

Authenticity ahead of interdisciplinarity – a scoping review of student experiences in interdisciplinary science projects

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Abstract

Interdisciplinary projects are reported to facilitate the development of both disciplinary and generic skills. They vary in their design and implementation, but the effectiveness of different project models has not been studied. The aim of this study was to determine student satisfaction, engagement with learning and development of employability skills across interdisciplinary projects with different delivery models.

This scoping review appraises interdisciplinary projects implemented in science-based undergraduate degree programs. Projects with varying models of delivery, interdisciplinarity, authenticity and external partner involvement were examined, and the reported student learning and satisfaction ratings compared. Descriptive statistics and cross tabulation using Fisher's Exact test were used to analyse the data.

The interdisciplinary project model had little effect on engagement with learning, but student satisfaction improved if the project task was rated as authentic ($p < 0.05$). Improved learning was reported in about half of the projects reviewed. Improved employability was reported in projects where students used discipline-based skills to provide a consultancy ($p < 0.05$), and those where an external partner was involved ($p < 0.05$).

The interdisciplinary project model did not affect disciplinary or employability skill development, apart from interdisciplinary competence, which was significantly improved in a truly interdisciplinary project ($p < 0.01$). Interpersonal skill development was significantly improved where projects had integrated rather than sequential tasks ($p < 0.05$).

Overall, interdisciplinary projects that were authentic and/or involved an external partner generated better student satisfaction and real-world experience. These results inform the future design of interdisciplinary project-based learning tasks and encourage involvement of external partners in project design and delivery.

Keywords
Employability, project-based learning, interdisciplinary competence, curriculum design

Introduction

Graduate employability is an important outcome of any degree, and in Australia graduates of general science and maths degrees have relatively low rates of full-time employment upon graduation (61%) (Australian Government, 2021). Indeed, less than 18% of science graduates in 2018 were employed in a field related to their degree (Palmer et al., 2018) and more recent data show

that around half of all science graduates felt their skills weren't sufficiently utilised in their current role, and nearly half (41%) continued in further full-time education (Australian Government, 2021). Employability in STEM (science, technology, engineering and maths) disciplines requires more than discipline-based knowledge, given that workplace settings typically require graduates to show skills in problem-solving, collaboration and communication, and employers value, and actively seek, these transferable skills in graduates (McGunagle & Zizka, 2020). Thus, it remains critical for science graduates to develop skills beyond disciplinary knowledge to improve their employability immediately after graduation.

Across higher education it is increasingly common to see project-based learning developed and implemented (Guo et al., 2020), both through local curriculum case studies as well as through broader strategic developments at the institutional level. A significant driver for universities to implement project-based learning is the opportunity to develop generic employability skills alongside the application of discipline knowledge. Project-based learning is related to inquiry-based learning, and actively engages students in the process of investigating a problem (Aditomo et al., 2013). Driven by a question or problem, project-related activities result in a product or artefact that addresses that question or problem (Blumenfeld et al., 1991), often in the form of a written report. Projects may be part of a capstone unit of study, where students integrate and employ the disciplinary content they learnt during their study program, or they can be broader and more interdisciplinary, with a focus on developing generic skills (Helle et al., 2006). These projects often require students to develop and practice their research skills in finding, collating, and disseminating information, as well as their critical thinking and problem-solving skills, to develop solutions to complex problems in a process of sustained inquiry. Completing project-based learning in teams can also develop and hone students' skills in project planning and management, collaboration, and teamwork (Acar & Tuncdogan, 2019; Alvarez-Bell et al., 2017; Lewis et al., 2019).

Interdisciplinary project-based learning is used as a further advance on project-based learning, requiring interaction between students from a variety of discipline backgrounds and, ideally, merging ideas and perspectives on critical problems. Research questions used in interdisciplinary project-based learning are authentic, relating to real-world and complex problems. This can improve students' motivation to engage with the task, since they are able to situate their work within both their personal experiences, and the context of contemporary research in the discipline (Blumenfeld et al., 1991; Spronken-Smith & Walker, 2010; Zafra-Gómez et al., 2015). Moreover, contemporary problems need interdisciplinary solutions, so interdisciplinary project-based learning is used to develop both discipline and employability skills. Despite these predictions of the wide-ranging benefits of this type of learning, however, there is a paucity of firm evidence on the efficacy and reliability of interdisciplinary project-based learning in delivering the promised outcomes: increased development of broad, transferable skills that may enhance students' future employability. Nor is there robust evidence that this type of learning activity is useful for improving learning, engagement, or overall satisfaction amongst the student body.

The aim of this study was to determine and compare student overall satisfaction, engagement with learning and development of employability skills with different delivery models of interdisciplinary student projects delivered in undergraduate science-based degrees. This study is a scoping review that appraises the effectiveness of interdisciplinary project-based learning and compares models for its delivery. Findings will assist in informing the future development and implementation of interdisciplinary project-based learning to facilitate the development of more skilled and employable science graduates.

Methods

This study is a scoping review of the literature on interdisciplinary projects offered in science-based undergraduate degree programs. Outcomes sought were reports of improvements in overall

satisfaction, engagement with learning, and employability skill development where interdisciplinary project-based learning was delivered.

