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Current best practice, support mechanisms and experiences of project-based learning

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ABSTRACT

CONTEXT

Project-based learning (PjBL) promotes the development of graduates who will be prepared to contribute to society (Mills & Treagust, 2003) which is aligned with the findings in the Engineering Futures 2035 (Reidsema et al., 2021) report. However, support mechanisms are varied between and within institutions. It has been challenging for teaching staff to know what they should seek in terms of teaching and learning support, and on the other side it is unclear for the teaching & learning leadership what they should offer in terms of support for this mode of education.

PURPOSE

This study aims to impact change in engineering by collating Australasian experiences of PjBL, to identify its strengths, and build a snapshot of current best practice. In addition, the study also aims to identify exemplar practices and units.

APPROACH

Unit information has been collected on 41 units from 11 institutions. Of these, most are discipline-specific units (n=29) while the rest are cross-engineering units (n=11) or include non-engineering students (n=1).

ACTUAL OUTCOMES

Results show that the larger classes are often coordinated and taught by junior staff while discipline-specific smaller classes were more often taught by senior staff. Many units are run by those who have only a few years of experience in industry. A total of the academic and casual teaching loads shows that units typically require a higher budget. Different purposes were observed in generalist over discipline-specific units, reflected through assessments and learning outcomes. Student satisfaction was found to be relatively low for PjBL units.

CONCLUSIONS

More scaffolding for junior/large units, team and shared teaching, reviewing administrative structures for enhanced industry collaboration are some important implications identified through this study. The study recommendations will allow schools, faculties, and T&L leadership across Australasia to make decisions around how best to support teachers of PjBL units.

KEYWORDS

Project-based learning, best practices, staff support

Introduction

Project-based learning (PjBL) promotes the development of graduates who will be prepared to contribute to society in line with the expected future graduate outcomes reported in Engineering 2035 (Crosthwaite, 2021). This results in implications for higher education in Australia in delivering an effective learning experience on PjBL for students through their engineering programmes. According to an Australian Council of Engineering Deans (ACED) report *"… future Engineering* pedagogy must focus upon replicating the types of environments, projects and settings within which future graduates will work" (Lawrence, 2020, p. 2).

Successful PjBL delivery requires teaching academics who are capable and motivated, which would to a larger degree depend on their perceived level of institutional support. However, academics who teach PjBL are reported as 'lone champions' taking 'maverick' efforts (Graham & Crawley, 2010). Anecdotally, teaching academics report existing support mechanisms for PjBL (such as resourcing, reasonable workloads, peer support) as being varied, with teaching staff not knowing what they should seek and teaching & learning leadership not knowing what they need to offer. Linked to COVID-19, many Australasian universities went through processes of restructure, or staffing reductions further reducing resourcing into complex PjBL. This observation and the findings of the "Engineering 2035" report (Crosthwaite, 2021) prompted a study with the aim of improving graduate outcomes through a strengthening of PjBL in Australasia. The purpose of this paper is to provide the current PjBL landscape across Australasia and the preliminary findings of this study.

The paper first gives a brief overview of the literature on challenges for teaching PjBL. Then the study method is presented, this included collating, through surveys, Australasian experiences of Project-Based Learning (PjBL) to build a snapshot of current best practice in PjBL and identify support mechanisms. The discussion of the results focuses on sharing the range of resourcing inputs, assessment modes, staff experiences, student satisfaction and industry involvement on current PjBL practice. In a concluding section, implications for engineering education are drawn with recommendations for practice, and future work.

Challenges for teaching PjBL

Project based learning (PjBL) is an experiential learning method which introduces students to professional practice by giving them an opportunity to work on real-life problems (Uziak, 2016). Benefits of PjBL for students include the development of professional skills and identity, better communication and teamwork skills, as well as a better understanding of how to apply knowledge in practice and complexities of practice (Mills & Treagust, 2003; Sanders et al., 2016). PjBL also promotes students' autonomy and lifelong learning (Uziak, 2016). In terms of higher education institutes (HEIs), drivers for PjBL include calls from industry and professional bodies to better equip students with professional skills and capabilities to face real-life engineering problems (Graham & Crawley, 2010). PjBL is also used by HEIs to make engineering degree programmes attractive to students, as it deviates from the traditional mode of knowledge transmission to experiential learning (Graham & Crawley, 2010; Uziak, 2016).

