European Journal of Engineering Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ceee20

A systematic literature review of university-industry partnerships in engineering education

R. Shah & A.L. Gillen

To cite this article: R. Shah & A.L. Gillen (2023): A systematic literature review of university-industry partnerships in engineering education, European Journal of Engineering Education, DOI: 10.1080/03043797.2023.2253741

To link to this article: https://doi.org/10.1080/03043797.2023.2253741

Published online: 03 Sep 2023.

EUROPEAN JOURNAL OF ENGINEERING EDUCATION
https://doi.org/10.1080/03043797.2023.2253741

RESEARCH ARTICLE

OPEN ACCESS Check for updates

A systematic literature review of university-industry partnerships in engineering education

R. Shah [a] and A.L. Gillen [b]

[a]School of Engineering and Materials Science, Queen Mary University of London, London, UK; [b]First Year Engineering Program, Northeastern University, 368 Snell Engineering, Boston, MA, USA

ABSTRACT

Over the last few decades, a wide range of works have featured studies documenting successful pedagogic collaborations in the form of university-industry partnerships in engineering education. In light of this, we conducted a systematic literature review of these studies centred around five key research questions: (a) purposes of university-industry collaborations, (b) theories used to guide such work, (c) types of methods employed, (d) evidence-based best practices identified and (e) areas of future work to be explored. Publications were selected for inclusion by screening and appraising results obtained from databases and keywords refined through a scoping study. We conclude from our findings that future studies would benefit from better alignment with literature or theoretical frameworks and specific robust methods. Additionally, early and middle years of undergraduate engineering programs offer underutilised opportunities for partnership, in line with designing a more futures-focused educational curriculum.

ARTICLE HISTORY
Received 1 April 2023
Accepted 28 August 2023

KEYWORDS
systematic literature review; university-industry partnerships; engineering education; educational collaboration; undergraduate curriculum

1. Introduction

Developing university-industry partnerships aligns well with current US workforce development goals calling for broadening participation in Science, Technology, Engineering and Mathematics (STEM) (National Science Board 2021). Likewise, the UK Royal Academy of Engineering has made it clear in the past that industry requires more involvement with undergraduate education (Educating Engineers for the 21st Century 2006). Forging partnerships between industry and universities is a global phenomenon and has long been touted as a way to achieve excellence through strategic changemaking at universities (e.g. Graham 2012). However, there is a need to bridge this ideal with the more conceptual study of collaboration from other fields if we are to gain a better understanding of exactly what makes collaborations work in engineering education. Some newer work has begun to bridge this gap (e.g. Gillen et al. 2021), but in order to continue to make theoretical strides and find gaps and new avenues for scholarship, it has become necessary to now map the landscape of literature around university-industry partnership in engineering education.

To start, it is necessary to briefly explore the fundamental research around collaboration across organisations in general. This has been studied for decades in a variety of contexts. There are a few highly cited works that come close to foundational pieces in interorganizational collaboration from Barbara Gray and others (e.g. Gray 1989; Gray and Purdy 2018; Gray and Wood 1991). While

CONTACT R. Shah rehan.shah@qmul.ac.uk
This article has been corrected with minor changes. These changes do not impact the academic content of the article.

Gray and Wood (1991) acknowledge that a comprehensive cross-contextual theory of collaboration may not be possible, these conceptualisations are arguably the closest we have. The general principles build on negotiated order theory (Day and Day 1977; Strauss 1978). Later and more taxonomised works branching off what came before give us processes around organisational interactions such as the tension between organisational interests and collaborative interests as described by public administration scholars (Thomson and Perry 2006; Thomson, Perry, and Miller 2007). While these works are arguably of the most robust categorisation and have been applied within engineering education (Gillen et al. 2021), collaboration has also been characterised across a continuum, for instance, considering superficial partnerships all the way to fully collaborative ones (Kernaghan 1993).

