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Industry Perspectives on Project-Based Learning as a Form of Work-Integrated Learning in Science

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Abstract

Growing concerns about the employability of science graduates has led most Australian higher education providers to incorporate work-integrated learning (WIL) into their science curricula. Project-based learning (PjBL) is a student-centred approach to learning that focuses on the application of discipline specific skills and knowledge in real-world contexts. While a large body of research exists exploring PjBL frameworks and theories related to student experience, research into industry perspectives and viewpoints is limited. This study aimed to determine the views of industry professionals on PjBL as a form of WIL, and to ascertain whether industry professionals consider PjBL effective for the development of desirable graduate skills. The perspectives of industry partners were canvased through a mixed-methods approach comprising surveys and interviews. Participants (*n*=18) were asked to indicate their opinions regarding development of graduate skills through PjBL generally and in relation to two authentic examples of PjBL in WIL. The results of this study indicate that industry partners preferred longer-term, workplace-integrated industry projects for developing graduate skills and preparing graduates for the workforce. Industry partners interviewed generally exhibited positive views of PjBL, identifying students' attitudes and communication skills as beneficial factors. Some industry partners indicated current graduate programs where insufficient in preparing students for employment. These results highlight the importance workplace integration in successful implementation of PjBL as a form of WIL, and the need for stronger collaboration between employers and academia to correct the current misalignment between graduate skills and industry requirements.

Keywords
Employability; Work-Integrated Learning; Project-Based Learning; Industry; Graduate Skills; Biotechnology; Postgraduate

Introduction

Graduate Employability

Over the past decade, a focus on graduate employability has brought significant changes to higher education, with STEM disciplines facing pressure to produce work-ready graduates. Graduate employability is the capability of individuals to move into new employment within a labour market (McQuaid, Green, & Danson, 2005). In contrast to fields like medicine and law, natural science and biological science graduates have experienced lower post-graduation employment rates (Department of Education, Skills and Employment (2021). Views of desirable graduate attributes and what constitutes 'work-ready' graduates evolve according to current economic, technologic, and societal trends. Rapidly evolving technologies such as artificial intelligence (Karimi & Pina, 2021), and trends toward workforce agility (Ferns & Lilly, 2015) are suggested drivers. The balance between soft and hard skills is debated, and ongoing discussions revolve around whether skills, mindset, or knowledge should be the learning focus in higher education (Hendarman & Tjakraatmadja, 2012, Wheelahan et al., 2022). Increasing evidence suggests that science disciplines should prioritise the development of soft skills. Studies like Coll and Zegwaard's (2006) found that STEM stakeholders considered soft skills, such as the ability to learn, as crucial. Surveys by Rayner and Papakonstantinou (2015) concluded that higher education should adapt to offer more opportunities for skill application in industry contexts. Discrepancies between graduate and employer views exist, reflecting different opinions on skill development.

The development of desirable graduate attributes and outcomes has been conceptualised by Tomlinson (2017) into five graduate capitals: human, social, cultural, identity, and psychological capital. Acquired by a combination of formal and informal experiences, Tomlinson's model frames employability as a dynamic interaction between different graduate capitals, rather than a simple assessment of skills and attributes. Human capital involves discipline knowledge, technical skills, and transferable skills which are gained primarily through formal education specific to a graduate's chosen field. Social capital is the 'sum of social relationships and networks', which benefit a graduate in their pursuit of labour and market opportunities. This may be harnessed through direct contact with employers through online profiles or career events. Cultural capital is drawn from culturally accepted values and behaviours that directly relate to the markets and workplaces that graduates seek to enter, often reinforced by exposure to both formal and informal employment networks through internships and work experience (Tomlinson, 2017). Psychological capital is strongly related to the ability of graduates to adapt to career challenges and adversity (Tomlinson, 2017); higher education has a vested interest in developing graduates with high levels of psychological capital, particularly in highly competitive and intense markets where a proactive employee with strong coping ability has a higher possibility of success. Identity capital has a potentially significant role in the development of professional identity, defined by Tomlinson (2017) as the level of personal investment a graduate makes towards their future career and employability. Tomlinson (2017) suggests that reinforcing a graduate's self-presentation and goals relating to their future professional identity can have a tangible effect on their career progression upon leaving higher education. Tomlinson (2017) posits that higher education should therefore prioritise improvements in professional skill development and a structured effort to develop graduate capital by strengthening the link between higher education and industry.

Work-Integrated Learning

As an approach to developing well-rounded and work-ready graduates in science disciplines, work-integrated learning (WIL) has emerged foremost, being acclaimed by both students and educators. *The WIL Report*, an Australian national scoping study, defines WIL as a range of strategies which combine theory with work practice within the structure of a curriculum (Patrick et al., 2008). WIL takes a myriad of forms which can include internships, research, clinical rotations, study abroad, and professional work placements (Kramer & Usher, 2012). McRae and Johnston (2016) proposed a global framework to alleviate confusion, allowing flexibility in program design. Rowe and Winchester-Seeto (2021) presented a more holistic learning-support framework considering all WIL aspects but mostly suited for workplace-based WIL. Development of professional identity is another key WIL outcome. Bowen (2018) found that internships allowed graduates to reconstruct their image of their professional self. McNamara (2013) suggested collaborative assessments for evaluating professional competence. There is no standard WIL approach. Different models include work placements, industry projects, networking events, micro-placements, online projects, and more. Jackson & Dean (2022) classified WIL into work-based, non-workplace, and global forms. Results from their study emphasized the value of diversifying WIL to increase gains in skill outcomes and professional capabilities.

Student Perspectives of Skill Development with WIL

Work-Integrated Learning (WIL) significantly impacts academic and employment outcomes. Divan & McBurney (2016) found that students engaging in WIL activities were more positive about their career prospects compared to those who did not. Likewise, Jackson (2015) noted that WIL gave students more direction for their future, while Durham et al. (2020) found that WIL allowed students to apply theoretical knowledge in real-world contexts. Jackson & Collings (2018), in a comparison of employment outcomes of graduates who completed WIL in the form of a work placement with those who did not, found that the perceived benefits of these placements were replicated in non-workplace WIL, being an increased understanding of their profession and skill development through practical evaluation.

Industry and Employer Perspectives of Skill Development with WIL

Empirical studies show mixed results on WIL's impact on employment post-graduation. Jackson & Collings (2018) found that paid employment, rather than WIL, increased the likelihood of full-time work. Meanwhile, Lloyd et al. (2021) noted that industry stakeholders in STEM value WIL for contributing to organizational objectives. Concerns remain around assessment and supervision, with a lack of accessible resources and feedback processes being a common issue (Ferns et al., 2016; Du Plessis, 2019). On the other hand, industry stakeholder feedback sourced by Govender & Taylor (2015) suggested a positive view of WIL as a method of screening graduates for future employment. It is evident that further investigation into industry perspectives of WIL experience in potential employees is required to gain a clearer understanding of whether WIL programs are meeting their main objectives; to create employable graduates.