As PjBL shifts focus from traditional teaching, distinct features of PjBL have emerged in engineering education. PjBL is student centred (Mills & Treagust, 2003; Uziak, 2016) and is more about what the students learn than what the teacher teaches (Uziak, 2016). PjBL tries to promote active learning from the student with the intention of cultivating skills such as critical thinking, group work skills, problem solving skills (Chen et al., 2021). While traditional teaching is mostly one-way knowledge transmission, PjBL is known as a method which can put a greater focus on the individual student, catering to varying degrees of pace of learning and varying learning styles (Uziak, 2016). PjBL tries to deliver an authentic experience for students giving students the opportunity to work on projects and assessments which represent real-life industry practice (Mills & Treagust, 2003). Therefore, PjBL is realistic (focuses on real-life problems) but complex. The emphasis in PjBL is more about the process than the product and focuses on integration of previously gathered knowledge and application (Uziak, 2016). PjBL makes effective use of relevant educational technologies and uses assessment paradigms that consider project processes as well as end products. PjBL implementation is diverse; with unit-level, cross-unit level, curriculum-level and project-level implementations (Chen et al., 2021). With all these features, PjBL is resource intensive and therefore costly when compared with traditional approaches in terms of time, teaching staff, specialist staff, equipment, materials, learning spaces (Graham & Crawley, 2010).

The distinct features of PjBL along with deviation from traditional teaching create unique challenges for teachers who deliver PjBL. Although PjBL implementation is diverse, these challenges are similar (Chen et al., 2021). One recurring challenge reported in the literature is about the burden of heavy workloads for teachers (Chen et al., 2021). PjBL consumes more time and effort as it is more complex to design and deliver than a traditional unit (Chen et al., 2021; Sanders et al., 2016). This is exacerbated by the lack of sufficient resources such as supporting staff, materials, equipment and learning spaces (Chen et al., 2021; Graham & Crawley, 2010). Another challenge is the changes required to curriculum, assessment and (delivery) instructions which sometimes is seen as a daunting task by the academics (Sanders et al., 2016). One of the main reasons attributed to academics' low confidence in designing and implementing assessment tasks appropriate for PjBL is attributed to their lack of knowledge (Graham & Crawley, 2010), as a result of insufficient pedagogical training (Chen et al., 2021). There are also challenges in terms of large class sizes, with some assessment tasks and (delivery) instructions becoming unsustainable with scale (Sanders et al., 2016). In the midst of these challenges, there is also a high degree of expectation from PjBL teachers. They are expected to design their projects in such a way that an authentic experience is given to the students while also giving consideration that the project is relevant to the discipline and of interest to the students (Uziak, 2016). With these student-focussed teaching and experiential learning aspects of PjBL, the delivery or the teaching style also demands changes, from a more traditional approach of instructor-led teaching to more of a facilitator style of teaching (Chowdhury, 2015; Uziak, 2016). However, the literature reports difficulties faced by teachers in changing their teaching styles from a traditional approach to one that suits PjBL (Chen et al., 2021; Sanders et al., 2016).

Students also need to have a good understanding of the nature of PjBL (Shekar, 2014). Students who are used to results-focussed learning could be ill-prepared for PjBL (Chen et al., 2021), exacerbating the challenges for teachers. Conflicting demands by HEIs in terms of teaching and research, could not only make it difficult for teachers to put aside time for their own PjBL unit design and delivery, but also hamper collegial support (Graham & Crawley, 2010). The wide range of PjBL implementation is attributed to the lack of formal training for staff on PjBL, resulting in 'maverick' efforts by the teachers in designing and delivering PjBL according to individual understandings "as lone 'champions' with limited time, resources and support" (Graham & Crawley, 2010, p. 41). It is also pointed out that in terms of designing authentic projects for students, the lack of academics' relevant experience could be a barrier for successful project designs (Graham & Crawley, 2010), thus necessitating more industry involvement. There is a need for addressing these challenges, as "…unless these barriers were addressed, PjBL may lose ground within the engineering curriculum." (Graham & Crawley, 2010, p. 43).

