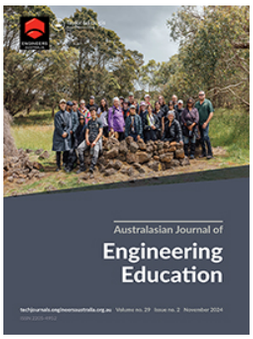


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ARTICLE



# Project-based learning in Australian & New Zealand universities: sustainability and scalability

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**ABSTRACT**

Project-based learning promotes the development of graduates who will be prepared for future professional engineering practice. Whilst there is much literature on project-based learning, the long-term viability of project-based learning within the Australian & New Zealand context needs further exploration. There is a need to better understand the sustainability and scalability of project-based learning within a context where class sizes can extend to over 800 students. This paper draws on interview data with current project-based learning unit coordinators and industry collaborators to identify (un)sustainable and (un)scalable practice, as well as consider how current practice can move towards sustainable and scalable practice. Key support mechanisms include: resourcing; workload allocations; the freedom to design project units as required; co-coordination models; and a shared understanding of how to interpret student feedback. These findings highlight the support mechanisms required for successful delivery of project-based learning, and provide guidance for academics and their Learning and Teaching leadership on how best to sustain and grow project-based learning in Australia & New Zealand.

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**KEYWORDS**
Project-based learning; sustainability; scalability; staff support; industry collaboration

## 1. Introduction

There is a need for engineering educators to support the development of graduates who will meet the needs of future professional engineering practice and hence there are calls for: better integration of the potential impact of engineering practice in society; stronger interaction with professional practice contexts; embedding external industry; and, more widespread use of open-ended projects in curriculum (Crosthwaite 2019). One key approach is project-based learning (PjBL), which can simulate professional engineering practice and accommodate real-world focus. However, whilst PjBL will play an important role in the future of engineering education, there remain significant barriers to wider adoption of PjBL, across a range of areas including: unit design; academic staffing, workload and resourcing; industry involvement, assessment; and student feedback. Whilst these barriers continue to impact the sustainability of PjBL and scaling up of PjBL for larger cohorts, there will be impacts on the scaling out of PjBL across the curriculum. This paper explores the sustainability and scalability of project-based learning in Australian & New Zealand universities through the experiences of PjBL unit coordinators from large units (>120 students) and industry collaborators. The findings identify a range of barriers and enablers of PjBL delivery and hence provide guidance for Learning and Teaching leadership on how to better support and retain academics running PjBL so that PjBL continues successfully and grows in usage.

## 2. Literature review

PjBL is an approach to learning that engages students in authentic learning experiences that have practical industry relevance (Blumenfeld et al. 1991; Herrington and Herrington 2006). PjBL supports the development of technical skills and understanding (Harris and Bigham 2014; Stappenbelt and Rowles 2009; Taylor, Harris, and Dargusch 2015) as well as professional competencies and identity (Mills and Treagust 2003). The coupling of technical and professional competencies in an authentic PjBL learning experience, where students work on real engineering problems, provides opportunities to engage with the complexities of practice and how to apply knowledge in practice (Balash et al. 2020; Li and Howell 2019; Mills and Treagust 2003) and builds a stronger understanding of the role

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of engineers (Foley and Willis 2014; Li and Howell 2019).

However, there are significant barriers to improvement and wider adoption of practice-based approaches such as PjBL in Australian institutions, including:

- unit design concerns, e.g. appropriately qualified teaching staff (Brown 2020; Chowdhury 2015; Mavoa et al. 2016), resistance to change (Kolmos 2009) and organisational structures (Lam, Cheng, and Choy 2010)
- academic staffing, workload and resourcing concerns, e.g. the cost of scaling up projects for large cohorts (Balash et al. 2020) and perceived resource-intensive requirements (Brown 2020; Tse and di Bona 2019)
- industry involvement concerns, e.g. limited access to industry partners (Mavoa et al. 2016; Ståhl, Sandahl, and Buffoni 2022)
- assessment concerns, e.g. added difficulty in showing that PjBL assessment meets accreditation requirements (Crosthwaite 2021)
- student feedback concerns, e.g. challenges with engaging diverse cohorts (Chowdhury 2015; Gupta and Bailey 2014)

