that STEM degrees need to provide a concerted effort to enhance cognitive skills alongside disciple specific knowledge, with open-ended problem solving given as a potential solution. Hämäläinen et al expanded on the concept of "creative" engineering graduates by comparing the 'capacity for engineering systems' (CEST) framework with generic skills mentioned by a World Economics Forum report as essential for the 4th industrial revolution [17]. They termed "Systems Intelligence" as a conceptual way to encompass the personal mastery, systems thinking, and the emotional intelligence skills required of 21st century engineering graduates. They suggested that Systems Intelligence can be effectively implemented in higher education through gamification or conceptual implementation within lecture content.

Christie and Graaff state that the problem with a traditional lecture/tutorial/laboratory structure is that lectures cannot tell "*if students understand what they are explaining*" [18]. This compartmentalizes students conceptual understanding and their practical skills, which limits their ability to adequately generalize problems. They propose active learning (using student-centered PBL) as a solution and note that the 'Conceive, Design, Implement and Operate' (CDIO) PBL framework has been working successfully since its conception in 1997. Student evaluations from a project-based course in [19] show that students believe that project-based learning is an effective tool to increase their creativity and provide them the opportunity to solve generalized problems. The students also appreciated that grades were not arbitrarily derived from test performance, but rather project outcomes. This instills an attitude of fairness, as students can see their progress during the course and know that their grade will reflect the ongoing effort they put into their outcome. Scott et al outlines the effectiveness of project-based learning in engineering education as a way of increasing student autonomy and industry-readiness [15]. They propose a mixed-mode approach with traditional courses taught in early years, with an increased focus on project-based learning in later years of a program. The authors in [20-22] outline the difficulty in implementing an effective PBL program, with increased demands placed on the staff member undertaking the role of project supervisor. However, if implemented effectively, PBL can provide a sufficient basis for engineering education in a world of "*rapid pace engineering innovation*" [18].

Izu outlined the challenges experiences in running a capstone project course with masters students of varying academic competencies [14]. Izu showed that by allocating projects that can be incrementally implemented, alongside clear goal setting and a student-led implementation process, overall student outcomes can be improved. A practical outworking of this is given by Sameulsen and Graven in [23] which showed that student motivation can be maintained by providing ongoing access to varying hardware platforms. They attribute part of the success to incorporating a 'housekeeping' system that allows the students to deploy their code on costly RC cars/drones for testing, while allowing the system to automatically shut down if hardware damage is likely. This maximizes student engagement and encourages them to try out new concepts at all stages of the degree. A limitation of [14] and [23] is that they predominantly focused on improving students technical proficiency, which may limit ongoing soft skills development. While [13][15] proposes implementing PBL in later years of a degree program, we believe PBL must be incorporated in all years of a program to optimize soft skills growth alongside the inherent technical foundation knowledge. In this manuscript we show an example of how PBL can be used as a low risk way to teach soft skills in the early years of a degree program, with tangible flow-through benefits to later PBL papers.

III. Degree Overview

The New Zealand tertiary education commission report outlines three non-technical capabilities that are vital for training successful engineers, and provides four recommended implementation pathways [6]. The three non-technical themes include:

- *"Emotional maturity: the ability to work in teams and communicate well,*
- *Life-long learning: the ability to assess and improve their abilities and performance, and*
- *Contingent reasoning: the ability to work in a context of risk and uncertainty."*

The recommended implementation pathways for the themes include: targeted teaching of emotional intelligence within early years of the degrees, implementation of the CDIO framework, greater emphasis on engineering internships undertaken during the degree, and multidisciplinary team working.

Based on accreditation advice, industry requirements and current literature on best-practice engineering education, Massey University restructured the engineering program in 2013 to include a 'project-based spine'. This is shown by the green sections in Fig. 1. Each 15 PBL credit course is run for 12 weeks. The 30 credit courses run during a double semester for a total of 24 weeks.