Literature search strategy

For this review, A+ Education, EBSCO education, ERIC and ProQuest databases were searched using the terms: science (OR math*, biology, chemistry, physics, psychology, geology) AND project-based learning (OR student projects, capstone projects, projects) AND interdisciplinary (OR multidisciplinary, cross disciplinary, trans-disciplinary) AND undergraduate (OR higher education, post-secondary, college). A PRISMA diagram (Page et al., 2021) showing the record identification, screening eligibility and inclusion process is shown in Figure 1. The search was restricted to peer-reviewed journal articles published in English from 2010 to 2021.

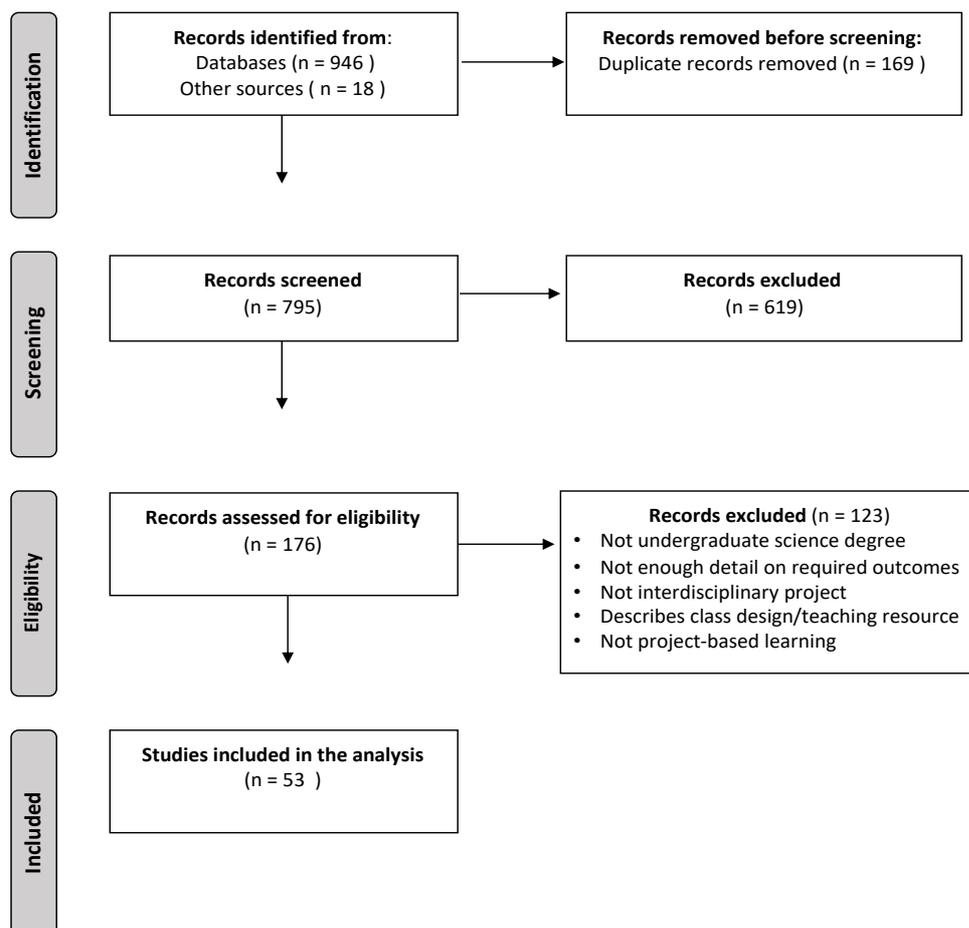


Figure 1. PRISMA Flow Diagram Showing the Record Identification, Screening, Eligibility, and Inclusion of Studies for the Analysis.

The literature search was carried out independently by each co-author and a consensus reached on the inclusion list. Included articles described an undergraduate project-based learning task, which involved students enrolled in a science-based degree program (including Science, Engineering, Biomedical Science and Computer Science) from various sub-disciplines, or a project-based learning experience with the addition of a specific interdisciplinary task. Included articles reported on student satisfaction outcomes from the project task; those that did not include a measure of student satisfaction, whether quantitative or qualitative were excluded. Contemporary student satisfaction outcomes mirror customer satisfaction ratings (Clemes et al., 2008) and include teaching quality and effectiveness leading to improved engagement, learning, and employability. Studies reporting on

improvements in any of: overall satisfaction; engagement; employability; learning (depth or breadth); interpersonal skills, or a real-world experience of the work, were included. Following exclusion of duplicates, many further records were excluded as they did not provide enough detail of the outcomes sought in this review. There were many descriptive case studies that explained a novel, interesting course but did not evaluate the student outcomes adequately. Some records were excluded as their student projects were not 'interdisciplinary' according to our definitions, usually because they did not enrol students from multiple disciplines into the project. Data were extracted by both authors independently and cross-checked for consistency. Background data collected from the records included country of study, study methodology, type of degree program and year level, the disciplines involved in the project, cross-faculty partners, the length of project, student group sizes and assessment task type.

Project category definitions

Projects were assigned categories in four domains: interdisciplinarity breadth; interdisciplinarity depth; authenticity of the project task, and mode of delivery of the project. These categories are defined below.

Interdisciplinarity

Information on the type of interdisciplinary project work was collected by categorising each described project by interdisciplinarity width and depth (Jantsch, 1970).

Interdisciplinarity width is determined by the mix of student disciplines involved in the project. It was considered in three categories (Hart, 2019):

- **Narrow:** within a single discipline, or combining closely related disciplines (e.g., biochemistry and molecular biology).
- **Medium:** within the same faculty (e.g., biology and mathematics).
- **Wide:** cross-faculty (e.g., chemistry and law).