The existing literature proposes some approaches to overcome these barriers. Kolmos and de Graaff (2014) note that PjBL is most effective when implemented at the institutional level due to the systemic support mechanisms available, 'e.g. physical facilities, training of academic staff, distributing resources, development of new culture, etc.'. Another approach is greater use of groupwork and self/peer review to reduce the marking load on teaching staff. However, some students indicate that they do not find peer feedback helpful, and there are concerns with workload associated with teaching staff reviewing self/peer reviews (Rienties et al. 2013). Also, the development of curriculum materials that can be used by different educators is recommended, but there is a need to tailor materials to a specific context and not all educators will have the time to develop tailored projects with quality materials (Krajcik and Blumenfeld 2005). Another approach is used of design challenges that are designed and run by external bodies, such as the EWB Challenge, in which first-year students work on a community-identified set of project briefs (e.g. Stappenbelt and Rowles 2009), or the Warman Design and Build Competition, in which second-year mechanical engineering students work on a theoretical problem (e.g. Cuskelly and McBride 2017). However, these are not used consistently across the sector, nor address all the barriers noted.

As these barriers are deterrents for current PjBL academics to continue and for other academics to implement PjBL, they significantly impact the long-term sustainability and the scalability of PjBL (whether scaling up current PjBL units for increasing class sizes or scaling out PjBL across the curriculum). Teaching staff are more likely to persist in using PjBL when they receive appropriate support (Lam, Cheng, and Choy 2010). This includes: school/infrastructure support; being given the autonomy to choose to participate in a project unit, and freedom to design and run their own project units; and collaborations on project units, which lead to peer support and lower psychological pressure due to shared ownership and responsibility of project units. As acceptance and adoption of new teaching approaches is often driven by communications with colleagues who have already adopted the approach (Rogers 2003, 36), this support will also benefit the scaling out of PjBL.

## 3. Summary

Ensuring the sustainability of existing PjBL units through greater support is required to encourage wider adoption of PjBL. Scaling project-based learning up for increasing student numbers is already problematic in overseas contexts, and these issues are likely to be magnified in the Australian & New Zealand context where class sizes can be much larger. Scaling project-based learning out to other units is unlikely unless sustainability issues are resolved. More data on aspects of current practice that are (un)sustainable and (un)scalable is needed for the Australian & New Zealand engineering education sector to respond to the Engineering 2035 recommendations in an effective and targeted manner.

## 4. Objective

The objective of this study is to provide guidance on what academics and leadership can do to ensure PjBL is sustainable and scalable in the light of Engineering 2035. The study was guided by the following research question: What are the barriers and enablers of current PjBL practice to meet the Engineering 2035 agenda?

## 5. Method

To answer this research question, a qualitative approach was used. The method comprised semi-structured interviews with industry-based PjBL collaborators ($n = 6$) and PjBL unit coordinators ($n = 7$), referred to as IC1–6 and UC1–7 respectively. Unit coordinators were identified as having large classes (namely, 160–900 students) and drawn from five universities within Australia and New Zealand (Go8: $n = 3$; non-Go8: $n = 5$). Unit coordinators were nominated by their department heads prior to being

approached via email invitation to participate. At the time, their academic levels were Level A ($n = 3$), Level B ($n = 3$) and Level C ($n = 1$) and industry experience was varied (0 years: $n = 4$; 0–5 years: $n = 2$; over 5 years: $n = 1$). Industry collaborators were identified from prior collaborations with unit coordinators on PjBL activities and had backgrounds in humanitarian, chemical and transport engineering. Due to the interest in the sustainability and scalability of PjBL, unit coordinator participants were selected from units with class size of >120 students. The interviews were conducted in 2021–22. The ethical aspects of this study have been approved per UNSW HREAP H: Science/Engineering REF NO. HC210523.

Questions asked of industry collaborators were:

(1) How many projects have you done and over what time period with a partner university?
(2) How many institutions have you been involved with?
(3) What is the structure of the project?
(4) What do you see as the aim of the projects?
(5) What aspects of the projects do you consider as authentic to engineering practice?
(6) What do you see the benefit of your involvement as?
(7) What are your contributions to the project?
(8) Can you describe some positive experiences and why you think they were positive?
(9) Can you describe some negative experiences and why you think they were negative?
(10) What would be your ideal vision for future projects?