One goal of the project spine is to facilitate creative problem solving and focused soft skills development during the first two years. This leads to increased social awareness and improves overall technical competency when students undertake their 3rd and 4th year projects as they work more effectively in teams and can present their designs in a coherent professional manner. An example of each years

Fig. 1. Massey University undergraduate engineering program structure.

finished project output is given in Fig. 2. The learning objectives (LO) for each year of project work are outlined in Table I. This structure has proven to be beneficial as students learn to work in teams and present their work orally and in written form early in their degree. This provides students with more feedback early in their degree, which improves the quality of submissions that are received in their 3rd and 4th year projects.

Project competency is built over time, with the technical expectations increasing as shown by the outcomes in Fig. 2. The 1st year projects involve simple deliverables, with the focus being on the students learning fundamental soft skills. This includes discussions on sustainability, manufacturing processes, safety risks and cultural responsibility in both a New Zealand and global content. When presenting their prototypes, innovative thinking is encouraged where students are asked to imagine what the ideal commercial solution may involve, and what impact would this have on production/end-of-life recycling and the potential environmental impact. These discussions/presentations are useful for building communication, time management, teamwork, and design feasibility skills in parallel with their ongoing technical foundation courses which focus on engineering principles and theory. This has had a positive effect on student motivation, as they can see the relevance of mathematics/physics principles to practical engineering outputs early in their degree.

IV. Course Overview

To demonstrate the progression from a 1st year project-based course to a 3rd year project-based course, the assessment schedules for two courses are shown in Table II and Table III respectively. In the 1st year project courses, the emphasis is on teaching fundamental skills, while introducing them to the concept of project-based learning with the goal of improving their creative problem solving, teamwork and oral presentation skills. This can be evidenced by the learning objectives of Year 1 - Project 1 in Table I and the assignment weightings in Table II. LO 1 in Table 1 (Year 1 - Project 1) is the only LO that explicitly measures completion of the project tasks themselves. LO 2 and LO 6 are used to assess skills shown during the project undertaking, but do not require the project to be successful for the students to meet these learning outcomes. LO 3 focusses on fundamental technical skills learnt alongside the project itself, while LO 4 and LO 5 are used to assess complementary assignments to improve students' awareness of the cultural and safety implications of building new technology within New Zealand.

In terms of assignment weighting (shown in Table II), assignments 3 and 4 teach fundamental skills (20%); 1, 2,6 and 7 are used to improve students' presentations skills and teamwork (40%); 5 measures creative thinking and societal awareness (20%); and 8 measures the success of the final project (20%). As shown, a concerted effort has been made to award the development of both soft/technical skills alongside the project undertaking. Another benefit is that since the weighting on the final project's performance is relatively low, undue pressure is not put on students during their 1st semester at university, where individual technical competencies can vastly vary based on prior knowledge or hobbies.

In contrast to 1st year projects, all learning objectives for a 3rd year project center around the projects design and successful delivery. LO 1-3 in Table I (Year 3 - Project 1) required students to incorporate the societal, environmental and life cycle design criteria that they have learnt throughout their degree into their project design. LO 4 and LO 5 are used to assess the technical design and measure overall project completion. This is also seen in the assessment schedule in Table III where assignment 1 is the only assignment (5%) that marks students intentions/project pitch, with the other 95% coming from assignments that

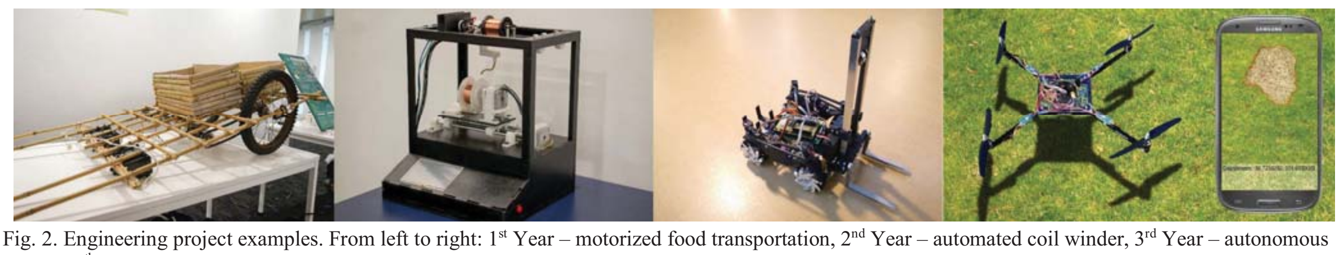

Fig. 2. Engineering project examples. From left to right: 1st Year – motorized food transportation, 2nd Year – automated coil winder, 3rd Year – autonomous forklift, 4th Year – autonomous pasture analysis.