Interdisciplinarity depth was determined by the project task, not by student discipline background (Hart, 2019). Projects were assigned to one of two categories:

- **Sequential tasks:** where tasks are completed separately by each disciplinary student group, with one discipline group handing over project tasks to another sequentially. This results in each disciplinary group essentially doing their own discipline work and little integration of discipline skills.
- **Integrated tasks:** where the student teams were required to work together and integrate their disciplinary skills and knowledge to undertake the project.

Project authenticity

Project authenticity was considered by assessing the project tasks as either **contrived**, where they were manufactured by the academic staff, or **authentic**, where students undertook a project with tasks and standards typically found in the world of work (Villarreal et al., 2018), generating genuine and usable outcomes one would expect from a real-life project. In practice, this category included authentic problems proposed by clients from industry, government or community groups and other entities at the university (Beier et al., 2019) or authentic, open-ended, client-based projects (Rees Lewis et al., 2019).

Mode of project delivery

Project delivery modes were defined across four categories:

- **Multi-disciplinary:** projects combined students from multiple, but within faculty disciplines (e.g., multiple science disciplines).
- **Cross-faculty;** projects combined students from multiple disciplines from more than one faculty (e.g., Science and Business or Humanities).
- **Consultancies:** where students acted as discipline-based consultants. Consultancy-style projects could be cross-disciplinary, client-based projects. This is also known as authentic client-based or client-oriented project-based learning in the literature (Mason, 2008; Shanahan et al., 2019).
- **External partnerships:** projects involving an external partner (e.g., industry, government, or community group). This was not mutually exclusive from the other project modes as any of the other modes may have had an external partner.

Definitions of the student satisfaction outcomes assessed

From each included article, data on project interdisciplinarity, authenticity, and mode of delivery were extracted, along with student satisfaction measures. Student satisfaction outcomes extracted included overall satisfaction, where students or academic staff reported an improvement in satisfaction, engagement with learning or employability skills development due to completing the interdisciplinary project-based learning tasks. The students' perception of the real-world nature of the tasks was also recorded. An online form was used as a template to extract the data to a spreadsheet. Data were extracted by two assessors, cross checked, then agreed by consultation and consensus.

Publication Quality Assessment

Publication quality assessment was made for each included paper, by two assessors independently and cross-checked for consistency. This was based upon a method for critically appraising qualitative studies (Long & Godfrey, 2004) and involved assigning a rating of 1 (poor) to 5 (excellent) on the following 12 items: details of phenomenon studied; theoretical context; details and appropriateness of setting; sample selection; clarity of outcome criteria; ethics, data collection; data analysis; data presentation; potential researcher bias; policy and practice implications, and details of limitations.

Data analysis

The data collected were heterogeneous and a standard meta-analysis was not feasible. Descriptive statistics were used to summarise the data. Not all included articles reported on all satisfaction measures; therefore, data are shown as the proportion of studies reporting an improved outcome within each group (e.g., project mode, interdisciplinarity, presence of an external partner and authenticity). Data were analysed by cross-tabulation and by using Fisher's Exact test to compare results for each outcome item across project groups. A value of $p < 0.05$ was accepted as statistically significant. All data analysis was conducted using SPSS version 28.

Results

Background information on the included studies

A list of the included data can be found in Supplementary Data 1. The included studies came from a variety of geographic regions, the majority (74%) from North America (See Supplementary Data 1). All studies included undergraduate Bachelor of Science (59%) and Bachelor of Engineering degrees (22%), or variations (e.g., Bachelor of Computer Science (12%) or Earth, Environmental or

Agricultural Science (8%). Many studies did not state the student year level involved in the projects (24%), although studies that assessed interdisciplinary projects in each of the four undergraduate years were included and some studies examined mixed year levels (27%). Most projects ran for a semester (65%), some as intensive units between semesters or over summer (18%), some ran over multiple years (10%), others varied in duration from one week to many months (8%). Student project group sizes varied and were not always reported (33%). Three to five students per group (39%) was the most common group size, with a minimum group size of two students and a maximum of 20 students per group. Some studies reported that faculty members or senior student mentors were also part of the groups.

The science disciplines involved in project units were broad, with engineering disciplines making up most studies (23%), followed by computer science and information technology (12%), mathematics and statistics (12%) and biology (11%). A variety of scientific disciplines made up the remainder of included studies (See Supplementary Data 2). Projects running across faculties involved a range of faculty partners, with humanities disciplines the most common collaborator (47%) followed by business (24%). (See Supplementary Data 3). About half (47%) had no listed cross-faculty partner, and one did not state who their cross-faculty partner was.

The data included were heterogeneous regarding the study type and the mode of project unit offering. Most of the reports were descriptive case studies (82%), with some intentional project evaluation studies (14%) and education research papers (4%). Five of the 53 studies (10%) included a specifically designed intervention. Each included paper was subjected to a quality assessment (Long & Godfrey, 2004), which was rated as fair to good over the 12 domains (Mean 31.9, SD 8.8, Range 12–50, possible maximum of 60; Supplementary Data 4).

Distribution of projects across domains

Projects were assigned categories within the four domains of: 1. Interdisciplinary breadth; 2. Interdisciplinary depth; 3. Authenticity of the project task, and 4. Mode of delivery of the project task. External partners were involved in projects across all the other domains. The distribution of the projects by these domains and categories is listed in Table 1.