Strategies to minimise the burden on teachers are reported in the literature. Replicating successful PjBL units could save time and effort by teachers, but it is often not seen as a feasible option due to critical differences such funding/institutional support, low student numbers in exemplar units, or dependence on in-house expertise or special equipment (Graham & Crawley, 2010). This in turn, raises concerns over sustainability of PjBL when reliant upon individuals who act as champions for PjBL delivery (Graham & Crawley, 2010). Other than replication, other support mechanisms at institutional level include building better communication channels within institutes to share and learn from others' PjBL teaching experiences (Chen et al., 2021), financial support, appropriate learning equipment and infrastructure, and recognition of teachers (Chen et al., 2021).

The support from institutions is critical for the success and sustainability of PjBL (Chen et al., 2021; Graham & Crawley, 2010). However, there is a gap in the literature advising teachers on what to seek for from their institutions in order to deliver a successful PjBL experience. In response, a small cross-institutional study, funded jointly by AAEE, ACED, and the lead institutions was initiated with the objective of building a snapshot of current best practice in PjBL in the Australasian context and identifying support mechanisms for teachers designing and delivering PjBL.

Methodology

The full study uses a mixed-methods approach to examine current best practice, support mechanisms and experiences of project-based learning (PjBL). This paper reports on the first findings from this study which includes insights from an analysis of data from 41 units of study (also known as courses or subjects or papers) across 11 universities. The unit data presented in this paper are from 2020; while the study collected both 2020 data and a 2017-2019 average data, there was no significant change between the two sets of data. The majority of the units (n=29) are discipline-specific with the remainder being taught across disciplines (n=11) or include non-engineering students (n=1). The cross-engineering units are often also large (class size>120), first-year transition units. In the results and discussion note that 7 units had co-coordinators and the sample size in some figures are less than 41 because of incomplete data.

Results and Discussion

Academic staffing and workloads

Project-based learning is used by academics across all academic levels; however, larger classes are often coordinated by junior staff (Figure 1) and these larger classes tend to be first-year transition units. Some unit coordinators have suggested that this may result from expectations that senior staff teach within their specialisations whilst junior staff teach more general units. Academic workloads (including coordination, sourcing projects, lecturing, marking, tutor training) and casual teaching budgets were also analysed. For relatively small units (up to ≈20 students), there is often no casual teaching budget. Furthermore, a total of the academic and casual teaching loads shows that units typically require ≈4 hours per student (Figure 2).

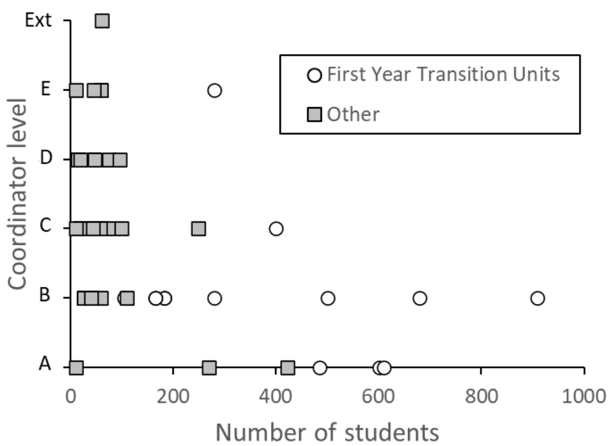

Figure 1: Coordinator level against class size (n=49)