TABLE I. MASSEY UNIVERSITY PROJECT-BASED LEARNING OUTCOMES

PBL Course Outline	Learning Objectives
Year 1 - Project 1	1. Solve a well-defined engineering or technology problem with practical constraints. 2. Apply software tools relevant to engineering and technology disciplines as part of a problem solving process. 3. Demonstrate practical skills with use of tools and instruments in engineering laboratories and workshops. 4. Explain the cultural and ethical issues relevant to engineering or technology practice. 5. Identify and evaluate the safety risks in an engineering or technology context or system. 6. Communicate to a variety of audiences using written, oral, and digital media.
Year 1 – Project 2	1. Critically appraise information. 2. Use scientific information to communicate issues of sustainability to a range of audiences. 3. Discuss the impact of mātauranga Māori for advancing sustainability. 4. Work collaboratively to explore society- through to individual-level solutions to sustainability challenges. 5. Reflect on the concept of sustainability.
Year 2 - Project 1	1. Apply science and technology principles to the solution of a complex problem - where complexity is defined by the context of new product identification, design and development. 2. Clearly define a problem and desired outcomes, recognising stakeholder needs, commercial and social requirements. 3. Use research skills to acquire and integrate knowledge from a range of sources, including the voice of customer, that underpin commercial decision making. 4. Explain a product as a system and be able to analyse that system in terms of its component sub-systems. 5. Perform a detailed project feasibility analysis relating to the key success factors including financial return, social and environmental impact, manufacturability and overall commercialisation. 6. Demonstrate oral communication skills in a group and one-on-one environments. 7. Recognise the inputs and processes required for project management and apply the key elements through a product development process. 8. Recognise the value of intellectual property and identify ways in which this value can be realised. 9. Develop detailed product specifications.
Year 2 – Project 2	1. Develop a prototype that meets product and technical specifications. 2. Apply science and engineering principles to the solution of a complex engineering problem - where complexity is defined by the variables associated with a manufacturing environment. 3. Identify the constraints and criteria necessary for the selection of appropriate materials and manufacturing processes. 4. Apply logical processes to evaluate trade-offs in terms of defined product specifications and manufacturing variables. 5. Explain a manufacturing process as a system and be able to identify that system in terms of its component sub-systems. 6. Develop and implement a project plan accounting for time, costs and resources. 7. Develop appropriate systems to ensure desired quality outcomes. 8. Evaluate ones progress towards meeting the graduate professional competencies.
Year 3 - Project 1	1. Apply social constraints and interactions to technological design. These include ethics, appropriate technology, health and safety (e.g. HAZOP) and legal implications including Treaty of Waitangi obligations, liability and duty of care. 2. Apply environmental constraints and interactions to technological design. These include discharge of pollutants to air and water; noise; climate change; depletion of physical and energy resources; environmental law and regulation. 3. Apply principles of life cycle thinking and life cycle analysis as a guide to design refinement. 4. Specify, design, prototype and develop a manufacturing scale-up proposal of a complex engineering system that is of acceptable quality, fit for purpose and fulfills the 'life cycle' obligations. 5. Employ CAD and engineering simulation software to analyse and design critical components of the system under consideration.
Year 4 - Project 1 (Group Capstone)	1. Manage a complex engineering design/development project in a "near to commercial context"; requiring problem definition, scoping of system and sub-systems, planning to complete required deliverables and outcomes, sound decision-making based on well researched knowledge and definitive action. 2. Complete a detailed design solution based on a complex engineering problem related to the specific major being studied, where the final solution requires the evaluation of trade-offs based on a range of contextual inputs including, manufacturing capability, stakeholder requirements, investment capital availability, market competition, social and environmental factors, and regulations. 3. Work effectively as both team leader and team member, recognizing the strengths and contributions of individual team members to successfully complete a complex, multidisciplinary project. 4. Exercise professional judgment, self-monitoring, peer assessment and adherence to ethical principles and professional codes of practice. 5. Identify stakeholders of particular importance to a project and effectively communicate key information in a form that is appropriate to specific stakeholder requirements and expectations. 6. Evaluate the feasibility of a project from a commercial perspective with consideration of the needs and expectations of all key stakeholders.
Year 4 - Project 2 (Individual)	1. Identify and define topical research problems. 2. Critically review and synthesise relevant and necessary data, information and knowledge. 3. Select and apply appropriate research methodologies. 4. Accurately analyse research data. 5. Effectively articulate research findings. 6. Evaluate the value of research findings in relation to previous research.