Project-Based Learning

Project-Based Learning (PjBL), an approach emphasising long-term, student-centred, real-world practices, has been co-opted by WIL practitioners. Influenced by early psychologists like Piaget and Dewey's philosophies, PjBL encourages self-direction and enhances employability (Pecore, 2015). Dewey's theories influenced William Kilpatrick's ‘Project Method’, a precursor to contemporary PjBL, outlining four main types of projects focusing on central plans, aesthetic experiences, intellectual problems, and specific skills (Beckett & Slater, 2018, Kilpatrick, 1918). PjBL today remains widespread, with no single definition or universally accepted approach. A century later, Kilpatrick's ideas have evolved into student-centred investigations guided by regular assessments and evaluations, now also used as an industry tool for professional development. Berry et al. (2012) proposed three models for STEM learning through PjBL, ranging from structured central projects to open-ended student-led designs. While student-led projects provide more opportunities for skill development, they are more challenging to implement (Berry et al., 2012).

Roessingh and Chambers (2011) provided eight guiding principles for socio-constructivist approaches to PjBL, highlighting the joint efforts of learner and teacher. These include that the instructor should have expertise in the content area as well as in pedagogical competence; that the instructional deign is learner centred; that as a catalyst for learning there be a central question or problem to focus on; that the learning and teaching objectives are made explicit to students; that there is authentic learning in the tasks and they are engaging; that tasks within the project are sequenced so that they require combined effort from the project community; that the learning promotes critical reflection and higher order thinking; and that there is continuous monitoring of learning and assessment. Such approaches lead to knowledge integration, critical thinking skill enhancement, and align projects with professional realities, often waning guidance as students gain control (Beckett & Slater, 2018).

Student Experiences of Project-Based Learning

Project-Based Learning (PjBL) has a significant positive impact on students' career aspirations and self-efficacy, especially in STEM fields (Beier et al., 2019). Research, including a study by Tseng et al. (2013), indicates that PjBL strategies can change students' attitudes towards STEM and engineering, enhancing their future career views. It promotes active roles for both students and educators and fosters an environment where learners engage collaboratively and independently. PjBL targets the development of problem-solving, critical thinking, and soft skills in demand in the workplace. When combined with WIL, PjBL may help equip students with essential skills to improve their employability and smooth the transition from academia to professional life (Musa et al., 2012).

An example of successful PjBL has been reported by Rahman et al. (2009) who examined the impact of PjBL on meta-cognition, motivation and self-regulation among mechanical engineering students. The study compared the impact of PjBL in comparison to traditional instructional learning and teaching. Students reported increased motivation and a sense of responsibility following a purposefully designed PjBL model within a project management subject. The study found that students undertaking the PjBL module reported feeling increased self-confidence and self-regulation. Students also reported a feeling of being guided, which was facilitated by close monitoring of student progress by supervisors in sequential tasks, as well as continuous and frequent assessment, and self-assessment and reflection on project progress by students. These findings align with pedagogical principles that stress the importance of educator guidance, evaluation, and self-reflection (Barron et al., 1998).

A Gap in the Literature: Industry Perspectives on PjBL

PjBL as a form of WIL has been explored widely from the viewpoint of pedagogies and practices which maximise the student experience. However, existing literature on employer and industry viewpoints on PjBL, especially as a form of WIL, are sparse. There exists little understanding of industry perspective into the utility of pursuing graduate skill development through PjBL and whether this would improve graduate employability. Even though PjBL is often noted for its involvement in developing technical and transferable skills, a link between PjBL and graduate employability has not yet been investigated in-depth. The act of placing a meaningful, realistic project at the centre of a curriculum can create a learning environment that mirrors real-world challenges encountered within STEM industries (Balve & Albert, 2015). Given this gap in knowledge, it may be important to gather industry opinions and perspectives on current PjBL initiatives within Australian WIL programs, to better inform practice when designing and delivering PjBL activities as a form of WIL, and to determine whether these activities align with desired graduate outcomes.

Aims and Research Question

This study aims to examine the perspective of science industry professionals related to PjBL as a form of WIL. The study seeks to compare industry views with student perspectives as explored in the existing literature. Ultimately, this study seeks to answer the question: do science industry professionals support PjBL as an effective WIL approach for the development of graduate skills and graduate employability? To meet the study aims, science industry professionals partnered with a postgraduate-level WIL program were invited to undertake an online survey and subsequent interview where they were presented with authentic examples of PjBL in a WIL context. Participants were canvased to determine whether, in their perspective, PjBL in WIL facilitates development of graduate skills, and students' future employment prospects.

Methodology

This study was conducted within a post-positivist framework, rejecting the notion of conclusive interpretations found in a positivist approach, in favour of an integrated analysis (Adam, 2014). This post-positivist framework was chosen as it incorporates philosophical, interpretivist and comparative analyses suitable for exploring the complexities of individual perspectives on PjBL in WIL, conceding that one absolute truth cannot be reached (Panhwar et al., 2017). Within the post-positivist framework, the study utilises a mixed-methods approach, encompassing both qualitative and quantitative methods, being a well-recognised model of educational research for use in capturing the complexity of the study matter (Ponce & Pagán Maldonado, 2015). Additionally, this methodology follows a sequential design, which is a two-stage explanatory process whereby the quantitative data is gathered first, then used as the basis for constructing and describing the qualitative data (Almalki, 2016). By utilizing interviews to augment and explain the quantitative data gathered in the survey, this study aims to create a richer base of data from which conclusions can be drawn. This methodological design is suited to a post-positivist approach, where theoretical frameworks generally inform the quantitative phase of data collection, and then guide the design of the qualitative stage – in this case the type of questions explored in interviews which followed initial surveys (Creswell & Plano Clark, 2017).

This study received human ethics approval from The University of Melbourne Human Research Ethics Committee (HREC), Project I.D. number 2022-25248-34998-3. Participants in this study were recruited from a pool of 136 Master of Biotechnology WIL industry partners at the University of Melbourne, Australia. The participants had engaged with WIL programs in the previous five years. Invitations to voluntarily participate in this study were sent through a bulk, blind carbon copy email to the pool of industry partners describing the study aims and background, participant requirements, included a plain language statement (Appendix 1), and a Qualtrics hyperlink to participate in the survey. Participants were not compensated for their time or engagement.

Qualtrics software (https://www.qualtrics.com/en-au/) licensed by The University of Melbourne was used to construct and distribute surveys and to collect quantitative and qualitative data. The survey duration was approximately 20 minutes, with 24 items (Appendix 1), separated into four sections; demographics, PjBL example 1, PjBL example 2, and general PjBL views. After providing informed consent, participants were asked five demographic questions related to their area of expertise, the duration in years that they have worked in their current area, where they obtained their highest degree, the type of company or business they currently operate in, and their gender. The survey utilised a mix of 10-point Likert-scale questions (Strongly agree to Strongly disagree), ranked-order questions (1 – 10), as well as text entry question-response items. Participants were presented with two authentic examples of PjBL used in WIL within the Master of Biotechnology program at The University of Melbourne. These PjBL examples are referred to as 'Item 1' which comprised a 3-week in-class individual project mimicking a real-world work task, and 'Item 2' which was a year-long group industry project in collaboration with a host organisation external to the university. Participants were asked to indicate the degree to which they thought that either PjBL example aligned with desired graduate skills in the biotechnology industry, would equip students with skills required for employment in biotechnology industry, and would better prepare a student for employment in biotechnology industry. Through ranking, participants were asked how either PjBL example would help students improve to list of ten graduate skills, and how important these skills were in the participants workplace/profession. The graduate skills explored in this survey were sourced from the *2021 Graduate Outcomes Survey* (QILT, 2021). They include; innovative thinking, written communication, capacity to work independently, oral communication, ability to adapt knowledge in different contexts, working well in a team, ability to solve problems, broad general knowledge, ability to develop relevant skills and ability to apply skills in different contexts.