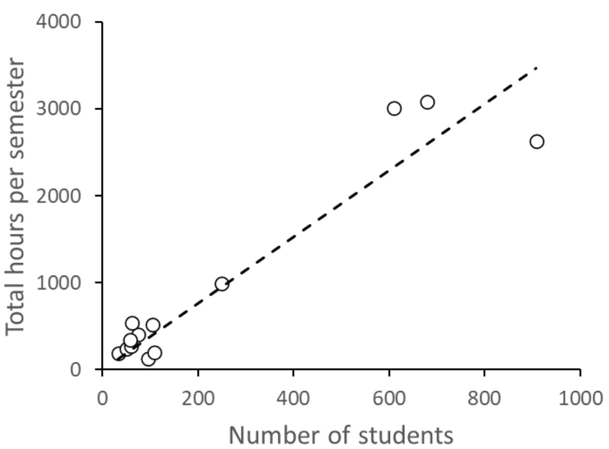

Figure 2: Total hours (t) against class size (s) where t = 3.8s; R^2 = 0.94 (n=13)

When considering only academic hours, the hours per student tends to reduce with class size (Figure 3). However, the total hours can be significant (Figure 4) and may result in excessive workloads for coordinators of larger units. Since these larger units tend to be coordinated by junior staff, this raises concern over how these coordinators are supported in delivering these large units. Only a few units in this study (n=7) are coordinated by more than one person and, of these, fewer than half (n=3) have large class sizes. This perhaps highlights a greater need for collegial support through shared coordination of units given the significant benefits of team-teaching (opportunities for feedback and mentorship, decreased workloads) identified by Baeten and Simons (2014).

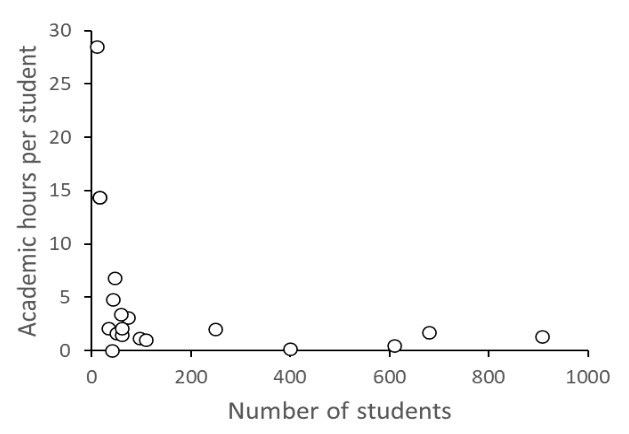

Figure 3: Academic hours per student against class size (n=18)

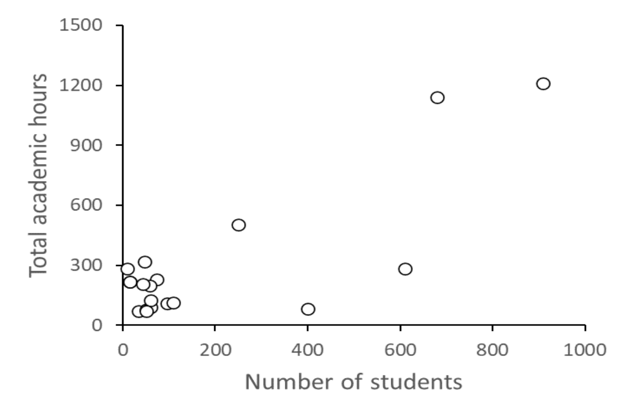

Figure 4: Total academic hours against class size (n=18)

Industry involvement

An Australian Council of Engineering Deans report highlighted that engineering education should replicate the “types of environments, projects and settings within which future graduates will work” (Lawrence, 2020, p. 2). Two mechanisms for replicating the industry context are 1) coordinators drawing on significant industry experience and 2) involving industry partners in the co-creation of experience. This study found that few (n=3) coordinators draw on industry experts as mentors in their delivery and 43% of coordinators have less than two years of experience in industry themselves (Figure 5). Whilst there may not be many years of experience, there is an attempt to replicate industry standards within all units (n=41) using some form of final project report (Figure 6).