Questions asked of unit coordinators were:

(1) What is the structure of the project in your unit?
(2) What do you see as the aim of the project?
(3) What aspects of the projects do you consider as authentic to engineering practice?
(4) How do you feel you are equipped to deliver your unit?
(5) Is there industry involvement in your project? If yes, what do you see the benefit of their involvement as?
(6) Can you describe some positive experiences and why you think they were positive?
(7) Can you describe some negative experiences and why you think they were negative?
(8) What would be your ideal vision for future projects?

These questions were developed from a prior survey of Unit Coordinators on current PjBL practices (reported elsewhere). Points of interest were identified from the survey results where further depth and meaning were needed to understand the enablers and constraints for these existing practices. The interviews were recorded and transcribed for coding against themes identified from the survey results: unit design; academic staffing and workloads; industry involvement; assessment; and student feedback.

## 6. Results & discussion

### 6.1. Unit design

#### 6.1.1. Sustainability

Authenticity of projects is a significant concern amongst both industry collaborators and coordinators. There are concerns amongst industry collaborators that the way that projects are designed may not deliver outcomes that are realistic, e.g. *'they had to make milk and powdered milk for baby formula … I look back on that project and that's a feasible project … whereas I feel like the ones I've seen in the last few years have been "use this crazy new technology to create this whole wonderful thing"'* [IC1]. Coordinators are also constrained by the need to balance authenticity with alignment to the learning outcomes of the unit, e.g. '*[unit coordinators might say] "we need the students to process to go through these equations and to demonstrate that they can use these equations to design a retention basin and device volumes" … but then it's no longer about solving this problem, you're trying to devise a solution not a problem*' [UC1]. A clash between specific technical learning outcomes and authenticity of projects can result, e.g. '*I feel the professor sometimes encouraged that because that's their job. Their job is to look at this really forward technology and it's just not what industry always is*' [IC1]. This speaks to the need for support to meet training needs and/or provide time to reach out for support from industry collaborators.

In principle, many institutions support PjBL approaches, e.g. '*there is a move in the university to have more hands-on flip classrooms, project based learning, so-called authentic assessments over exams*' [UC5]. However, there is division between local (school, Faculty) leadership and senior (Faculty, institutional) leadership in terms of support. Many coordinators noted that their local leadership often have a much better understanding of how to support PjBL, e.g. '*I think the immediate leadership [the head of school and the teaching and Learning Committee] does, the higher leadership probably has competing priorities that interfere with understanding what's needed to implement it very well*' [UC2]. This can be attributed to leadership's own experiences, e.g. '*when I started working, he was just [a] course coordinator. Now he's got into a Deputy Head of School role … it's*

*very encouraging to have someone at such a kind of a management position pushing for that in the classrooms*' [UC3] and personal interest, e.g. '*the Deputy Dean of Education in the schools are generally good at driving this stuff, but that's maybe a bit more individual as well – what's on their agenda, what are the initiatives they want to drive*' [UC6]. In contrast, senior leadership are criticised for not understanding the practical implications of advocating for authentic approaches to learning like PjBL, e.g. '*I think those higher up give more lofty statements – they just don't teach and so they don't know [what's feasible or not]*' [UC5] which local leadership have a far better grasp of, e.g. '*The Associate Head of Education, on the other hand, did – very, very clear understanding project based learning . . . But was also cautious of encouraging people to do project-based learning, probably due to that*.' [UC7].

Moreover, university timelines can be difficult to navigate, particularly given how short they are compared to real engineering projects. Chattopadhyay and Larkins (2020) highlight the misalignment of industry-based projects and university timelines more generally. However, there are also time constraints imposed by program changes, e.g. '*we had to merge the unit with another unit that taught tendering and so, their eight week design process got confined down to four weeks*' [UC5] or institutional decisions, e.g. '*it wasn't a lot of time when it was 14 weeks and then they took almost 35% of that away*' [UC7]. These institutional constraints can affect the authenticity of projects, as can be seen by COVID-19 impacts, which '*did also constrain complexity because for the sake of the quality, I needed to be able to deliver things for both modes of delivery, whether they were face-to-face or online only*' [UC7].