Participants were then presented with various PjBL-related questions seeking Likert-scale, ranked-order and text-entry responses, on areas including; advantages today's biotechnology/biosciences graduates have compared to graduates 10 years ago, what today's biotechnology/biosciences graduates lack in their preparedness for employment, importance of graduate attributes to gaining employment within the biotechnology industry, whether graduates of biotechnology/biosciences courses have had sufficient opportunities to collaborate with industry, whether PjBL in the field of biotechnology benefits both students and employers, whether PjBL in groups better prepares graduates for employment compared to individual projects, and how could higher education could better prepare biotechnology/bioscience graduates for employment.

Participants who indicated at the conclusion of the survey a preference to undertake a one-on-one interview were sent an invitation for a time that they would find convenient. Interviews attained a 3% response rate (*n*=4). Interviews were held online using Zoom videoconferencing for participant convenience and comfort. Interviews were semi-structured, allowing each participant to elaborate on their survey responses and their own personal experience facilitating PjBL. Interview questions were broadly informed by responses to surveys by individual participants. Each interview was no longer than 30 minutes in duration and were recorded and transcribed anonymously at the conclusion of each interview. Recordings were permanently deleted within 7 days, whilst anonymised transcripts were retained for data analysis. The interviewees comprised three males and one female. Two interviewees worked for small/midsized biotechnology companies while two worked for multinational biotechnology companies. Their areas of work included research, commercialisation, biological product manufacturing and pharmaceutical operations.

Quantitative data taken from the survey downloaded in .csv format and deidentified, before it was tabulated in Excel (Microsoft, Redmond) and processed, graphed, and statistically analysed with R code (Ihaka and Gentleman). Ordinal logistic regression analysis was used to examine the difference between participants' Likert scale responses for Item 1 and 2, as well as for the general Likert questions. Participants' rankings of graduate skills were analysed using rank aggregation, while chi-squared tests were conducted to determine the difference between the skills selected for each item. Qualitative data from both surveys and the interviews were de-identified and summary data was analysed thematically using NVivo software (https://lumivero.com/products/nvivo/).

Results

Participants

The survey attained a 13% response rate (*n*=18), comprising 10 (55%) males and 8 (45%) females, almost representative of the general population. All but one obtained their highest degree in Australia. Their areas of work included research, commercialisation, marketing, medical consulting, patents/intellectual property, pharmaceutical operations, and business/industry development (Table 1), and the average experience working within their profession or area of expertise was 22 years. 33% of participants worked in a multinational biotechnology company, 50% worked in a small/mid-sized start-up, and 16% worked in other areas.

Table 1: Professional Background of Study Participants

Current profession/area of expertise	**Frequency**
Research	5 (27%)
Commercialization/MedTech	4 (22%)
Marketing	1 (6%)
Medical consulting	1 (6%)
Patents/intellectual property	1 (6%)
Pharmaceutical operations	3 (16%)
Business/industry development	2 (11%)
Other	1 (6%)
Where highest degree was obtained	**Frequency**
Australia	17 (94%)
Internationally	1 (6%)
Duration working in current area of expertise	**Frequency**
0 – 10 years	3 (16%)
11 – 20 years	6 (33%)
21 – 30 years	6 (33%)
31 – 40 years	1 (6%)
41 – 50 years	2 (11%)
Type of current company/business	**Frequency**
A multinational biotechnology company	6 (33%)
A small/mid-sized start-up	9 (50%)
Other (government, etc.)	3 (16%)

Industry perspectives on different PjBL activities

Participants were presented with two different PjBL examples - the 3-week in-class individual project (Item 1) and the year-long industry project (Item 2), and asked a series of questions on whether these PjBL activities aligned with the development of desirable graduate skills. The response option was a Likert scale from 1 = strongly disagree to 10 = strongly agree, and these are represented below in Figures 1 to 3 inclusive. For ease of interpretation, the Likert-scale is presented in the numerical reverse of the scale presented in the original survey.

Figure 1 shows the response to the question 'This project aligns with desirable graduate skills in the biotechnology industry' (Question 1). When asked whether Item 1 and Item 2 aligned with desirable graduate outcomes, respondents displayed significantly stronger support for Item 2 in comparison to Item 1 (ordinal logistic regression, z=-1.997, p=0.0458, n=18).

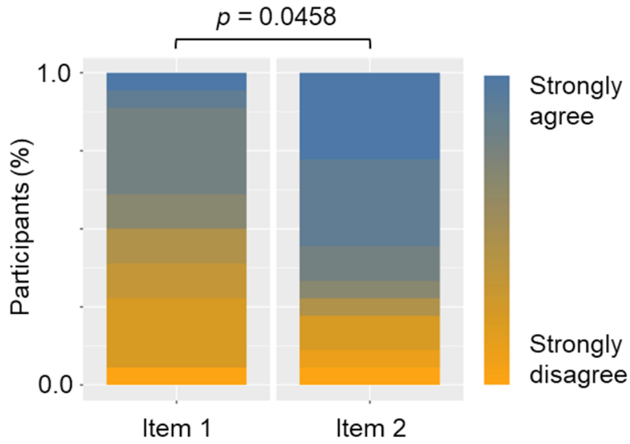

Figure 1: Industry Stakeholder Perspectives on Two Different PjBL Activities – Question 1

In response to the question ‘This project will equip a student with the skills required for employment in the biotechnology industry,’ participants were 4.83 times more likely to score in a higher category for Item 2 over Item 1 (ordinal logistic regression, z=- 2.424, p=0.0153, n=18) (Figure 2).

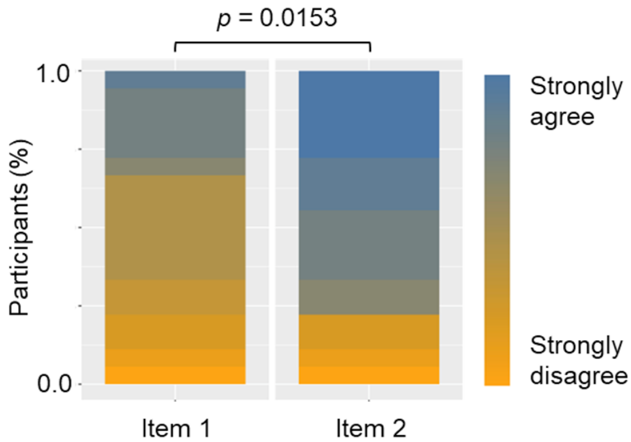

Figure 2: Industry Stakeholder Perspectives on Two Different PjBL Activities – Question 2

Figure 3 shows that participants were 3.56 times more likely to select a greater Likert score for Item 2 in response to the question ‘A student who has undertaken this project will be better prepared for employment in the biotechnology industry’ (ordinal logistic regression, z=-1.994, p=0.0461, n=18).