directly assess the ongoing level of project completion. This results in 40% of the 1st year course solely focusing on soft skills development, with this reducing to 5% by 3rd year. However as shown by Table II and Table III, soft skills assessment is woven into almost all course assignments.

The marking rubric for a 3rd year assessment (Table III assessment 5) is given in Fig. 3. The rubric is provided to students in advance of the assessment and is left intentionally vague to allow groups to structure the progress interview as they please. The students are requested to present their progress to date, discuss which team members are responsible for which tasks, outline the current expenditure, and provide a timeline to project completion. The 'Current Status' and 'Plans' section of the rubric are used to assess both technical progress, and soft skills development. The teams are expected to discuss how they have operated as a team to date; and what mitigation strategies they are putting in place due to student illness, uneven technical competence between members, or unexpected project difficulties. The interview is led as a

TABLE II. FIRST YEAR PROJECT COURSE ASSESSMENT SCHEDULE

Assessment	Type	Assignment	Due Date	Weighting	Soft Skills Assessed	Technical Skills Assessed
1	Recorded Video	Vlog 1	Week 3	5%	Teamwork, Communication, Goal Orientation	N/A
2	Oral Presentation	Design Review	Week 7	10%	Teamwork, Communication, Goal Orientation, Problem Solving, Creativity & Innovation	N/A
3	Written Exercises	Matlab, R	Week 8	10%	N/A	Matlab, R software
4	Written Exercises	CAD, Excel	Week 8	10%	Spatial Reasoning	SolidWorks, Excel
5	Poster	Professionalism	Week 10	20%	Creativity & Innovation, Cultural/Ethical/Environmental Awareness	Risk/Ethical issue identification
6	Recorded Video	Vlog 2	Week 12	5%	Teamwork, Communication, Goal Orientation	N/A
7	Oral Presentation	Final Design	Week 12	20%	Teamwork, Communication, Goal Orientation, Problem Solving, Creativity & Innovation	N/A
8	Final Evaluation	Competition	Week 13	20%	Teamwork Ability, Time Management, Autonomy, Problem Solving, Attention to Detail	Electrical/mechanical prototype fabrication

TABLE III. THIRD YEAR PROJECT COURSE ASSESSMENT SCHEDULE

Assessment	Type	Assignment	Due Date	Weighting	Soft Skills Assessed	Technical Skills Assessed
1	Oral Presentation	Initial Project Plan	Week 4	5%	Communication, Leadership	N/A
2	Interview	Design Review	Week 10	15%	Teamwork, Time Management, Decision Making, Leadership, Spatial Reasoning	SolidWorks
3	Written Report	Report 1	Week 12	20%	Problem Solving, Environmental/Ethical Consideration	Environmental/Ethical issue identification, Life Cycle Analysis, Prototype specification/design
4	Interview	Milestone 1	Week 16	5%	Teamwork, Communication, Conflict Resolution, Time Management, Decision Making, Leadership	Budgets, Project timeline, Implementation pipeline/segmentation, Electrical/Mechanical prototype fabrication
5	Interview	Milestone 2	Week 21	5%	Teamwork, Communication, Conflict Resolution, Time Management, Decision Making, Leadership	Budgets, Project timeline, Implementation pipeline/segmentation, Electrical/Mechanical prototype fabrication
6	Written Report	Final Report	Week 26	25%	Conflict Resolution, Problem Solving, Creativity & Innovation, Teamwork Environmental/Ethical/Cultural Consideration, Attention to detail	Environmental/Ethical/Cultural issue identification, Specification/design/prototype/development documentation
7	Project Showcase	Final Demonstration	Week 26	25%	Teamwork	Electrical/Mechanical prototype operation