There is also an onus on industry collaborators to understand these constraints and be open to accommodating them, which requires coordinators to be provided with sufficient time to form strong relationships with industry collaborators, e.g. '*where you've got specific industry needs, working beforehand to align that with the current academic calendar and the student resources . . . – just really nail[ing] the project timeline would be fantastic. It's such an easy crossover when the communications there*' [IC2]. Substantial time is often required for academics and industry collaborators to co-design briefs that are suitable (Lloyd and Bland 2014). Design challenges can offer a different approach to managing time constraints as they are designed specifically for university teaching. Due to economies of scale (e.g. 700+ students in the 2022 Warman Design and Build Competition; 10000+ students in the 2022 EWB Challenge), challenge organisers can be better placed to take on the workload associated with designing and running projects. Coordinators highlight that budget costs for challenges well and truly offset time costs, e.g. '*even if the partnership with [challenge provider] costs like $20,000, I think it's actually really good value for money . . . it will cost that much to go and do it properly . . . that money is buying you time*' [UC1]. However, UC1 also commented that leadership are often reluctant to provide this resourcing.

Implementing PjBL for the first time can be challenging (Ståhl, Sandahl, and Buffoni 2022). However, inheriting an established PjBL unit where there is a history and existing support systems for PjBL can significantly reduce barriers to using PjBL approaches, e.g. '*I inherited the course, as it were. So I just became course coordinator and was told "Here is the course, this is the partnerships that it uses, this is the PBL that it uses. And then, we expect you to continue using this same model of teaching this topic"*' [UC1].

#### 6.1.2. Scalability

Industry collaborators indicate a need to scale PjBL out across the curriculum and use real-world problems throughout the degree, e.g. '*the future of project based learning is an opportunity for students to step through authentic projects throughout the course of their degree*' [IC3]. Similarly, coordinators highlight the need for incremental development of skills, '*some of these skills that take time to mature . . . so the only way to really get competency in that regard is to put in activities throughout the 8 units, four years*' [UC4]. There is importance of a consistent learning journey and alignment between different units of a degree which requires support from colleagues to scale out across the curriculum; however, this support is not necessarily available, e.g. '*It was always a bit of a nightmare, but to get a bit more buy-in across the school so there is a bit more consistent tone or exposure to teaching styles and strategies – I think would have paid a lot of dividends*' [UC7].

Autonomy to not choose PjBL approaches should also be extended to unit coordinators. Many coordinators reported motivations stemming from personal experiences or beliefs in PjBL and acknowledged that their colleagues may not hold the same views, e.g. '*I think the main thing is you need to really want to do it . . . I know a lot of people just didn't want to do it, a lot of educators within the school, for valid reasons*' [UC7]. Colleagues may not want to use PjBL due to the need for considerable change, e.g '*by the time that you do your normal assessments – like exams and normal assignments – once you get into the groove of those, it's kind of hard to uproot everything to change to PjBL*' [UC5] and workload concerns, '*there's an incredible amount of work to set it up and to get the assessment structure feasible and working*' [UC7]. Academic reluctance to transition to project-based learning has also been noted in the literature because

such a transition requires simultaneous changes in curriculum, instruction and assessment practices (Barron et al. 2014).

Moreover, some coordinators (even those who are invested in PjBL) believe that some units are more aligned to PjBL, '*like design, it's a natural fit for design courses … if you're teaching design you're teaching project based learning. But in other courses that's not the status quo*' [UC6]. In contrast, others highlight counter-examples such as Olin College where all units are project-based. This approach is also taken at Charles Sturt University. However, student numbers are relatively low for both programs, with Olin College numbers at ~ 100 students per year (Olin College, n.d.) and Charles Sturt University numbers capped at 50 per year to ensure appropriate staffing (Senevirathna et al. 2023), which highlights concerns with scalability. Moreover, some coordinators are less convinced in a completely project-based curriculum and believe that students need variety in the learning experiences, '*I do think that students need to experience learning through different mechanisms and some sort of material and course better suit themselves to PBL than others*' [UC1].

### 6.2. Academic staffing, workload & resourcing

#### 6.2.1. Sustainability

There is significant workload associated with designing and running PjBL. Unfortunately, workload was one of the most common concerns raised by coordinators, e.g. '*it was very common for me to be doing 50–60 hour weeks. And the agreement was I worked 35 hours a week. So, almost double to make sure that these things ran smoothly*' [UC7]. Moreover, university timelines can also be unrelenting, e.g. '*for the three months of semester plus a week or two before, plus a week or two after, it's very hard to get anything else done really or think about it*' [UC1]. These workload concerns contribute to attrition amongst engineering educators. In fact, one coordinator indicated during their interview that they had plans to leave for industry due to workload concerns. Participants reported a lack of recognition of these concerns by University leadership, e.g. '*I think that certainly when you look at the strategy, there's an interest in doing more PBL or authentic assessment … but the workload model stayed the same*' [UC1]. Workload models also do not recognise that project-based units require a different approach to teaching that often requires more effort to be invested by the coordinator, particularly in responding to students and decision-making (Mesquita et al. 2009). These insights are consistent with findings from other studies noting high workloads for PjBL academics (Brown 2020; Taylor, Harris, and Dargusch 2015).