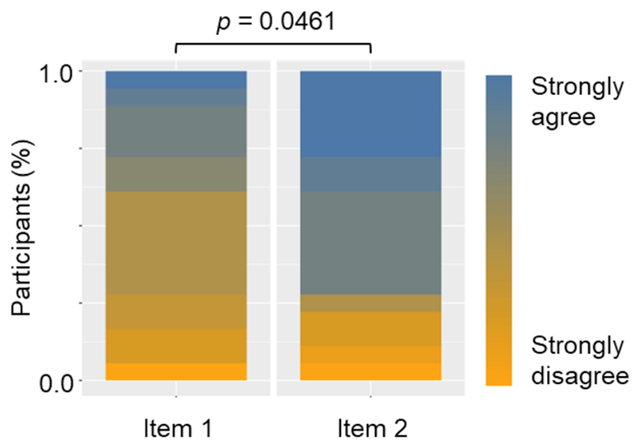

Figure 3: Industry Stakeholder Perspectives on Two Different PjBL Activities – Question 3

Ordinal logistic regression showed that for all three questions, there was a significant difference between the Likert-scale ratings for Items 1 and Item 2 ($p<0.05$). Furthermore, a proportional odds ratio model showed that respondents were 3.52 times more likely to score Item 2 in a higher Likert category than Item 1.

Participants reported divergent perspectives on which skills each PjBL activity would be likely to improve in students (Figure 4). Twenty-two and a half per cent of participants chose 'written communication' as the graduate skill that Item 1 would most help a student improve, followed by 'ability to adapt knowledge in different contexts' (12.5%). 'Broad general knowledge', 'ability to apply skills in different contexts', and 'innovative thinking' were equally chosen by 10% of respondents as the skill most likely to be improved. In comparison, for Item 2, 'working well in a team' was chosen most frequently (16%) by participants as the most likely skill the PjBL activity would improve, followed by 'ability to develop relevant skills' (15%), and 'written communication' (12%). A chi-squared (χ^2) analysis was performed on each skill separately, comparing the participant counts between the two items, and only 'ability to develop relevant skills', showed a significant difference between Items 1 and 2 (χ^2, p=0.025), the rest being non-significant. When participants were asked if the graduate attributes they had selected in Figure 4 were important to their workplace/profession, the response showed a strong agreement for both Item 1 and Item 2 (Figure 5). Statistical comparison between response to Item 1 and Item 2 for this question found that there were no significant differences (ordinal logistical regression, z=0.833, p=0.405, n=18). As with Figures 1 to 3 above, the response option was a Likert scale from 1 = strongly disagree to 10 = strongly agree, and the Likert-scale is presented in the numerical reverse of the scale presented in the original survey.

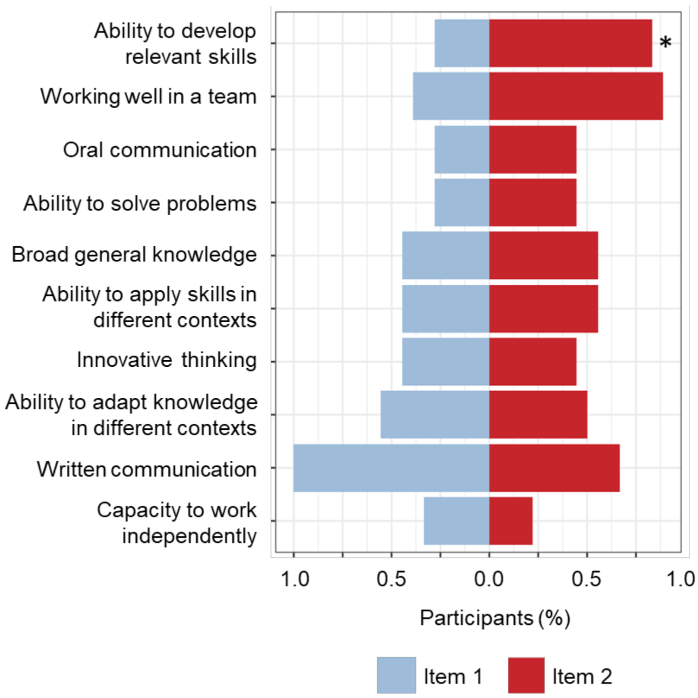

Figure 4: Comparison of Graduate Attributes Perceived to be Improved by Each PjBL Activity

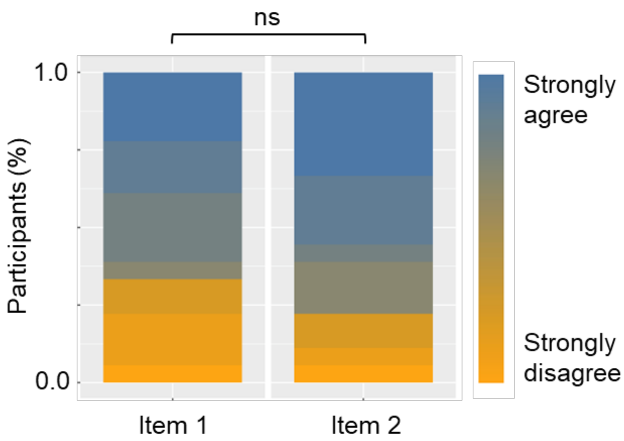

Figure 5: Importance of graduate attributes to the workplace/profession of participants

Participants were canvassed to garner general perspectives on PjBL and its relationship with graduate employability. When asked whether biotechnology/bioscience graduates have had sufficient opportunities to collaborate with industry, responses were evenly distributed between strongly agree and strongly disagree (Figure 6A). However, participants were more strongly in agreement that PjBL in the field of biotechnology benefits both students and employers (Figure 6B). Participant perspectives were mixed about whether PjBL in groups better prepares graduates for employment compared to individual projects (Figure 6C). A proportional odds logistic regression model analysis indicated no significant differences in Likert scores between any of the three questions canvassed (p=0.2200, n=18).The same Likert scale (1 = strongly disagree to 10 = strongly agree) was used, and Figures 6A, B and C are presented in the numerical reverse of the scale presented in the original survey.