While these efforts from public administration, organisational behaviour, and other fields begin to articulate a strong background for the study of collaborating across organisations, there is a need to see to what extent engineering education takes this into account in the study of university-industry partnerships. Moreover, if researchers in engineering education are not utilising this rich history of interorganisational collaboration, what do their studies look like? Thus, while the relevance of university-industry partnership is clear, the landscape of research guiding the practice has not been clearly articulated. To this end, the purpose of our systematic literature review of university-industry partnerships in engineering education is to map five key areas:

- RQ1: What are the purposes/goals of university-industry collaborations for education?
- RQ2: What theories/lenses have been used to guide the study?
- RQ3: What are the methods that have been used in the study of university-industry partnerships?
- RQ4: What are major findings/conclusions from such studies and what evidence-based best practices have been identified?
- RQ5: What are the areas of future work that need to be explored further?

These questions are structured around the traditional components of human-subject research articles, including purposes/goals, theories/lenses, methods, findings/conclusions, and future work. This approach allows for easier development of future scholarship by making plain the gaps in current literature. It also has the potential to streamline the process for translating key findings to practitioners. Detailed methods, including criteria used in this systematic review, are further articulated in the next section and closely follow standards of practice in systematic literature review.

2. Methods

2.1. Methodological framework

We identified our sources for review by following the systematic process of identifying key search terms and databases as outlined by Tranfield, Denyer, and Smart (2003), in order to adopt a robust and well-documented process that would be transparent enough to be replicable by other researchers. In filtering the literature results obtained, we employed the search-screen-appraise method from Borrego, Foster, and Froyd (2014) and performed a qualitative thematic content analysis both within and across studies, in line with systematic review methodologies prevalent within the field of engineering education. This has been successfully implemented within a systematic literature review study of engineering identity conducted by Morelock (2017), whose methodological approach served as a model for our work.

2.2. Inclusion criteria

As emphasised by Gough (2004), it is crucial for systematic literature reviews to have an explicitly tight focus and scope, which can be achieved through identifying well-defined research questions as well as by prescribing a clear set of inclusion criteria. These criteria must be characterised both by conceptual as well as operational definitions, with the latter undergoing continual iterative refinement (Cook and West 2012). They must also seek to minimise bias (i.e. they should not intentionally or unintentionally exclude undesirable or inconclusive results).

With this in mind, we developed the following set of inclusion criteria for a source to be selected for review. It must be (a) written in English and from a peer-reviewed source, a common practice adopted in systematic reviews (e.g. Abdul Jabbar and Felicia 2015; Brown et al. 2015); (b) relevant to one or more of the research questions outlined in Section 1 (as endorsed by EPPI-Centre 2010); (c) published within the period 1980–2020 (sources earlier than 1980 were not considered to be as relevant or up to date, as per the guidelines from Cook and West (2012), and it is important to note that the early 1980s were time at which engineering industry was starting to become more vocal about workforce skills in conversation with universities (Jørgensen 2007)); (d) focusing on a university-industry partnership dedicated exclusively to teaching or pedagogic research within engineering education (studies solely on research-focused partnerships were excluded); (e) documenting US/UK-based university-industry partnerships (this geographical restriction was necessary in order to narrow the context of our work in conjunction with the tight scope required, for which there is a precedent, for example in Holloman et al. (2021) for scoping to a US context to make the scope more feasible); (f) concerned with partnerships dedicated to undergraduate education (sources targeted to graduate students were only included if studies were also conducted in conjunction with undergraduate students).

As a consequence of the above criteria, the following types of sources were excluded: (a) studies focusing on school/K-12/pre-college/pre-university/postgraduate education (as we want to focus our study on undergraduate education); (b) studies documenting outreach work, community partnerships, distance learning, faculty professional development and workplace training for practising engineers (as we are primarily concerned with intracurricular university-industry partnerships); (c) sources primarily featuring outputs of symposiums/workshops/conferences as well perspective articles and opinion pieces (as these are typically devoid of some form of research or evaluation); (d) studies within the disciplines of software engineering/computer science/information technology/engineering entrepreneurship (as we wish to limit our focus to the traditional engineering sub-disciplines); (e) studies featuring case studies highlighting non-US/UK university-industry partnerships (these were necessary to omit in order to constrain the large number of relevant works obtained including those from Australia, Ireland and Brazil).

Contexts outside our scope, such as non-US/UK partnerships and studies focusing primarily on graduate education, merit their own reviews. This is based on our assessment of the quantity of literature available in these areas during our scoping review. Limiting ourselves was necessary to protect the feasibility of our review and transferability of our findings.