There are certainly examples of well-resourced units, e.g. '*we're very well supported in terms of staffing. These courses have a project coordinator on each project, a technical stream coordinator runs the technical streams, we have administrative support at the faculty level and at the school levels, we have sufficient budgets for an undergraduate teaching team*' [UC6]. Also, some coordinators are able to access funding for consumables and software (albeit with varying levels of difficulty), e.g. '*because [challenge] requires, I think it's $20,000 a semester or a year, in order to partake in the competition – it's not only just saying to the line manager, "Is this ok and can I use this in my unit?". It's a lot of, "Can you find the funds to help me out?"*' [UC5]. However, not all units have the same level of resourcing support. There is a lack of clarity around budgets, '*They're always trying to go, "how much do you need? come ask when you need"*' [UC4]. As a result, obtaining suitable budgets to sustainably run and improve units can be difficult.

We also find that the support of colleagues is very important to coordinators, particularly in mentorship, e.g. '*I work very closely with the people who work the subject before me and after me*' [UC2], and, '*we almost treat it like a mini apprenticeship … we'll assign a buddy … with a lot of experience and they'll kind of step them through every stage of the process*' [UC6]. Unfortunately, redundancies as a result of COVID-19 accelerated the loss of such mentors, e.g. '*we've lost a lot of experience – a lot of that support came from a lot of knowledge in those mentors … they all took early retirements*' [UC1]. Coordinators also endeavour to create diverse teaching teams who can support them and model to students that individual weaknesses can be addressed through team strengths, e.g. '*I've surrounded myself with people who are really experienced or [more] experienced than myself, like any sort of highly functional team*' [UC4]. There are also co-coordination models that manage contingency through sharing the load amongst multiple coordinators, e.g. '*we've been trying to instigate a group teaching approach where you have multiple conveners on a unit. So then if one falls sick or ill then someone else can take on that responsibility*' [UC4] or sharing the load between a coordinator and head tutor, e.g. '*I have a head tutor, so having someone else who can help me*' [UC2]. Collaborative teaching has been a successful alternative to traditional 'lone-champion' approaches (Barron et al. 2014), particularly given that unit coordination by a single academic can be highly stressful, e.g. '*I always felt an overwhelming burden of responsibility for these projects, very, very stressful … the ultimate responsibility lay with the course convener for better or for*

*worse*' [UC7] and can have negative effects on the retention of these coordinators.

#### 6.2.2. Scalability

The challenges described above can become magnified at greater scales. There can be significant timetabling issues when cohorts are large, e.g. '*because we have 44 tutorials this year . . . spread out across the entire week, which does cause problems*' [UC1] and practical concerns around allocation of suitable teaching spaces, e.g. '*putting us in a lecture theatre when you want to do project based learning is not great*' [UC2]. As indicated by existing studies (Felipe et al. 2017; Inchbold-Busby and Goldsmith 2017; Stappenbelt and Rowles 2009), considerable time is needed to ensure that tutors are on board with the ethos and expectations of the unit, e.g. '*I can have a vision and a plan for how we can do work in this course, but unless the teaching team actually enact it, it doesn't mean anything right?*' [UC1]. As PjBL is scaled up, a greater budget for training tutors is required to ensure consistency amongst the teaching team as '*one of the major issues that we have is quality control when it comes to dealing with units of that size . . . the quality of the teaching sometimes suffers*' [UC5]. Some coordinators believe that technology will be important in scaling and improving the long-term sustainability of PjBL, e.g. *'It's just about chunking it out into manageable groups. And then in terms of educational technologies, you just have to automate everything*' [UC6]; however, there are often costs associated with such technologies.

Scaling PjBL both up and out also requires support, with a focus on gathering colleagues with an interest in implementing PjBL. Our participants indicated that they are given the autonomy to dictate unit design and choose PjBL as the vehicle for learning in their units, e.g. *'I do have to make program changes and I do have to get them signed off, but otherwise I think that I have a lot of freedom over how the course is run, definitely*' [UC1]. In contrast, issues can occur when coordinators do not choose PjBL of their own volition, e.g. '*not all the supervisors were doing so because they wanted to – they just have to be involved in that unit . . . I found it difficult to engage those supervisors directly or the team*' [IC4].