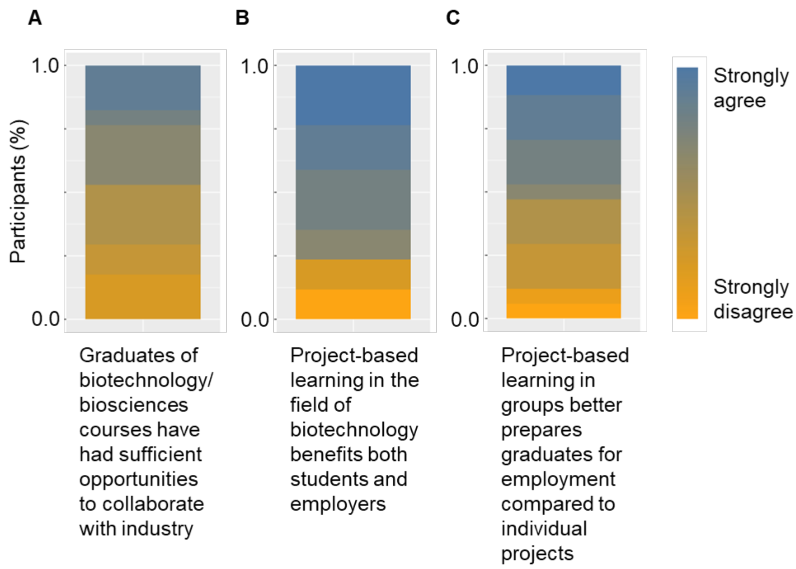

Figure 6A, B, C: Participant Perspectives on the Relationship Between PjBL and Graduate Employability

Graduate work-readiness and attributes valued by industry professionals

Participants were tasked with ranking a list of ten graduate attributes in order of their perceived importance to gaining employment within the biotechnology industry. The graduate attributes were graphed individually in R to illustrate the proportion of each rank that was chosen for each attribute. (Figure 7) and is shown from lowest ranked to highest ranked graduate attribute. Rank aggregation was then performed in R to create a single aggregated rank order based on consensus between all respondents. The highest ranked graduate attribute was innovative thinking, followed by written communication, capacity to work independently, oral communication and ability to adapt to knowledge in different contexts. The lowest ranked graduate attribute was the ability to apply skills in different contexts. The colours in Figure 7 represent the proportion of each ranking represented in the data (*n*=15).

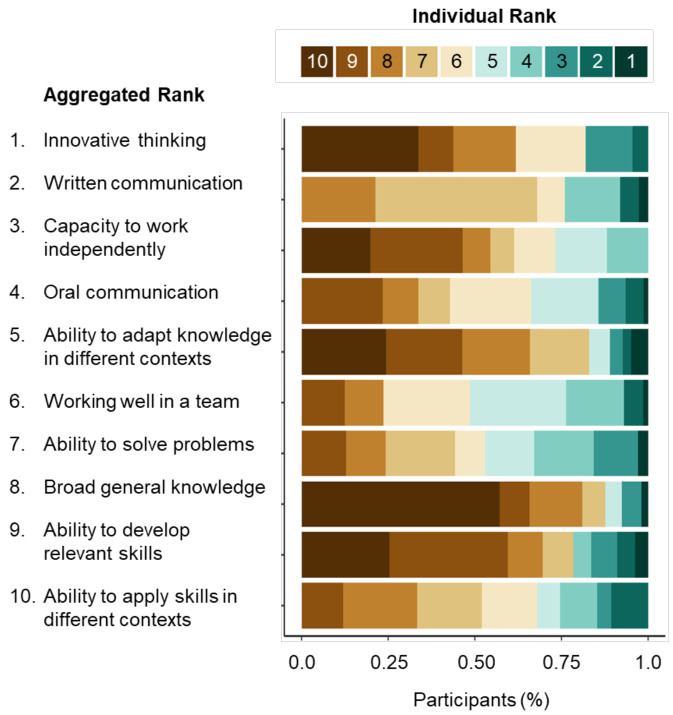

Figure 7: Graduate attributes ranked by industry professionals from most (1) to least (10) important

Opinions of industry professionals about current bioscience graduates

Within the survey, participants were given the opportunity to report their opinions on what today's bioscience graduates lack in terms of employable skills, as well any perceived advantages held by these graduates compared to graduates of a decade earlier. In terms of graduate advantages, respondents tended to highlight increased access to information, industry mentors and advisors, and a more practical focus on developing an understanding of industry within biosciences and biotechnology courses. Representative comments include 'More engaging and real-life now, with a focus on industry, placements, etc.', 'access to mentors and advisors, and engagement with industry', 'access to a broader range of information sources and courses at tertiary institutes' and 'real -world experience through such programs as Industry Projects'. When asked what today's graduates lack, industry professionals generally focused on skills and attributes such as patience, perseverance, and awareness, as well as an understanding of the biotechnology sector. A broad range of representative comments included 'awareness of the economics of the industry and global understanding', 'general knowledge of the industry and how it operates', and 'a lack of willingness to learn, a lack of drive/motivation, failure to take advantage of an industry project to learn.' A lack of oral and written communication skills was also a common theme in the responses to what today's graduate lack.

Participants were also asked to present suggestions for how higher education could better prepare biotechnology and bioscience graduates for employment. Common themes to responses were exposure to real-world scenarios through industry projects, internships, and guest lectures from industry representatives. Some representative quotes were 'clearer communication to students of likely employment roles post-graduation – particularly for students not undertaking post-grad studies', 'ensure course align with supply of jobs; experienced folk from industry are guest speakers;

short term assignments within the industry', and 'having industry experience helps student identify their enthusiasm and supports motivation.'

Positive experiences of PjBL garnered through interviews with industry professionals

Across four interviews, each participants' personal experiences facilitating PjBL as part of WIL industry projects or other internships were explored. Participant views on the employability of today's science graduates were canvased. Interviewees commonly indicated positive views of WIL and PjBL, particularly regarding longer industry projects. When asked what had been done well in their experiences of PjBL, participants cited students' attitudes and sense of responsibility, as well as their communication skills, as areas of strength. One interviewee stated: 'Instilling a sense of responsibility and ownership of the project was done really well' (Interviewee 3). Students' attitudes towards their projects were also praised by participants, who indicated that students were 'very enthusiastic, they really look forward to taking on challenging sorts of projects, and mostly they're able to communicate very effectively'(Interviewee 1). The theme of communication as a driver of project success was common across participants. When asked what was needed to create a successful PjBL experience, one participant reported, 'I think regular communication is really important. I think it needs to be planned, and I think people need to be really diligent at sticking to the schedule' (Interviewee 3). This sentiment was reflected by another interviewee, who stated that 'I think I would always encourage more of the direct communication face-to-face between the project students and the industry partner' (Interviewee 4).

Interviewees also highlighted the importance of briefing and preparation, both by the universities and by students themselves, as a factor contributing to the success of PjBL. One industry partner mentioned that 'The University sets the expectations very early for the industry partner and what the University is trying to achieve through the program' (Interviewee 3). Other interviewees identified the preparedness of students as having allowed them to 'be involved earlier, rather than taking a long time to assimilate to the new environment' (Interviewee 4), and that the thorough briefing of students by the university allowed them to have 'a very good appreciation of what the industry partner was looking to get out of the project' (Interviewee 1). Furthermore, there was common agreement across interviewees that PjBL industry projects were beneficial to the host company as well as to the students – a way of getting 'additional hands on a project' (Interviewee 4). One participant stated that 'as the industry partner, the projects provided some excellent reports that really helped us' (Interviewee 3). Another interviewee described industry projects as a 'win for the industry group that's working with them' (Interviewee 2).