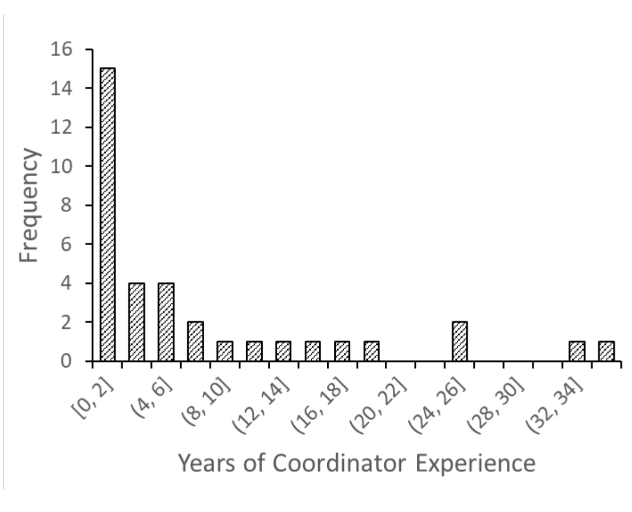

Figure 5: Coordinators’ industry experience (n=35)

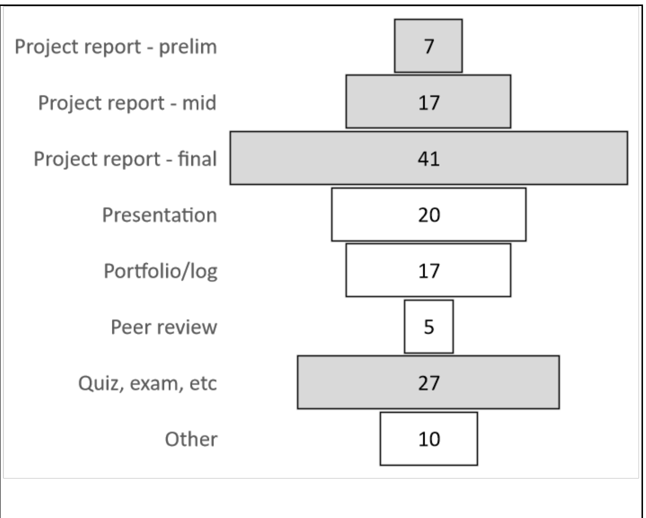

Figure 6: Types of assessments in use (n=41)

The lack of significant industry experience among coordinators may necessitate direct involvement of industry partners to support wider adoption of practice-based approaches. Effective university-industry collaborations for PjBL would require support from university processes and policies (Pan et al., 2020).

The lack of such may have implications on the long-term relationship between the academics and industry partners, and potentially poses a reputational risk, especially when academics are asked to draw on professional and potentially personal contacts to generate the industry connections. Further, concerns are raised around the intent of PjBL (Ståhl et al., 2022), often a compromise between a focus on developing student learning outcomes and developing value for the industry collaborator. Academics can fall into a trap by diluting the industry problem to ensure students can demonstrate a particular knowledge set resulting in the PjBL becoming inauthentic, say by turning an open-ended problem into a closed problem. This balance is delicate, without practical constraints the value of solutions that students come up with can be questionable.

In either way, the balance of learning and industry value must be carefully considered to ensure industry involvement and PjBL remains authentic.

Assessment

Figure 6 shows the different types of assessments used and their prevalence. A scaffolded approach for project-based assessments is frequently observed with preliminary, mid and final project reports along with a presentation. This is complemented by quizzes, peer review, self-review, portfolios or logs and others (including participation or attendance). Out of these types, all units (n=41) had a final project report while project presentations (20) and quizzes/exams condition type assessments (17) were the next most used type of assessments. While all units assess the final project outcome (that is, the final project report), they do not all assess the process followed by students in producing the outcome. Specific examples of process-based assessments include self/peer review and/or evaluation, data management (design journals, portfolios or logs). Only 12% of the units considered peer review assessments. Both traditional assessments such as exams and assessments that are more innovative such as self/peer review are adopted in PjBL practice (Chen et al., 2021).