There are also opportunities to widen the implementation of PjBL through improving support by creating broader communities of practice for PjBL, '*I don't think there's enough exposure between the different people running project-based courses in Australia*' [UC6]. Moreover, this might ameliorate issues around loss of local mentors, particularly given that mentorship can play an important role in wider adoption of PjBL, e.g. '*I think that's why a lot of people just abandon the idea of project based learning, because there isn't much support to help people learn how to implement it first*' [UC5].

Support in sufficient resourcing is also important for scaling out PjBL. One approach could be to maintain the same tutors or training tutors who can teach across a number of PjBL units, e.g. '*we've set up a teaching team of tutors, not casual tutors, but they teach across a few subjects . . . They know what else to expect from our students, which is really good*' [UC2]. There will nevertheless always be attrition concerns; however, this approach could minimise the time and effort spent on training of tutors.

### 6.3. Industry involvement

#### 6.3.1. Sustainability

Industry involvement in PjBL units can be through several avenues, including guest lectures, field trips and the projects. The level of engagement with projects can vary significantly, e.g. '*maybe they're just the point of inspiration or maybe they're a partner and writing up the project brief and then they give a series of 6-hours of lectures*' [UC6]. For some PjBL units, industry involvement is minimal, e.g. '*we include industry just in terms of case studies or exemplars . . . but we don't have any direct involvement with industry*' [UC2]. Greater participation of industry in PjBL can be limited by both institutional and industry collaborator constraints. Whilst industry collaborators are often highly motivated to contribute to engineering education, they too have time and workload constraints, '*If you're asking, could I put in several hours a week for a couple of weeks in – yes, absolutely, I could help out. But if you're asking me to do it full time for three weeks, I probably would say not likely*' [IC6]. Universities can also impose administrative barriers that can impact the long-term sustainability of relationships with industry collaborators, e.g. '*some of the bureaucracy involved in the university getting things set up and going can make it challenging, so you really want to know that there's some benefit to go through some of the hurdles*' [IC2].

To ensure sustainable industry relations, coordinators recognise the importance of providing value to industry collaborators, e.g. '*I don't expect to just extract information from them without giving something back to them*' [UC4]. Based on the industry collaborator interviews, the value can be in:

- personal intrinsic motivation to provide a good education experience;
- positive public relations;
- access to ideation from students; and
- building capability in potential employees and creating connections.

which are also more widely noted in the literature (Goldberg et al. 2014; Ståhl, Sandahl, and Buffoni 2022).

#### 6.3.2. Scalability

On the industry side, constraints on the availability of industry collaborators are an issue for scaling up to large courses, e.g. '*as long as there was enough time in the day to facilitate these things, that was fine. It was an extra workload on top of what to do that day … flexible in the working arrangements with that, so you can dedicate time to do that, but no extra remuneration*' [IC2]. Industry collaborators not being able to set aside sufficient time for the project is considered one of the key risks for successful PjBL delivery (Ståhl, Sandahl, and Buffoni 2022). To address this, a gatekeeping role from either the coordinator or challenge providers is necessary, e.g. '*I think if about 120 students emailed me, it'd probably be a bit much. By all means, sending a collection of emails or a collection of questions*' [IC1] and '*[challenge organisers] can be that filter to make sure that our community partners aren't fielding all of the students' questions because there are so many*' [IC3]. Again, this has workload implications for the coordinator or cost implications for the institution.

Support that may alleviate workload concerns (and hence improve the scaling out of PjBL) include support with building and maintaining industry connections. Industry collaborator-coordinator relationships currently develop in several ways. Some are formed via opportunities at the institution, e.g. '*we got involved with the university as part of the co-op program several years ago*' [IC1], which speaks to a demand for administrative staff to generate and manage the partnership. Others are formed at a more personal level, e.g. '*that relationship was built up from us supervising an honours student with them*' [UC3].