Areas for improvement in PjBL industry projects

Interview participants were also asked if they had pinpointed any areas of improvement in the PjBL industry projects that they had facilitated. Common areas of improvement that were highlighted during interviews were narrow timelines (all four interviewees had been directly involved with the year-long Master of Biotechnology industry projects), as well as clarification of outcomes by the University. For instance, one industry partner suggested that

> *… knowing those clear outcomes that are needed for each of the parties would be the main area for some of the academic institutes to improve on. So being a bit clearer on what they want the student to come out with.* (Interviewee 2)

Interviewees also noted that the COVID-19 pandemic had been a disruptor of the capability and efficiency of PjBL industry projects, particularly when student teams had members overseas. Participants found that students who were undertaking the project remotely were at a disadvantage, as having another three or four students who could meet in person while they were located elsewhere caused a 'change to the dynamic.'

Industry expectations of today’s science graduates

A component of each interview focused on participants’ views on the employability of graduates, and graduate skills desired by industry stakeholders. When asked to describe their expectations of today’s science graduates, participants tended to focus on both baseline foundational skills and transferrable skills. One participant stated: ‘What I would expect now is a sort of introductory understanding, or a theoretical understanding of methods of strategies or protocols’ (Interviewee 1). Another commented that: ‘you don’t need to be an expert, but you need to know about the basics’ (Interviewee 4). A common theme was the ideal graduate as someone who had the foundational skills necessary for a smooth transition into the workplace, and general knowledge about their field that could be nurtured into experience. When interviewees were prompted for more specific skills that made a graduate more employable, they suggested that ‘You need to be able to communicate – to ask the questions, to get the understanding, to give information back’ (Interviewee 1). Work ethic and organisational skills were also highlighted, as well as an ability to work independently. One participant stated:

> *Displaying an ability to work outside of the University context is important. Whether it's in part-time employment or in a volunteering capacity, or some other mechanism to demonstrate they have some social skills to work well with other people and a cultural mix.* (Interviewee 3)

Barriers facing today’s science graduates

Participants were also asked to identify any barriers facing today’s science graduates. A lack of understanding of graduate pathways and futures open to them as well as of the applications of their skills was touched upon by participants. For instance, one participant said:

> *I think a lot of young graduates don't appreciate how transferable their skill sets are. And so have quite a narrow perspective of what they think they are now qualified to do… and it narrows it in a sort of artificial way, where they're probably using quite narrow search terms on SEEK, or all that kind of thing.* (Interviewee 1)

Several potential reasons were given for this lack of understanding; for instance, insufficient preparation within their courses, as well as students’ ‘casual’ approach to planning their careers. Some participants touched on the role of universities in preparing graduates for employment; it was suggested that universities may not have sufficient information about industry needs and opportunities and may not see the development of an employable graduate as part of their remit. On the subject of the role that universities play, one interviewee commented:

> *I think the University is very much incentivized to keep particularly the high achieving students within that channel towards becoming staff…and I think generally pretty minimal potential effort is placed on what industry science looks and feels like. It's very much focused on what academic careers of science look and feel like.* (Interviewee 3)

This view was mirrored by other participants, who questioned whether Australian universities are ‘actually making all of the things that students do relevant to industry’ (Interviewee 4). However, though interviewees generally did not agree that universities were doing enough to create employable graduates, the contribution of academic assessments to graduate work-readiness was generally supported. Raw marks (Weighted Average Mean, Grade Point Average, etc.) were considered useful in determining graduates’ ability to engage with work material but were nonetheless deemed less important than the skills demonstrated by those assessments. For instance, participants highlighted teamwork, time management, and technical skills as attributes of interest when interviewing graduates. Experience with industry projects was also mentioned as a contributing factor towards work-readiness.

Aggregated NVivo analysis of themes within the qualitative data led to the identification of five factors that may be important for the successful implementation of PjBL in WIL programs (Figure 8). These included the need for longer-term projects with clear outcomes, preferably embedded into the workplace – as one participant stated in the survey, 'students would gain more from the industry project if they were required to come into the office from time to time'. Other key factors were the importance of consistent communication and outcomes relevant to industry needs.

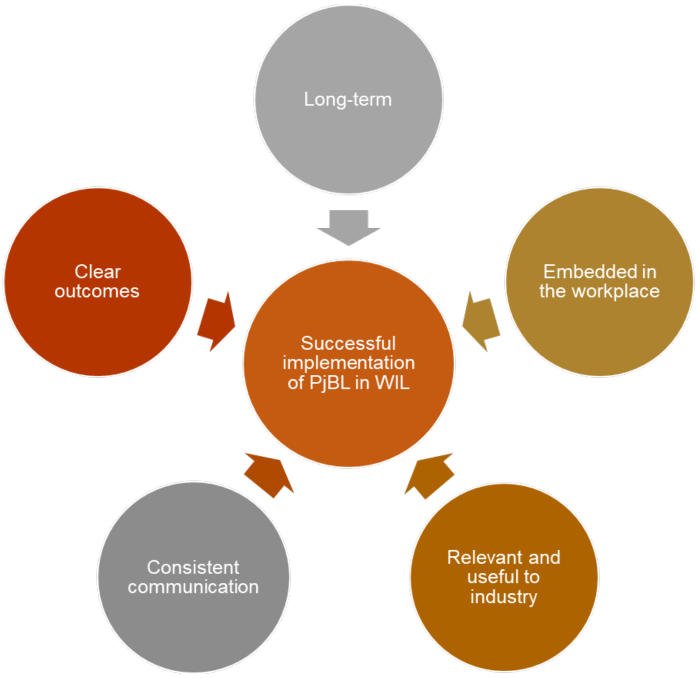

Figure 8: Five Factors that may be Important for the Successful Implementation of PjBL in WIL Programs

Discussion

Employer views on PjBL as a form of WIL

Industry professionals were presented with two authentic examples of PjBL, an in-class project and a year-long industry project, in order to solicit their perspectives on the effectiveness of these projects in developing graduate skills and employability. The marked inclination towards Item 2 (the year-long industry project) likely reflects a preference among industry professionals for broader skill development and capabilities among graduates. In comparison, Item 1 (the in-class individual project) was focused on a narrower set of skills, predominantly written and visual communication. These views were also demonstrated in comments made within the survey about possible changes within higher education that could improve graduate outcomes. Participants reported that assignments within industry, placements, and general industry experience all contributed, in their view, to the development of work-ready graduates. While the in-class project may reflect the kind of work a graduate may be expected to complete in a future employment, industry professionals overall did not support this project as a way to prepare students for the workplace or equip them with the skills necessary for employment. This supports current literature into industry perspectives on PjBL, that employers have been found to perceive greater value in PjBL experiences that are 'long-term, substantive, and authentic' (Vaz & Quinn, 2015, Results section, para. 7). However, this is not to say that the in-class project does not contain aspects that align with desirable graduate skills. For example, it should be noted that written communication was the skill perceived to be most improved by Item 1 and was also a graduate attribute that ranked highly individually. Aligning with desirable graduate attributes and skills (as viewed by employers) should be a primary goal for industry based PjBL activities. It is evident from these findings that extended industry projects which integrate real workplace tasks within the curriculum, rather than merely simulate them in-class, are viewed by industry professions as more effective at developing graduate skills).