Assessment type and learning outcomes appear linked. Where there are more technical-focused learning outcomes (concepts, technical methods, etc.), there also may be a greater component of the assessment through quizzes and exams that aim to assure individual technical competencies (Figure. 7). In units that have 100% technical-focused learning outcomes, over 70% of these units have predominantly quiz/exam-based exams and correlates to these units being or senior discipline-specific units. This suggests that professional skills (that is, non-technical competencies) are less likely to be explicitly taught or assessed in the senior years. Some units (n=10), however, do have technical learning outcomes that are assessed only through project-based assessment. Furthermore, these observations are confirmed in Figure 8, where first-year units tended to have fewer exams which is attributed to the more generalist and multi-discipline approach to such units. The assessment types of these units also correlate with the non-technical learning outcomes, where all the first-year units involved have predominantly process-type assessments rather than outcome-focused assessments.

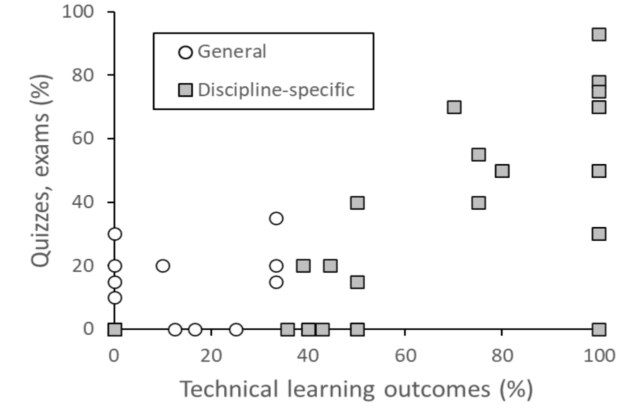

Figure 7: Learning outcomes that are technical against assessments that are exams/quizzes (n=41)

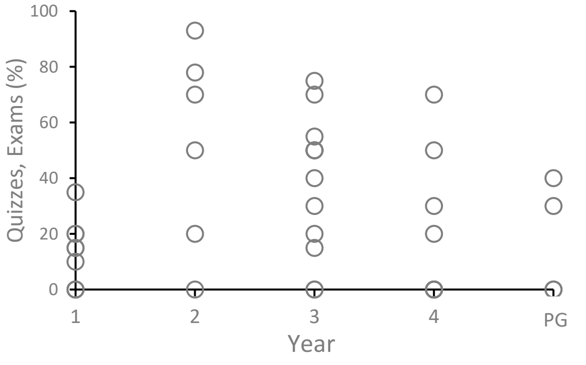

Figure 8: Assessments that are exams/quizzes against year level (n=41)

Student satisfaction

Student satisfaction with project-based units in this study ranges from 68% to 97%. For units with student numbers greater than 120 (Figure 9), student satisfaction is typically 70-85%.

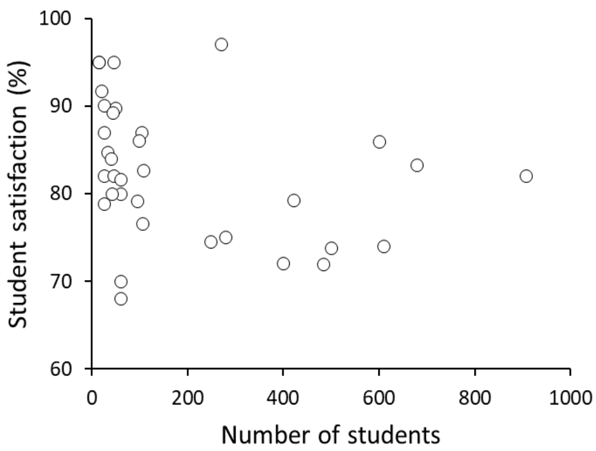

Figure 9: Student satisfaction against class size (n=33)