Effective university-industry collaborations for PjBL require support from university processes and policies (Pan et al. 2020). A lack of institutional support may have implications on the long-term relationship between the academics and industry collaborators. It may pose a reputational risk when academics are asked to draw on professional and potentially personal contacts to generate industry connections. Access to teams that manage partnerships with industry is currently problematic, e,g, '*the partnerships and turnover are a challenge … every year, there's different teams that are involved in partnership management*' [UC1] and there is a focus on research, e.g. '*if there is, I don't know anyone that uses them from the educational point of view*' [UC7]. Although these teams do not currently address workload concerns for coordinators, e.g. '*I've been personally working with people in that business unit to acquire that list. … [still], it does take a lot of our time to cold-call different companies*' [UC4], they are a potential mechanism that would support the scaling out of PjBL.

### 6.4. Assessment

#### 6.4.1. Sustainability

Assessment structures for PjBL can be vulnerable to institutional assessment frameworks and limitations imposed by budgetary restrictions. Fortunately, there is recognition by local leadership that traditional assessment frameworks that are dictated by the institution can constrain PjBL and there are measures put in place to accommodate, e.g. '*[institution] has a bit of a requirement that any subject has 70% individual marks and only 30% group marks. But even within that framework, they allow us to do project-based learning and for students to work in groups*' [UC2] and '*we now have a limit of having [a] maximum of three assessments for each unit … they've been happy with us including a portfolio assessment where a student puts in a presentation and a progressive report and a final report and a peer assessment component*' [UC3]. This flexibility in assessment structure that is often required by PjBL reflects the range of skills, both technical and non-technical, that are taught and assessed in PjBL units (Felipe et al. 2017). In contrast, there appears to be less support in terms of budget, e.g. '*we have a limit on how much marking allocation time is allowed for each student, and if you're getting them to delve deeper and do a bigger project and then reflect and review on their learning … it doesn't let you have a free reign in what and how you'd like to assess*' [UC2]. This may impact decisions on assessment design, with coordinators potentially not providing sufficient scaffolding due to obligations to take a fiscally-conservative approach.

#### 6.4.2. Scalability

Concerns around the scaling up of PjBL assessments focused on collaborative assessment. In line with findings from existing studies (e.g. Rienties et al. 2013), group-based projects can reduce workloads associated with assessing large cohorts, e.g. '*it's a very, very large cohort, about thousand students a year. And by getting them to do a project together, it helps in managing outcomes and deliverables if they work in the project*' [UC2]. However, the management of groups becomes increasingly important, with both industry collaborators and coordinators fully aware of unequal group contributions, e.g. '*That's always tough to see – really good kids saddled with duds. It is what it is*' [IC1] and '*One of the problems that we find with PjBL – and this is same with any group activity – is that there are some people in the group that do the work and some people that don't*' [UC6]. With accreditors (Engineers

Australia 2019, 28) and institutions requiring assurance of individual student performance, there is also a need to quantify individual contributions in group-based assessments. As highlighted by coordinators, there is substantial workload and resourcing associated with this, e.g. '*I think it's very important to train people how to set up when they're setting their assessment structure for group-based, making sure there is a highlight on individual contribution, there are check-ins with the groups*' [UC3].

### 6.5. Student feedback

#### 6.5.1. Sustainability

Student feedback on PjBL is mixed. Interviewees indicated that students enjoy the experience of working on a problem brief set by a real client, e.g. '*from feedback from the students, it was great for them as well, because they're working more closely with industry as well and trying to learn first-hand*' [IC2] and '*they like the fact that it starts off by getting them excited about the fact that they're designing for a real client*' [UC1]. This positive feedback has also been noted in existing studies (e.g. Balash et al. 2020; Gupta and Bailey 2014). However, there can also be resistance from students due to their expectations of engineering as a predominantly technical discipline and more positive feedback often takes student hindsight and reflection, e.g. '*they constantly tell us, "why do we need to write so much when all I'm going to do is math and science, equations for the rest of my career?" . . . in fourth year they say "wow that was a great unit" but that doesn't help me because first year students are saying "oh, that sucks"*' [UC5]. Teaching & Learning leadership must recognise the potential for poor student feedback to negatively impact coordinator decisions to use PjBL approaches, as well as cause retention issues.