Table 1: Distribution of the Projects by Rating of Interdisciplinary Width and Depth, Authenticity, and Mode of Delivery

Domain	Sub-group	n (%)	n (%) with External Partner
Interdisciplinary Width	Narrow (involves only sub-disciplines)	13(25)	6(11)
	Medium (within faculty)	15(28)	1(2)
	Wide (cross-faculty)	25(47)	7(13)
Interdisciplinary Depth	Sequential tasks	17(32)	4(8)
	Integrated tasks	36(68)	10(19)
Authenticity	Contrived	4(8)	0(0)
	Authentic	49(92)	14(26)
Mode of delivery	Multidisciplinary, Cross-faculty Project	24(45)	5(9)
	Multidisciplinary Project	24(45)	4(8)
	Consultancy type project	5(9)	4(8)

Employability skills developed by interdisciplinary projects

A range of employability skills were reported to be developed by the interdisciplinary project offerings examined in this study, in line with previous reports (Guo et al., 2020; Hart, 2019). Additional skills reported to be developed by interdisciplinary projects included career planning, reflective practice, research skills, entrepreneurship, social responsibility, and civic engagement.

Table 2: Employability Skills Reported to be Developed Across Studies Selected for Analysis

Skill	<i>n</i>	%
Disciplinary expertise	41	77
Communication skills	45	85
Teamwork	46	87
Interdisciplinary competence	32	60
Critical thinking and problem solving	31	58
Interpersonal competence	14	26
Information and digital literacy	9	17
Leadership and management skills	8	16
Lifelong Learning	4	8
Work ethic or motivation	9	18
Inventiveness or Creativity	11	22

There was little effect of project delivery mode on the reported improvement in skills development, except for interdisciplinary competence, which was not reported in any of the consultancy-type projects ($\chi^2=9.4$, $p<0.01$, Figure 2D). There was no effect of project delivery mode on development of interpersonal skills (Figure 2F). However, there was an effect of interdisciplinary depth as articles reported a significantly higher improvement in interpersonal skills where projects had integrated tasks (62%) rather than sequential tasks (29%, $\chi^2=4.7$, $p<0.05$) and where projects were authentic (100%) compared to contrived projects (0%, $\chi^2=4.5$, $p<0.05$).