discussion where teaching staff can ask questions at any stage, and all team members are expected to actively contribute.

The benefit of Massey University's approach is that the students get introduced to the soft/technical skills required of engineers early in their degree and are encouraged to produce innovative high-risk solutions, knowing that a failed implementation will not have an significant impact on their grade. This is further emphasized by the degree structure which only uses 2nd-4th year papers when calculating the class of honors awarded to students. This encourages risk tasking and creative thinking in 1st year, which helps students come up with more innovative solutions in later project years. This multi-year staging also allows for students to properly reflect on complex concepts such as mātauranga Māori (cultural awareness in a New Zealand context), and how this practically impacts engineering projects in a New Zealand.

V. IMPACT OF COVID

On 23rd March 2020, the New Zealand government gave 48 hours' notice that the country was going to go into lockdown, and University campuses would be closed for at least 4 weeks. Massey University started the 2-week mid-semester break immediately to allow staff to take home any necessary equipment, and to prepare for online-only teaching for the remainder of Semester 1. This mandated changes to project papers across all levels, as students no-longer had access to the on-campus workshop facilities required to ensure completion.

The following subsections provide an outline of the considerations given to all project-based courses, with the 1st and 3rd year courses previously mentioned given as case study examples of course specific considerations. All project-based papers required similar considerations to remain operating during the lockdown.

A. Program-wide COVID-19 Considerations

The following measures were implemented for all project students to ease the burden when moving to online learning:

- Software licenses for SolidWorks/Matlab/etc were made available to students for home use.
- Virtual on-campus laboratories were also setup that students could remote into to access any software that was too demanding to run on their home computers.
- Lectures and presentations were undertaken using zoom, and full recordings were made available to further assist students with slow internet.
- Arranged for workshop technicians (mechanical and electrical) to do zoom interviews with the students to discuss their designs.
- Arranged for designs to be submitted online to the workshop team for remote manufacturing by workshop staff instead of students.

Aim and Review Criteria	Mark Allocation				Comments	Mark
INTRODUCTION	<20	20-26	26-32	>32		(40)
Overview of the design	Vague description of the design, with no description of how it meets the project goals in the brief.	Enough of a summary of the design to get a broad picture of what the product would be like. Limited description of how it satisfies the brief.	A good description of the design and how it satisfies the brief, but is limited in some way.	Paints a very clear picture of what the end product would like, and how the design would satisfy the goals stated in the brief.		
Current status	No attempt to show progress to date.	A limited attempt to describe the current project status.	Good description of current project status, but is overly wordy, or incomplete in some way.	Concise description of where development is currently at.		
MILESTONES	<30	30-40	40-48	>48		(60)
Plans	Vague description of the milestones, with no deliverables specified.	Primarily linear plan, with strong dependencies between successive tasks. Conflicting or contradictory description of the work required. Poor breakdown of tasks, or distribution between team members, with unclear deliverables.	Good description of the work to be performed by each team member for each task. A few tasks may be vague, or not completely specified, or some deliverables not clearly identified.	Excellent breakdown of the work, with clear linkages to project completion. Deliverables from each task clearly identified for each team member.		
Measures of success	Limited criteria to assess the completion of the milestone tasks.	Some attempt has been made to provide completion criteria, but many of these are not specific or quantifiable.	Most tasks have specific quantifiable assessment criteria.	Very clear, specific, measurable and quantifiable assessment criteria provided that cover all of the tasks.		