#### 6.5.2. Scalability

Scaling up a PjBL learning course has implications on the student feedback. Providing appropriate resourcing for larger cohorts is necessary, e.g. '*If feedback is no good, then students don't learn a lot, and they also feel very, the satisfaction drops because they don't*

| | | Enablers | Barriers |
|---|---|---|---|
| Unit design | Sustainability | • Industry collaborators who understand and are willing to accommodate university constraints<br>• Design challenges which take responsibility of designing projects<br>• Local leadership who have an understanding of PjBL<br>• Inheriting an existing PjBL course | • Balance between authenticity of projects and learning outcomes<br>• Lack of professional experience amongst academics<br>• Senior leadership who advocate for PjBL without an understanding of practical implications<br>• University timelines |
| | Scalability | • Alignment of course content with PjBL approaches | • Consistent learning journey and alignment between different units of a degree<br>• Resistance due to changes needed to adapt curriculum, delivery and assessment for PjBL, as well as associated workload |
| Academic staffing, workload & resourcing | Sustainability | • Resourcing, such as administrative staff and appropriate budgets<br>• Mentorship from other PjBL colleagues<br>• Diverse teaching teams<br>• Co-coordination models, e.g. multiple coordinators or head tutor | • Workload models that don't reflect actual workloads<br>• University timelines that don't provide sufficient down-time between terms<br>• Lack of clarity around budgets<br>• Unit coordination by a single academic |
| | Scalability | • Technologies to automate components of the coordination role<br>• Gathering colleagues with an interest in implementing PjBL<br>• Maintaining a team of tutors who can teach across a range of PjBL units | • University structures, such as timetabling and space allocation<br>• Consistency amongst the teaching team<br>• Coordinators who are forced to engage with PjBL |
| Industry involvement | Sustainability | • Articulating and providing value to industry collaborators | • Time and workload constraints on industry collaborators<br>• University bureaucracy |
| | Scalability | • Support with gatekeeping of student interactions with industry collaborators, e.g. design challenges | • Risk for academics to draw on professional and personal connections<br>• University's greater focus on industry-research partnerships |
| Assessment | Sustainability | • Leadership that accommodate non-traditional assessment structures | • Rigid assessment frameworks<br>• Limited budgets for marking assessments |
| | Scalability | | • Management of group assessments |
| Student feedback | Sustainability | • Positive student feedback, often long-term | • Poor short-term student feedback, which impacts academic metrics |
| | Scalability | | • Resourcing to provide quality feedback |

*appreciate what they've learnt. And that in itself takes a lot of time*' [UC7]. Students can respond negatively when teacher presence is reduced in an effort to reduce staff workloads (Brown 2020) or when marking hours do not allow sufficient feedback on assessments (Cuskelly and McBride 2017).

## 7. Conclusions and recommendations

The findings of this study present insights into the sustainability and scalability of PjBL within the Australian & New Zealand context. While this study has captured a limited sample of industry collaborator views and unit coordinator views, it has nevertheless highlighted a wide range of enablers and barriers, namely:

The enablers and barriers listed act as a recommendation for both unit coordinators and Learning & Teaching leadership for how to create environments in which PjBL can scale in a sustainable way. The recommendations build on previous research (e.g. Brown 2020; Tse and di Bona 2019) by providing a broader cross-institutional perspective rather than focusing on a single institution. We have also noted that our findings are consistent with those of single institution studies, highlighting the pervasiveness of these issues. Unit coordinators may use the table to identify suitable practices within their own contexts and/or for advocacy with their own Learning & Teaching leadership. The recommendations also provide guidance to Learning & Teaching leadership, who should consider implementation and support of enablers not currently implemented at their institution, and also review which of the barriers are within their capability to address. Given that sustainability is a key driver of scalability, Learning & Teaching leadership must first address sustainability issues. In particular, Learning & Teaching leadership should consider: providing better resourcing; providing sufficient time for coordinators to build connections and design their units appropriately; giving academics the freedom to design project units as required; introduce co-coordination models; and building a shared understanding of how to interpret student feedback. The findings of this study and subsequent recommendations offer opportunities to ensure not only the retention of unit coordinators who run PjBL units but also offer a pathway forward to widen adoption of PjBL within engineering units. This study, initiated in response to the Engineering 2035 agenda has already helped shape the Australian Council of Engineering Dean's response by defining objectives for a program set up to expand uptake of PjBL across Australian Engineering Schools, the *Engineering Futures Initiative.*

Further research on journeys into PjBL should be conducted to explore the process of diffusion of PjBL practice. Future work should continue to monitor the evolving landscape of PjBL, as well as wider developments that occur in light of this study's findings and recommendations.

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## Disclosure statement

No potential conflict of interest was reported by the author(s).

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