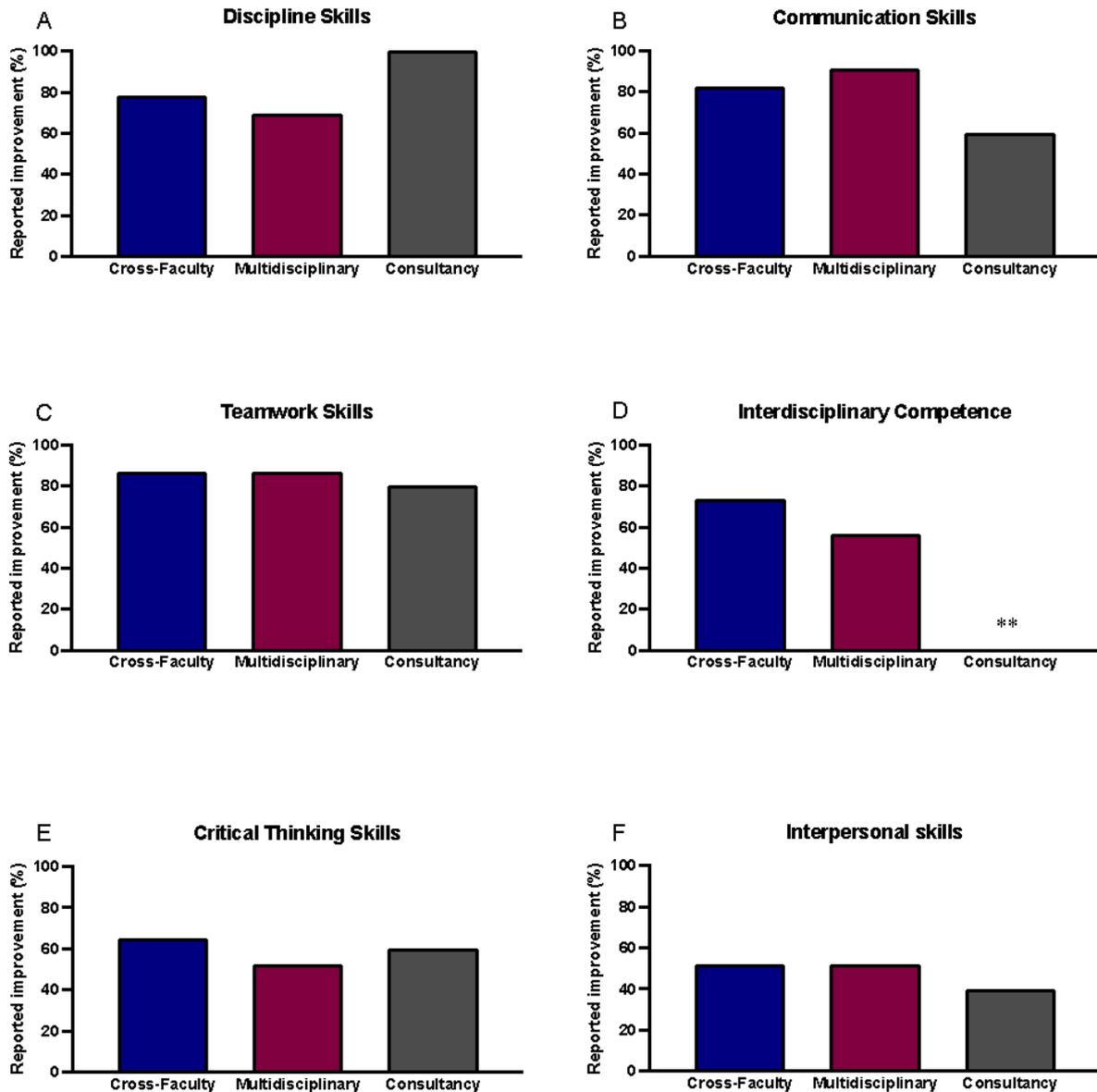


Figure 2. Employability Skill Development Reported by Project Delivery Mode ($P < 0.01$, Fisher's Exact test).**

Improved overall student satisfaction

Overall student satisfaction was reported to be improved by the project-based learning in 51% of the articles included. There was no significant effect of project delivery mode on overall satisfaction improvements, though consultancy-style projects were more likely to report improved satisfaction (83%, Figure 3A). There was no effect of interdisciplinary depth (sequential vs integrated project tasks) on the reporting of improved overall satisfaction.

Improved engagement with learning

Student engagement was reported to be improved by project-based learning in 53% of the articles included. There was no effect of project delivery mode or interdisciplinarity on the reporting of improved engagement. Improved learning of skills was reported in 45% of the articles included, and in 69% of the articles where projects involved an external partner. Regarding skills development, disciplinary skill gains were reported with all types of projects (78–100%, Figure 2A). Student skills in interdisciplinary competence were reported to be developed significantly more often when the project offering was cross-faculty or multidisciplinary ($p < 0.01$, Figure 2D).

Improved employability

Only 29% of the articles reported a perceived increase in employability due to the project. This was significantly higher with the consultancy-type projects (67%, $p < 0.05$, Figure 3B). Students reported that projects involving external partners significantly improved employability ($p < 0.05$, Fisher's exact test).

Effect of project mode of delivery

Just under half the projects (45%) were delivered in multidisciplinary mode, and the other half had cross-faculty partners. Notably, the inclusion of a cross-faculty partner had little effect on reported student discipline or employability skill development (Figure 2) or any of the satisfaction, engagement with learning, or employability outcomes (Figure 3). Consultancy-type projects were involved in only 10% of the included projects and were confined to maths and engineering majors. All had real clients (Anderson et al., 2011; Bramhall & Short, 2014; Diamond et al., 2011; Sanft & Ziegler-Graham, 2018), except for one where there were client scenarios (Cline et al., 2020). Whilst the number of studies that involved consultancy-type projects was lower, these were associated with higher overall satisfaction and perceived employability gains (Figure 3). Further, all consultancy-type projects were perceived to be more likely to deliver a real-world experience. However, consultancy-type projects did not report the development of interdisciplinary competence skills.