2.3. Scoping study, databases and search terms

We conducted a scoping review to initially test preliminary sets of databases and search terms and to survey the breadth of literature around university-industry partnerships in engineering education. During the course of this, we iteratively refined search terms and database selections to eliminate sources that did not satisfy the inclusion criteria listed in Section 2.2.

The final search terms used were:

> (University OR College) AND (Industry OR Business) AND (Partnership OR Collaboration) AND Engineering Education

The final selection of subject-specific databases, adopted from those suggested by Borrego, Foster, and Froyd (2014) were:

(a) Education Resources Information Centre (ERIC) (EBSCO)
(b) ERIC (ProQuest)

(c) British Education Index (EBSCO)
(d) Compendex
(e) Inspec

The first three of these (a), (b) and (c) are authoritative databases containing records of indexed and full-text education-related literature and resources, while the last two (d) and (e) constitute definitive scientific and technical databases within the engineering disciplines.

More general databases such as Scopus, PsycINFO, Journal Storage (JSTOR), ScienceDirect and Wiley were excluded as they yielded too many results as were the databases Communication Abstracts (EBSCO), Communication and Mass Media Complete (EBSCO), Academic Search Complete and Directory of Open Access Journals, which were not easily accessible. The focus on subject-specific, as opposed to more general databases, was guided by similar methodologies adopted by other systematic literature reviews such as those by Morelock (2017) and Holloman et al. (2021), whose approaches served as useful models for our work. Moreover, this decision was also endorsed by an experienced external colleague in systematic reviews, whom we consulted during the process.

We also considered expanding our scoping review by performing citation searching or snowball sampling (i.e. reviewing works cited by already identified sources), as recommended by Borrego, Foster, and Froyd (2014), in case of insufficient results being obtained through database searching. However, since our database searches yielded an adequate number of relevant studies, we did not need to pursue this option. Table 1 presents the final list of databases, search strings and additional details that may be useful for replicating the search.

2.4. Results and filtering

After obtaining the search results used for the final review, we filtered the 668 resulting articles using the search-screen-appraise method adopted by Morelock (2017), in which results were filtered using

Table 1. Databases and search strings used to locate articles.

Database	Search String	Search Details
ERIC (EBSCO)	(University OR College) AND (Industry OR Business) AND (Partnership OR Collaboration) AND Engineering Education	- Search mode: Boolean - Expanders: Apply equivalent subjects - Source type: Peer reviewed - Date range: 1983–2020
ERIC (ProQuest)	(University OR College) AND (Industry OR Business) AND (Partnership OR Collaboration) AND Engineering Education	- Search mode: Boolean - Source type: Peer reviewed, Journal Articles (scholarly journals) - Date range: 1980–2020 - Language: English
British Education Index (EBSCO)	(University OR College) AND (Industry OR Business) AND (Partnership OR Collaboration) AND Engineering Education	- Search mode: Boolean - Expanders: Apply equivalent subjects
Compendex	(University OR College) AND (Industry OR Business) AND (Partnership OR Collaboration) AND Engineering Education	- Search mode: Boolean - Source type: Journal Articles - Date range: 1990–2020 - Language: English - Controlled vocabulary: Engineering Education - Country/Region: United States, United Kingdom
Inspec	(University OR College) AND (Industry OR Business) AND (Partnership OR Collaboration) AND Engineering Education	- Search mode: Boolean - Source type: Journal Articles - Date range: 1990–2020 - Language: English - Controlled vocabulary: Engineering Education - Country/Region: United States, United Kingdom

a combination of title and abstract screening, after which the remaining studies were appraised for inclusion via full-text analysis. In lieu of the limitations identified there by the author, with regard to the filtering of articles solely through title screening, we decided to employ a mixed title/abstract screening procedure to improve the robustness of our method.

A result was therefore excluded if its title or abstract was specific enough to suggest the study's irrelevance, however in more ambiguous cases, the study was retained for appraisal in the next step. For instance, one of the works entitled '*The Role of Collaborative Capstone Projects – Experiences from Education, Research and Industry*' by Hess et al. (2013) was deemed relevant from the initial title screening phase, but was subsequently omitted during the abstract and full-text analysis stage in line with exclusion criteria (d) described in Section 2.2, as the study pertained to collaborative university-industry capstone projects within the software engineering curriculum.