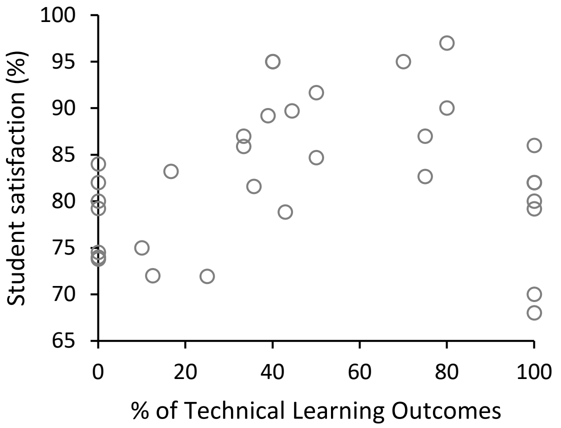

Figure 10: Student satisfaction against % of Technical Learning Outcomes (n=33)

The comparison of the percentage of technical learning outcomes in the unit with the student satisfaction (Figure 10) shows that subjects with fewer technical learning outcomes (from 0 to 25%) attract lower student satisfaction (72% – 85%) compared to the units with the percentage of technical – focused learning outcomes ranging between 33% to 80% where the student satisfaction starts from 79% and ranging up to 97%. There is generally a linear trend up to 80% of technical learning outcomes. However beyond this, the units with technical-only learning outcomes (100%), also attracted a lower student satisfaction being between 68% to 86%.

The majority of more general units with lower technical components are taught in the first year where students are expected to still be developing the study, research, and report-writing skills required for PjBL. Furthermore, other research has noted that students opting for a degree in engineering often come to the university with a mindset prepared to take on the challenges of learning technical engineering skills (Hatakka, 2016), and thus, are less engaged with more general, abstract subjects. On the other hand, the results suggest that engineering students also might not well receive technical-only PjBL units due to the complexity of the content. The enhanced student satisfaction is seen within the units with the blend of both technical and non-technical learning outcomes.

Discussion and Conclusions

The findings of this study to date present a useful snapshot of contemporary norms in PjBL in the Australasian context. While this study has captured a limited sample, it does represent the most complete and current assessment of its type. We have identified four key issues that warrant both further investigation as to their applicability across the sector, and active consideration by those delivering PjBL or in Learning and Teaching leadership positions with responsibility for resourcing PjBL units:

#1 Implications for workload & staff retention

Data presented here provides a benchmark for what is typical of staff resourcing in PjBL units. However, this may not be indicative of the *appropriate* level of resourcing to ensure retention of staff in these units, or the ability to attract senior staff to run them. In addition, shared/team teaching approaches warrant further consideration being a relative rarity in these units.

#2 Supporting authentic experiences
There is currently a lack of industry collaborations or industry experienced staff involved in delivering PjBL units. While this may not necessarily mean that learning experiences are inauthentic, it does suggest a risk of disconnect from real world practices. Removal of barriers to industry collaboration in PjBL units, particularly administrative ones, warrants attention.

#3 Understanding different purposes of PjBL
This sample demonstrates the range of learning focus PjBL currently supports, from generalist to discipline-specific. However, the data suggests that better outcomes are achieved with a mix of both technical and professional skills development that is reflected in a variety of learning outcomes and assessment types.

#4 Managing expectations of student satisfaction
Student satisfaction can be relatively low for PjBL, particularly for larger units and those with more emphasis on professional skills development than technical skills. Faculty leadership should consider the external benchmarks presented here when interpreting student satisfaction survey results for PjBL units.

Overall, the findings of this study echo those of much earlier work in PjBL in the need to support and resource this mode of teaching on its own merits, rather than in a manner on par with more traditional modes of delivery:

"The recommendations for continuing progress towards the intended project-based curriculum primarily revolved around continued training for both students and staff in the skills needed to make project-based or problem-based learning effective, such as teamwork and problem-solving, as well as continued education for staff in implementation and assessment methodologies that are more attuned to problem- and project-based learning philosophies." (Mills & Treagust, 2003, p.12)

Further work includes interviews with industry collaborators and course coordinators to build a deeper understanding about the current landscape and identify support mechanisms for PjBL.

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