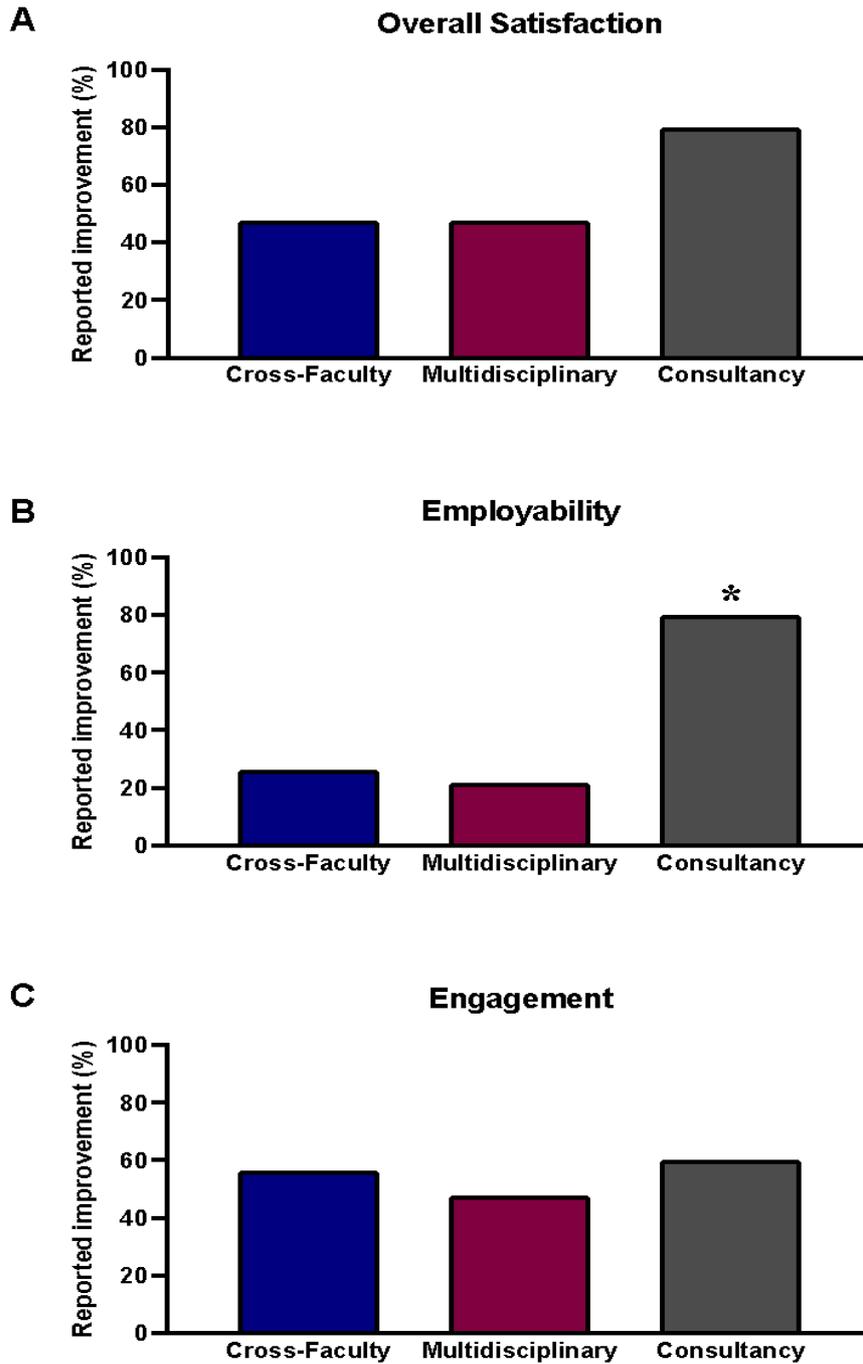


Figure 3. Student Satisfaction Outcomes Reported by Project Delivery Mode (*P<0.05, Fisher's Exact test).

Involvement of external partners

One quarter (26%) of the projects included in the review had an external partner. These varied from industry partners (Anderson et al., 2011; Bramhall & Short, 2014; Cheng et al., 2013; Corno & De Russis, 2017; Heikkinen & Isomottonen, 2015; Pellegrini & Jansen, 2013; Sanft & Ziegler-Graham, 2018; Vicente et al., 2018), community partners (Clark et al., 2013; Dunbar et al., 2013; Hun Bok et al., 2017; Warr Pedersen et al., 2017), academic partners (Anderson et al., 2011; Duncan et al., 2010; Warr Pedersen et al., 2017) and partners in entrepreneurship (Anderson et al., 2011). Students reported that projects involving external partners improved their overall satisfaction and delivered a real-world experience (Figure 4), as well as significantly improved their perceived employability ($p < 0.05$, Fisher's exact test).

Project Authenticity

Most articles included reported projects that were authentic, with only four being classified as having contrived project tasks (Ben Youssef & Berry, 2012; Everingham et al., 2013; Sangster et al., 2016; Talafian H, 2019). Around half (55%) of the articles reviewed reported that students perceived the project tasks as providing a real-world experience, which increased to 100% in consultancy-type projects. Projects delivering authentic project work reported higher overall satisfaction and sense of real-world experience (Figure 4).

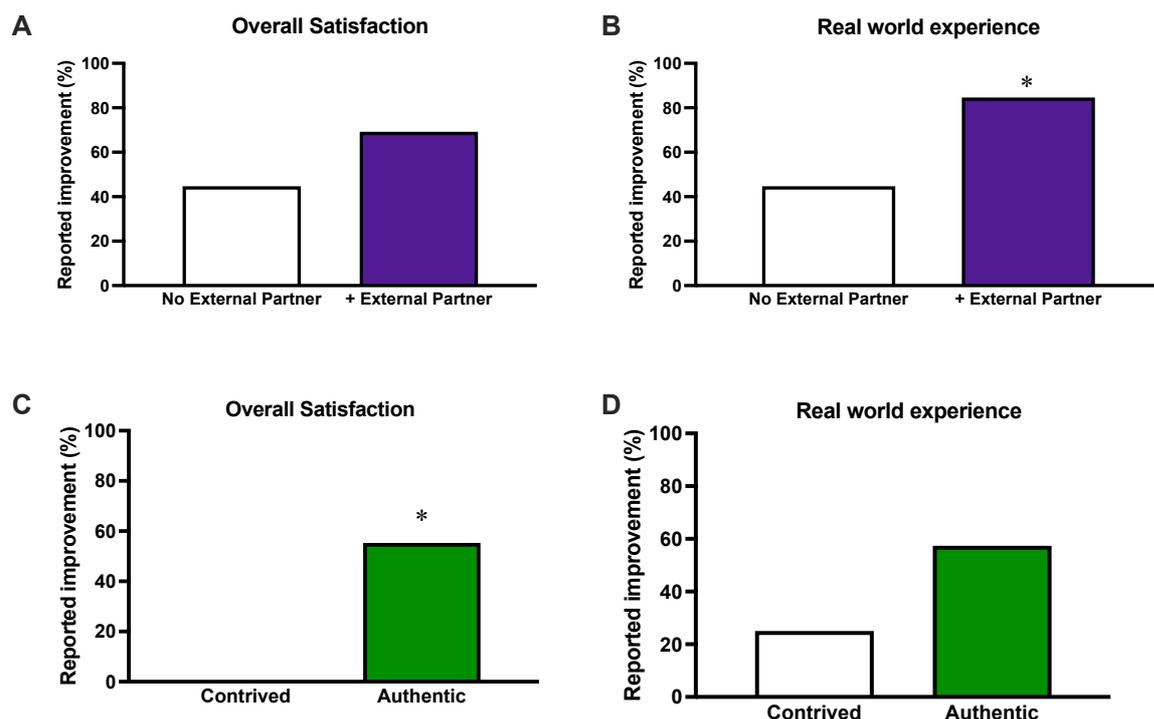


Figure 4 Reports of Improvements in Overall Satisfaction (A, C;, Reports of Real-World Experience (B, D) Where Projects Included an External Partner (A, B); or Were Rated as Authentic (C, D) (* $P < 0.05$, Fisher's Exact test).