Fig. 3. Third year project course Milestone 2 marking rubric

- When postage was allowed, allowed students to get components sent to their home addresses rather than the university. Online purchasing system that we had in place to authorize student purchases worked well in this situation.

B. Year 1 - Project 1 Considerations

For the 1st year paper, the loss of workshop access meant turning the project into a theoretical design exercise, replacing the project competition (Table II – assessment 8) with 2 theory-based assignments that could be accomplished at home. The vlog 2 video was also merged with the final oral presentation to ease student workload. This allowed students to continue working on the content even if they had limited internet facilities at home that could not facilitate video streaming. Even with these changes, students struggled to maintain a normal pace with assignments since face-to-face on-campus help was unavailable. Considering this, the deadlines for assignments 3 and 4 (Table II) were extended to week 13.

C. Year 3 - Project 1 Considerations

For the 3rd year paper, students are required to do a lengthy design process. By providing access to all on campus software tools through either take-home licensing, or the virtual laboratories, students could proceed with their designs as normal. The main limitation that arose was component sourcing and fabrication. Most students usually order project parts from china as this minimizes cost and keeps projects under budget. Under a COVID-19 setting, delivery timeframes from china were expected to blowout limiting sourcing to New Zealand or Australia. Students were encouraged to source time critical parts as needed locally, and to source from China if a significant procurement delay would not undermine their current progress. Daily office hours were setup through zoom where students could attend as needed to ask any queries of their lecturers. An issue that arose is modularity. Most teams would split up projects into mechanical/electrical modules among team members. Though most electrical/software prototyping could continue as normal, the lack of workshop access limited the potential for most mechanical prototyping. While mechanical CAD designs could be submitted through an online portal, for fabrication by the workshop staff, students often prefer to fabricate designs themselves. In light of this, the assessment rubrics for the report and interview (Table III, assignments 2 and 3) to have more emphasis on a design-based approach (CAD, Altium, simulation, system architecture, code block diagrams, component list ordered) and removed the demo component. This meant that students were not penalized for not utilizing workshop staff to fabricate their initial design, if they desired to do it themselves once campus reopened. If students had also been able to do prototyping prior to lockdown, that this would be used as part of their overall grade. However, students who had not obtained components before postage restrictions occurred would not be disadvantaged.

D. Post-Lockdown Considerations

The Massey University Auckland campus has experienced two lockdowns, with the Palmerston North campus experiencing a single lockdown. Since the country could be locked down again with as little as 48 hours' notice, an increased emphasis has been placed on project supervisors to identify project modules that necessitate campus access. Supervisors are working closely alongside their project students to ensure on-campus fabrication/testing can occur in a timely matter. This should minimize the ongoing impact, as project teams prioritize project modules that require campus access, allowing them to continue with the other modules if New Zealand entered a third lockdown.

VI. Ongoing Challenges

While implementing project-based spine through the whole undergraduate engineering degrees has noticeably improved student satisfaction, broad technical competency, and several soft skills including: teamwork; oral/written communication; time management; autonomy; problem solving; creativity; flexibility; and leadership, several ongoing challenges remain.

A. Increased staff workload

Supervising projects requires increased student contact time as staff need to be more involved with approving designs, parts sourcing, ensuring safety standards are maintained with varied mechanical and/or electrical implementations, among other tasks. To partially reduce the marking effort, Massey University uses 'client' based panels of multiple departmental staff members to assist with presentation marking. Further streamlining is needed however, as the overall workload remains higher than traditional paper offerings.

B. *Unbalanced team effort*

Attempts have been made to ensure fairness with some years using assigned team groups, and others choosing their own. Assigning team groups has often resulted in disgruntled members who wish to attain a higher grade than their peers and perceive themselves to be contributing at a higher level. When allowing groups to choose their own members, problems with equity of effort/competency remain. This also results in several groups of low achieving members who struggle to achieve at the required level. These issues are partially mitigated by including peer evaluations into the reports and including group/individual marking components. This allows for members on the same project to receive varying grades based on their overall contribution. Furthermore, low achieving groups are identified early in the semester, and asked to attend ongoing meetings with staff. This helps them to receive ongoing personal assistance and allows staff to step in and reduce the scope for the group if needed to ensure a successful project (at a lower level).