While industry professionals indicated that more workplace-based forms of PjBL were preferable in developing graduate skills, the results suggest that industry do not perceive graduates have sufficient opportunities to interact with industry. A general theme of graduates' unpreparedness when entering the workforce can be deduced from the study results. This is supported by studies in other science disciplines such as engineering (Thirunavukarasu et al., 2020). It is apparent from industry perspectives in this study that an increased effort needs to be made, not just on the part of students, but by higher education institutions to expose students to a greater range of career opportunities beyond academia. Indeed, the increased pressure upon universities to diversify their curricula to promote graduate employability in the past decade appears to be disconnected from employer expectations of graduate preparation (Anastasiu et al., 2017). Others have shown that employers prefer graduates who combine a practical core of competency in their field with soft skills such as communication and problem solving (Oraison et al., 2019), however this expectation is not well conveyed to students during their studies.

On the topic of improvements to PjBL in the fields of biotechnology and biosciences, industry professionals emphasised the importance of instilling students with a sense of responsibility and ownership of their work for industry, as well as clear communication between all stakeholders involved. This suggests that the type of PjBL most relevant to industry – and therefore, most preferred – is work that has tangible benefits for the host company. This supports Lloyd et al.'s (2021) finding that WIL supervisors value WIL programs as a way of contributing to the workplace, a sentiment that was reflected by several participants in this study. That PjBL industry projects can be used as an effective tool for developing graduate skills whilst at the same time pursuing industry objectives emphasizes its versatility and utility.

Industry professionals advised that a lack of clear messaging on the part of universities on the outcomes and goals of each project could be a limiting factor in the success of PjBL. Given that robust communication between students, industry and educators was paradoxically mentioned by several participants as a high point of their experiences with PjBL, this issue may lie primarily in the planning process rather than the project execution. These findings suggest that universities should extensively brief industry partners on student PjBL outcomes. Universities should also help industry and students plan project schedules to avoid situations described by interviewees where their visions for the project are curtailed by narrower-than-expected timelines. This supports findings from Ferns et al. (2016) that industry supervisors often feel that they are not being adequately supported with accessible resources and means of providing feedback on their students. While it is important that students feel they are gaining useful skills and experiences, making the process of PjBL as seamless as possible for industry partners is key to improving outcomes for all parties involved, and to ensure that partners view PjBL (and WIL as a whole), as an enterprise with advantages beyond altruism.

Can PjBL promote desirable graduate attributes?

These results suggest a degree of commonality between all industry professionals in terms of the skills they prefer science graduates to have. Multiple participants emphasized the importance of baseline knowledge, or a foundation of technical knowledge which could be built upon through workplace experience. This supports findings from Coll and Zegwaard (2006) where employers placed a great deal of emphasis on cognitive or 'hard' skills, but also acknowledged that 'soft' skills such as a willingness to learn had a role to play in developing an employable graduate. 'Technical knowledge' as described by interviewees, generally referred to discipline-specific skills, such as writing Standard Operating Procedures (SOPs). Broader general knowledge was generally placed relatively low in the ranking of desirable graduate attributes. It should also be noted that some of the attributes that participants mentioned as desirable in future employees had also been remarked upon as attributes that the industry professionals had appreciated in students during PjBL industry projects, particularly communication and a diligent work ethic.

Participants' rankings of graduate attributes reflected a skew towards graduate characteristics that cannot be easily conveyed or assessed in a classroom context. This may reflect the importance of WIL to developing tacit knowledge (Trede, 2012). In comparison to research by Rayner and Papakonstantinou (2015) into graduate attributes valued by STEM employers, a relatively lower emphasis was placed in this study on the application of knowledge and the development of knowledge relevant to a position. Instead, written and oral communication, as well as the capacity to work independently, were considered of higher importance in the present study. In contrast to the present study, Rayner and Papakonstantinou (2015) found that vocational skills were ranked by employers significantly higher than interpersonal skills, which indicated that STEM employers prefer a mix of the two to help employees adapt to a new workplace environment.

The findings of this study are in support of work by Karimi and Pina (2021), who interviewed STEM employers about their perspectives on STEM student employability. Karimi and Pina (2021) conclude that a gap in employable skills must be addressed through collaboration between industry and academia to ensure that STEM graduates are emerging with the attributes they need to thrive in the workforce. Karimi and Pina (2021) suggest that the misalignment between graduate skills and industry requirements can be corrected through free-flowing communication between employers and academia to create strategic tools that can be implemented throughout higher education. Indeed, it is evident that higher education providers generally lack comprehensive understanding of the evolving needs of contemporary STEM industries (McGunagle & Zizka, 2020). Suggestions from some participants in the present study that higher education places too little emphasis on industry science in favour of promoting academic science skills and careers must also be considered. This may reflect a belief that science graduates are educated in a manner where they are more prepared for academic careers (where employment opportunities are scarce) than careers in science industry (where employment opportunities are greater). Findings from this study and others suggest that science students must be presented with a wider range of potential careers earlier in their courses in order to make informed decisions on paths of study and to seek out opportunities for professional skill development. We suggest PjBL is a valuable pathway to students sampling a variety of careers during their studies.

Comparing student experience of PjBL with industry perspectives

The existing body of research on PjBL and its implementation in higher education focuses mainly on student and educator perspectives and experiences. PjBL has been shown to foster professional skills for future employment, such as teamwork, motivation and problem solving, and is considered by educators as an effective way to replicate the workplace in the context of higher education (Fernandes, 2014). Furthermore, students have previously reported an increase in competencies such as systems thinking and interpersonal skills when engaging in positive stakeholder interactions as a part of PjBL (Birdman et al., 2022). The value of industry stakeholder engagement is mirrored in results of this study; respondents of the survey and interviews highlighted the importance of workplace integration when conducting PjBL industry projects and other forms of WIL. This was demonstrated in the results from industry views on the industry project (Item 2), where participants generally believed that this form of PjBL better aligned with graduate outcomes and helped prepare students for future employment. Participants also viewed PjBL industry projects as more suitable for developing skillsets (such as teamwork and the ability to develop relevant skills) that they considered important for employment. This echoes the responses of students to an investigation by Musa et al. (2012) into student views on a PjBL course. Musa et al. (2012) found that students identified interpersonal skills and problem solving as employable attributes developed during the course. In summary, the results of the present study suggest that students and industry professionals are aligned in a generally positive view of PjBL. However, when considering the general employability of today's graduates, and whether their skills are up to par with industry needs, additional research into industry perspectives will be necessary.

Study constraints, implications, and future directions

This study has several limitations worthy of acknowledgment. This study was limited in both its sample size and its limited duration. Given an extended timeframe, this research would benefit from a longitudinal design; for example, following groups of students and industry professionals throughout the course of an industry project, with surveys, interviews and focus groups conducted at regular intervals. Results obtained from such a study could determine more conclusively the views of industry towards PjBL, including on its advantages and drawbacks for development of graduate skills. No one skill stood out significantly as being most useful for employment and industry views on graduate skills and deficiencies ranged widely. The difficulty in reaching a clearer consensus stems largely from the study sample size. The sample size meant that these results provide a less diverse and representative range of perspectives. Nonetheless, this study provides a snapshot in time of a sub-set of industry professionals working in the sciences. The small number of PjBL examples explored in this study is also important to note. At times, it was also difficult to ascertain whether industry professionals recognised the nuance between PjBL and WIL as these are predominantly academic concepts and terms.