Discussion

The broad findings of this study show that interdisciplinary projects that are authentic and involve an external partner generate better overall student satisfaction and development of employability skills. Further, this effect is independent of the type of interdisciplinarity used in the project design. The review shows that interdisciplinary projects are widely used, especially across engineering and computer science degrees. In science degrees, maths and statistics disciplines dominate with less interdisciplinary projects offered involving life sciences. The most common cross-faculty partners were from the humanities and business faculties.

The idea that we need interdisciplinary approaches to solve ‘wicked’ problems has encouraged the widespread development of interdisciplinary project work and many tertiary institutions have incorporated interdisciplinary project-based learning as part of their offering. In addition, this type of learning is thought to promote development of generic, employability skills and aid the application of discipline knowledge (Cross & Congreve, 2021; Kłeczek et al., 2020). However, the actual effectiveness of interdisciplinary project-based learning to fulfil these aims is not well-known. This study shows that interdisciplinary width or depth had little effect on reports of overall student satisfaction, engagement with learning, or development of employability skills. This implies that the nature of the interdisciplinarity is not critical, but that other factors are more important to consider when developing project-based learning.

Effective delivery modes

Project delivery mode was significant where the projects were consultancy-style offerings. Consultancy-type projects were involved in only 10% of the included projects and were confined to maths and engineering majors. Whilst the number of studies that involved consultancy-type projects was lower, these were associated with higher overall satisfaction, perceived employability, and real-world experience. Conversely, these projects were least associated with development of interdisciplinary competence skills. This is not surprising as the focus for these projects is to use the discipline-based skills in a work environment and other employability skills (e.g., communication skills) would be needed over interdisciplinary competence. Similarly, student skills in interdisciplinary competence were found to be significantly better developed when the project offering was cross-faculty or multidisciplinary, since the mix of disciplines involved in the project would highlight this. The two factors that were associated with improvements in overall student satisfaction, engagement with learning or development of employability skills were the perceived authenticity of the project work and the inclusion of external partners.

Authenticity

Most projects (92%) reviewed were rated as authentic project work, with only four delivering contrived project scenarios (Ben Youssef & Berry, 2012; Everingham et al., 2013; Sangster et al., 2016; Talafian H, 2019), which limited the viability of further analyses. Authentic projects include tasks and performance standards found in the real world, and authentic assessment of these tasks has been shown to have a positive impact on abilities related to employability (Villarroel et al., 2018). There are several aspects of authenticity that are applicable to project-based learning tasks. Students may see projects tasks as authentic if they involve personally meaningful work, and this personal connection can increase their intrinsic motivation to complete the task and invest extra effort (Warr & West, 2020). However, this review did not find an association between engagement in learning and projects rated as authentic. Indeed, there were no variables that improved engagement with learning, which may relate to how these aspects were reported in the included literature. A second aspect of authenticity in learning relates to the real world context of the problem being studied and the impacts on the broader community (Shaffer & Resnick, 1999). Here we see a connection as the review data do indicate that including an external partner or embarking on an authentic rated project is associated with a real-world experience. A final aspect of authentic

learning is that which provides opportunities for students to work in their disciplines (Shaffer & Resnick, 1999) and data from this review showing increased satisfaction with consultancy-type projects in the included literature concur with the prediction that this type of learning is beneficial to students.

About a quarter of the projects included had an external partner. These varied from industry partners (Anderson et al., 2011; Bramhall & Short, 2014; Cheng et al., 2013; Corno & De Russis, 2017; Heikkinen & Isomottonen, 2015; Pellegrini & Jansen, 2013; Sanft & Ziegler-Graham, 2018; Vicente et al., 2018), community partners (Clark et al., 2013; Dexter, 2021; Dunbar et al., 2013; Hun Bok et al., 2017; Warr Pedersen et al., 2017), academic partners (Anderson et al., 2011; Duncan et al., 2010; Warr Pedersen et al., 2017) and partners in entrepreneurship (Anderson et al., 2011). This review showed the involvement of an external partner in projects significantly improved the perceived gains in employability skills by students. Previous studies have shown that inclusion of an external partner has been shown to improve the project experience for students, by enabling work on real world problems and exposure to the work environment, including pathways to employment (Hayes & Cejnar, 2020; Kricsfalusy et al., 2018; Marcketti & Karpova, 2014). Additionally, the external partners gain resources towards solving a problem and to contribute to the education of the future workforce (Gruenther et al., 2009; Zanko et al., 2011). Furthermore, it is worth noting that the type of external partner was not important for the gains reported, and external partners should be sourced from a range of options including research, industry, community, and government.

Developing interdisciplinary project-based learning

One difficulty faced by those seeking to develop interdisciplinary project-based learning in their curriculum is the implicit differences in disciplinary approaches to knowledge, learning and pedagogy. These difference in epistemologies and signature pedagogies complicate both the process of designing, developing, and implementing interdisciplinary projects (Amador & Miles, 2016; Bacon et al., 2011) and the facilitation of effective teamwork across groups of students with diverse academic backgrounds (Bacon et al., 2011; Godemann, 2008). Sustainable facilitation of interdisciplinary project-based learning across the science curricula will require consideration of these cross-disciplinary differences in approach and support for the increased investment in time, resources and capacity building required of such learning models. Further development and research on the best ways to achieve these outcomes is needed; indeed, the current findings that the interdisciplinary aspects of these project offerings are not important may be due to a lack of teaching and learning insight into the pedagogical differences across disciplines, hindering the implementation of a true interdisciplinary experience.