During the final stage involving full-text appraisal, only studies that satisfied all of the inclusion criteria listed in Section 2.2 were included as part of the synthesis. Figure 1, adapted from Morelock

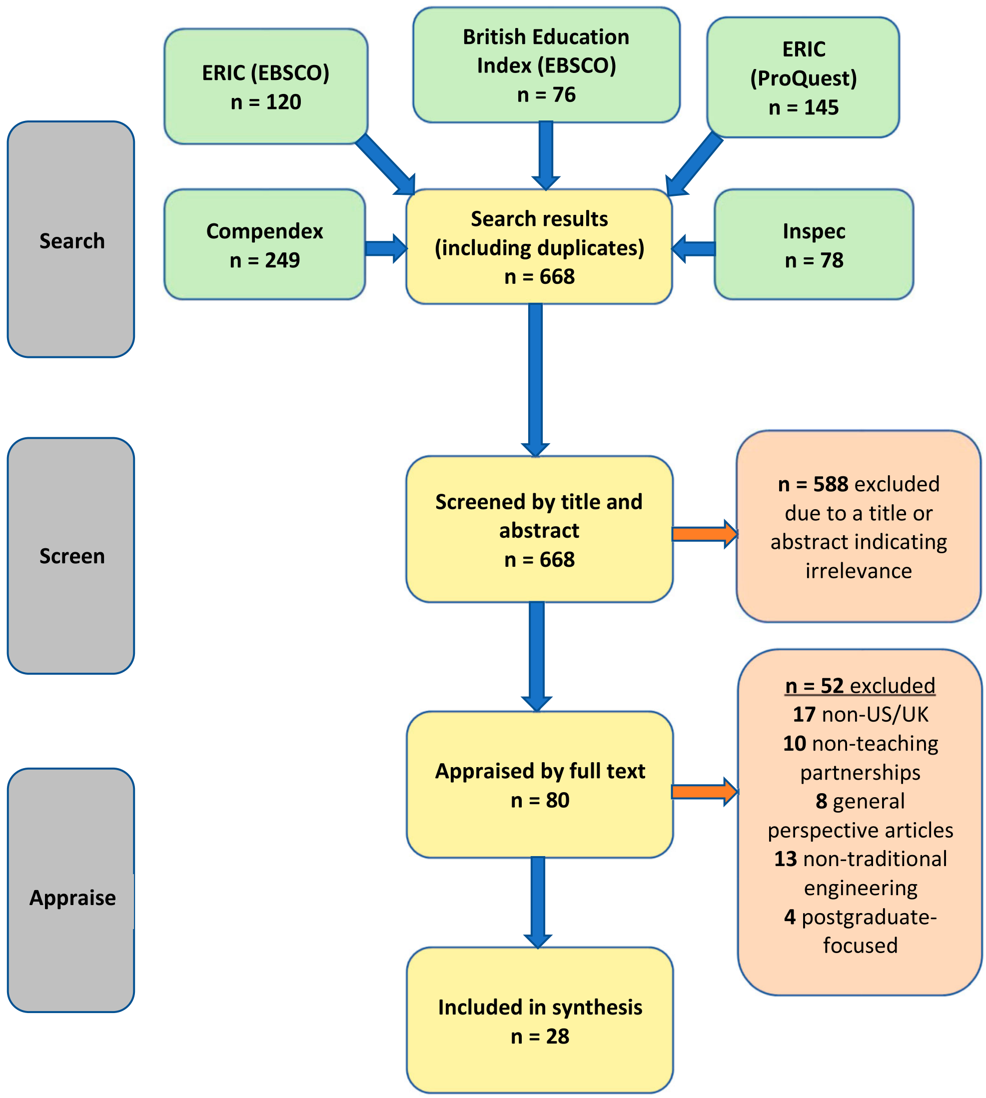

Figure 1. Variant flowchart following PRISMA guidelines (Liberati et al. (2009)) documenting filtering process and results (adapted from Morelock (2017)).

Table 2. Examples of studies excluded during the full-text appraisal stage.