Conclusion

This study aimed to determine the views of science industry professionals on PjBL as a form of WIL. The results obtained will help aid in a broader understanding of whether science industry professionals support PjBL as an effective approach to development of graduate skills and employability. The findings herein suggest that PjBL designed well can replicate authentic workplace activities and skill building. These results highlight the need for industry input and direct involvement in the implementation of PjBL in higher education to promote more effective outcomes for graduates. Future studies may benefit from exploring a wider range of PjBL approaches. For instance, it has been found that interdisciplinary PjBL can increase gains in employability skills as perceived by students (Hart, 2019). The findings of this study, and its implications for PjBL as an opportunity for skill development and workplace preparation, open avenues for further research that integrates industry and student views on PjBL. This could, in turn, address concerns by industry on the worrying misalignment between higher education and industry needs. The results relating to the two examples of PjBL (in-class projects and industry project) were somewhat unsurprising. It was anticipated that for the most part, industry professionals and potential graduate employers prefer students undertake PjBL experiences that most closely mirror the workplace, that being longer-term industry projects in direct collaboration with industry. Overall, this study suggests that industry stakeholders have a higher opinion on the merits of PjBL when it is long-term and embedded in the workplace. In the eyes of industry professionals, classroom-based projects that attempt to mimic authentic work tasks are not well supported by industry when compared with long-term industry projects.

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Appendix 1: Survey Instrument

Thank you for agreeing to take this survey - your time is greatly appreciated. This survey aims to gather information about current trends in industry recruitment of STEM graduates. By gaining an insight into the perspectives of industry partners on certain projects undertaken by graduate students, we aim to uncover any differences in student and industry views of work-integrated learning. Through this research, we hope to understand what types of learning create work-prepared graduates to inform best practice and improve industry collaboration in higher education.

Before we start please read this statement of consent.

- I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written plain language statement to keep
- I understand that the purpose of this research is to investigate industry perspectives of project-based learning
- I understand that my participation in this project is for research purposes only. I acknowledge that the possible effects of participating in this research project have been explained to my satisfaction
- In this project I will be required to complete an online survey. I may also be asked to take part in a follow-up interview, but this is optional
- If I am interviewed, I understand that it will be recorded, transcribed, and anonymised. I understand that the recordings will be stored for the duration of the project and destroyed at its completion
- I understand that my participation is voluntary and that I am free to withdraw from this project anytime without explanation or prejudice and to withdraw any unprocessed data that I have provided
- I understand that the data from the survey will be stored at the University of Melbourne and will be destroyed 5 years after publication
- I have been informed that the confidentiality of the information I provide will be safeguarded subject to any legal requirements; my data will be password protected and accessible only by the named researchers

Human Ethics I.D number: 25248

- ○ Yes, I agree → continue to survey

- No, I do not agree → end of survey

Q1 What is your current profession/area of expertise?

Q2 How long have you been in this profession/area of expertise?

Q3 What type of company or business do you operate within? Select all that apply.

- A small/mid-sized start-up
- A multinational biotechnology company
- Other: ____

Q4 What is your gender?

- Male
- Female
- Other: please specify _______________________________
- Prefer not to say

Q5 In which country did you obtain your highest level of qualification?

- Please specify: ____________________________________
- Prefer not to say

Q6 Below is an authentic example of a project undertaken by a graduate BioSciences student at The University of Melbourne. Students were asked to prepare a piece of written communication that promoted consumer acceptance of a particular example of innovation in biotechnology (in this case, the COVID-19 vaccine). This student chose to create a social media post (shown below). Other strategies included: letters to government bodies, infographics, podcasts and Q&A sessions.

Q7 This project aligns with desirable graduate skills in the biotechnology industry.

1. Strongly agree 10. Strongly disagree

Q8 This project will equip a student with skills required for employment in biotechnology industry.

1. Strongly agree 10. Strongly disagree

Q9 A student who has undertaken this project will be better prepared for employment in the biotechnology industry.

1. Strongly agree 10. Strongly disagree

Q10 Which skills will this project help a student improve? (You can choose more than one skill)

- Broad general knowledge
- Working well in a team
- Ability to apply skills in different contexts
- Capacity to work independently
- Written communication
- Oral communication
- Ability to adapt knowledge in different contexts
- Ability to solve problems
- Ability to develop relevant skills
- Innovative thinking
- None of the above

Q11 The skill(s) chosen above are important to your workplace/profession.

1. Strongly agree 10. Strongly disagree

Q12 Graduate students undertaking a Master of Biotechnology at the University of Melbourne are required to undertake a year-long industry project. Students are placed with a biotechnology company and work in groups to address a genuine industry need: for instance, they may be asked to compile a report on the competitive landscape for an upcoming product or medicine, or to sketch out a commercialisation plan for the company's use.

Casey undertook this project in her second year of her Master's degree. She was assigned to a biotechnology commercialisation business with three other team members, and worked closely with the biopharma marketing director at the company to conduct market research in preparation for a new drug to be launched within the next three years

Q13 This project aligns with desirable graduate skills in the biotechnology industry.

1. Strongly agree 10. Strongly disagree

Q16 This project will equip a student with skills required for employment in biotechnology industry.

1. Strongly agree 10. Strongly disagree

Q14 A student who has undertaken this project will be better prepared for employment in the biotechnology industry.

1. Strongly agree 10. Strongly disagree

Q15 Which skills will this project help a student improve? (You can choose more than one skill)

- Broad general knowledge
- Working well in a team
- Ability to apply skills in different contexts
- Capacity to work independently
- Written communication
- Oral communication
- Ability to adapt knowledge in different contexts
- Ability to solve problems
- Ability to develop relevant skills
- Innovative thinking
- None of the above

Q16 The skill(s) chosen above are important to your workplace/profession.

1. Strongly agree 10. Strongly disagree

Q17 In your opinion, what **advantages** do today's biotechnology/biosciences graduates have compared to biotechnology/biosciences graduates 10 years ago?

Q18 In your opinion, what do today's biotechnology/biosciences graduates **lack** in terms of their preparedness for employment?

Q19 Please rank each of these graduate attributes in terms of their importance to gaining employment within the biotechnology industry.

______ Broad general knowledge

______ Working well in a team

______ Ability to apply skills in different contexts

______ Capacity to work independently

______ Written communication

______ Oral communication

______ Ability to adapt knowledge in different contexts

______ Ability to solve problems

______ Ability to develop relevant skills

______ Innovative thinking

Q20 Graduates of biotechnology/biosciences courses have had sufficient opportunities to collaborate with industry.

1. Strongly agree 10. Strongly disagree

Q21 Project-based learning in the field of biotechnology benefits both students and employers.

1. Strongly agree 10. Strongly disagree

Q22 Project-based learning in groups better prepares graduates for employment compared to individual projects.

1. Strongly agree 10. Strongly disagree

Q23 In your opinion, how could higher education better prepare biotechnology/bioscience graduates for employment?

Q24 Thank you for your participation. Are you willing to be contacted for a short follow-up Zoom interview to further explore your perspectives on graduate employability?

- Yes
- No