C. *Project planning*

Students spend a long time finalizing their design and underestimate the time required to complete technical tasks. This is reinforced by the project plan in week 4 (Table III, assessment 1) which emphasizes their overall pitch, social, and environmental impact but requires limited physical prototype progress. We encourage students to work on the mechanical/electrical design in parallel with a focus on finishing electrical specification first. This allows parts to be ordered while the mechanical design is finalized and minimizes down time on waiting for parts. Since students often do not realize they are falling behind on year-long projects, regular staff contact has been used to provide recommended deadlines and ongoing support with logbook/milestone meetings. This has worked to-date; however, it requires significant staff involvement and is an area that needs to be addressed in time to minimize the required staff oversight, without compromising project completion.

D. *Campus access*

COVID-19 has been the first major event that has prevented students from accessing the workshops required to complete their projects. This was partially mitigated by allowing students to submit their files for manufacture, but this does not give the students the same hands-on learning experience. Ongoing efforts should be made to modularize required workshop access so that workshop projects can be manufactured by students during a block-course styled access period.

VII. STUDENT EVALUATION

A voluntary, anonymous survey was offered to over 60 undergraduate students who had completed multiple project papers within Massey University's engineering prog ram. Every question was voluntary, and 15 students completed the whole survey, though several individual questions were answered by more people. The students were asked questions on which papers from each year had actively contributed to their perceived soft skills development, their preferred learning style, and what Covid-19 considerations had/had not worked at improving their learning during related lockdowns. The results for the question 'Which 3rd year papers actively helped you develop the following soft skills' are summarized in Table IV. Since there is only one project-based paper in 3rd year (of seven total papers), all responses that explicitly listed this paper correlate with the paper described previously in Table I and Table III. Table IV presents the percentage of question responders that explicitly listed either a project-based or traditional course. Each responder had the option to mention multiple papers. For example, in Table IV row 1, 100% of responders indicated that the project paper helped them improve their teamwork ability, while 63% of responders indicated that a traditional paper contributed to the same skill. Of the 17 presented soft skills, students attributed 10 of them to have been developed more in the 3rd year project paper than any other course taken in their 3rd academic year.

TABLE IV. STUDENT SURVEY – WHICH 3RD YEAR PAPERS DEVELOP SOFT SKILLS

Soft Skill	Development from Project-Based Papers	Development from Traditional Papers
Teamwork Ability	100%	6%
Oral/Written Communication	73%	64%
Conflict Resolution	88%	13%
Time Management	67%	89%
Autonomy	50%	88%
Goal Orientation	57%	57%
Problem Solving	86%	57%
Creativity & Innovation	86%	86%
Continuous Learning	33%	89%
Attention to Detail	63%	100%
Flexibility	56%	78%
Decision-making	88%	63%
Leadership	100%	0%
Cultural Awareness	100%	0%
Environmental Consideration	84%	16%
Ethical Awareness	100%	0%
Spatial Reasoning	80%	40%

Survey results show that all students believe project papers positively contribute to their learning when used to provide a practical outworking of theoretical knowledge taught within traditional courses. When asked about Massey University's response to the Covid-19 pandemic and the tools provided to allow students to access software/request workshop components remotely, students responded favorably. The availability of online lectures both live, and recorded, alongside the availability of distributed software licenses for home use were attributed with increased student satisfaction more than any other implemented measure.

VIII. CONCLUSION

Project-based learning is well received by students, provides an easy integration pathway for incorporating both soft and technical skills into the program, and can function even with significant disruption from external factors (COVID-19). By iteratively introducing project-based content in 1st/2nd year allows for a strong focus on soft skills development that aligns with the best practice mentioned in literature. This has a flow-through effect and can result in better outcomes when students undertake their 3rd/4th year projects as they understand how to professionally present a design/project, even though the soft skills focus. Project-based learning does result in an increased staff workload;

however, this can be partially mitigated by sharing the marking workload over multiple staff.

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