The adoption of interdisciplinary projects within the science higher education curriculum, and their effective implementation may be challenging in several ways, some of which were articulated in papers examined as part of this review. For example, course and subject design is often heavily influenced by external bodies, and requirements for alignment of students' learning objectives to accreditation standards may restrict opportunities for project models that cross disciplines, schools, or faculties (Ben Youssef & Berry, 2012). Effective facilitation of project-based learning is more common, and thus potentially more readily achievable, with smaller student cohorts (Helle et al., 2006), such that implementing these types of curricula in large classes can be difficult in terms of the logistics, administration, staffing, and technical support required (Adair & Jaeger, 2014; Bennie et al., 2018). This remains a significant challenge to the integration of project-based learning early in the higher education curriculum, when cohorts are commonly large. However, some studies also reported that the benefits of implementing interdisciplinary projects were worth the substantial time investment (Amador & Miles, 2016) and provided opportunities to build shared understanding and rapport amongst both faculty and students (Anderson et al., 2011). For institutions that prioritise their ability to develop well-rounded graduates with good employment outcomes it may,

therefore, be worth investing in strategic initiatives to develop authentic, project-based learning opportunities across the curriculum.

Limitations

In line with findings of previous project-based learning reviews, the primary data in this field are limited to narrative course descriptions and anecdotal evaluations (Guo et al., 2020; Hart, 2019; Helle et al., 2006). Most projects are designed with a research framework and align with a project-based learning description (Blumenfeld et al., 1991), but the literature consists largely of course descriptions rather than educational research. Evaluations described were often anecdotal with little hard evidence to substantiate the claims, and the pedagogical framework was poorly articulated in many cases (Guo et al., 2020; Hart, 2019; Helle et al., 2006). The heterogenous nature of the articles included in the review, which examined a diverse range of course-specific goals and article-specific foci, made the assessment complicated. In most cases the implementation of the course was described well, though practice implications and challenges encountered were not always reported, nor solutions to them advised. Most articles reported perceived gains in learning or skills rather than objectively assessing them. This is difficult for some outcomes assessed; for example, objective tests for 'employability' don't exist and longitudinal studies would be needed to establish the effect of undergraduate project-based learning tasks on graduate employability. Of the quality domains appraised, the ethics and potential researcher bias rated least robust. The included studies would require human research ethics committee review in Australia (NHMRC, 2018) but most case studies did not mention having ethics committee review. This may mean the studies included were not rigorous in their approach to conflict of interest, or coercion where academic staff are using their own students as research subjects. Data collection, analysis and presentation were also rated below average, and this reflects the case study style of the included data (see Supplementary Data 4).

This study is a scoping review of outcomes from heterogeneous data sources, and many outcomes are based upon perceptions rather than hard evidence, thus they are subjective and susceptible to bias. To reduce bias, two reviewers were used, there were clear inclusion and exclusion criteria and a structured data extraction form, to enforce clear extraction of the information to construct the dataset. Not all reports on interdisciplinary project work included focussed on all student satisfaction outcomes reported in this study, though they all contained at least one of the measures, as per the inclusion criteria. Thus, this study can only report on what the primary studies report. Another area that needs to be noted is publication bias, as negative studies are unlikely to be published and not all academic staff are motivated enough to publish positive findings from their practice, so the studies included here are likely published by a dedicated sub-set of academics.

Future directions

The use of project-based learning as a means of developing employability skills is widespread, but there are few studies that evaluate these offerings effectively or interrogate whether interdisciplinarity itself is important in these projects, or being appropriately implemented. There has been little investigation of best practice for the mode of delivery of project-based learning, especially in science degree programs. Carefully designed evaluations from the perspective of all stakeholders; the students, academic staff, employer groups and external partner groups are required to further investigate the efficacy of project-based learning for developing employability skills. Objective measures of employability skills need to be developed and implemented to assist this. The role of teaching quality and effectiveness leading to improved engagement, learning and overall satisfaction also needs to be studied. Longitudinal studies are required to investigate the impact of an undergraduate project-based learning experiences on future employability.

Conclusions

This review shows that interdisciplinary projects are widely used to promote development of employability skills. Many projects involved disciplines within the same faculty, and the most common cross-faculty partners were from the humanities and business faculties. The interdisciplinary nature of project offerings had little effect on reports of improvements in any of the employability skills, except for interdisciplinary competence, which was the same regardless of interdisciplinary width, but absent in discipline-based consultancy projects. Similarly, the interdisciplinarity of project offerings had no effect on satisfaction outcomes. This study indicates that focussing on developing authentic project-based learning experiences, and involving an external partner (industry, educational, community, government), is well-received by students and contributes significantly to their satisfaction and perceived employability. The findings of this study should inform the practice of development and implementation of interdisciplinary project-based learning. Consideration of the goals of interdisciplinary project-based learning related to promoting development of more skilled and employable graduates needs to be undertaken, as well as further robust research into the effectiveness of interdisciplinary project-based learning.

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