Paper	Title	Reason for exclusion
Eberhardt et al. (2016)	*Team-Based Development of Medical Devices: An Engineering–Business Collaborative*	Study is exclusively focused on university-industry collaborations at postgraduate masters-level courses
Walz, Slowinski, and Alfano (2016)	*International Approaches To Renewable Energy Education A Faculty Professional Development Case Study With Recommended Practices For STEM Educators*	Study focuses on faculty-industry learning exchange programmes (i.e. a non-teaching university-industry partnership)
Fielding et al. (2014)	*Product lifecycle management in design and engineering education: International perspectives*	Study is a perspective article that focuses on outputs from symposium sessions
Acharya et al. (2017)	*Using Academia-Industry Partnerships to Enhance Software Verification & Validation Education via Active Learning Tools*	Study is concerned with partnerships within software engineering courses i.e. within a non-traditional engineering discipline
Wang et al. (2015)	*Simulating Industry: A Holistic Approach for Bridging the Gap between Engineering Education and Industry. Part I: A Conceptual Framework and Methodology*	Study focuses on university-industry partnerships using case study examples of a Chinese university (i.e. a non US/UK university context)

(2017) in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, depicts a visual flowchart documenting the removal of studies at each filtering stage. Table 2 below provides some examples of studies that were excluded for not satisfying various inclusion criteria during the full-text appraisal stage.

The final study comprised a total of 28 papers selected as part of the systematic review, a complete list of which can be found in the appendix Table A1.

To increase the reliability of the process, screening was first performed by one author and then audited by the second author. In addition, the authors consulted with an experienced external colleague in systematic review during the process.

2.5. Demographics of selected studies

In order to classify the 28 selected papers, we categorised them based on the year of publication, methods used, publication source (journal or conference) and geographical location of university-industry partnerships.

2.5.1. Year of publication

During our scoping study, we enforced a lower bound date restriction by searching for studies ranging from the 1980s through to 2020. This enabled us to limit our results to more relevant works featuring university-industry partnerships, considering that such collaborations only began to take place relatively recently. Our earliest included source appeared in 1996 (Tener 1996), though we found that a large proportion of our selected papers were published from 2010 onwards.

2.5.2. Methods used

The majority of our selected studies (11 in total) employed qualitative methods such as feedback surveys and questionnaires and thematic content analysis techniques.

Two of our selected studies (Burns et al. 2018; Na Zhu 2018) made use of statistical analysis tools to examine data procured from student assessments and survey questionnaires. Eight of the papers performed mixed methods research, defined by Tashakkori and Creswell (2007) as a combination of qualitative and quantitative methods in a single study. It is also worth noting that some studies (7 in total) adopted unnamed and non-specific methods of data collection and analysis, the implications of which are explored further in Section 4.

2.5.3. Publication source

Based on our inclusion criteria, almost all of our papers (27 out of the 28 studies) were published in peer-reviewed journals, most commonly the *International Journal of Engineering Education* (9) (dedicated to scholarly research related to engineering education), *Industry and Higher Education* (4) (focuses on the multifaceted relationships between higher education institutions and business and industry), the *Journal of Professional Issues in Engineering Education and Practice* (2) (explores issues of professional practice, ethics and diverse views of engineering education) and the *International Journal of Mechanical Engineering Education* (2) (concerned with the principles and practices of training professional, technical and mechanical engineers). The lone conference paper (Shooter and Buffinton 1999) included in our selected studies featured in the *Institute of Electrical and Electronics Engineers (IEEE) Frontiers in Education* conference (a major international conference focusing on educational innovations and research in engineering and computing education).

2.5.4. Geographical location of partnerships

In accordance with our selection criteria, the majority of our studies (21 in total) featured US-based case studies highlighting university-industry partnerships, with five studies documenting collaborations between UK-based universities and companies. The remaining two studies (Conradie et al. 2016; Shaul Norback et al. 2014) were more general in nature in that they did not explicitly describe any specific case study examples of partnerships between universities and industries.

2.6. Thematic analysis

In addition to recording demographic information, we coded our selected studies around the five research questions pertaining to university-industry partnerships stated in Section 1. These questions essentially mirror the expected structure of our selected research studies, thereby facilitating an easier transferability of common characteristics as part of the content analysis and key findings to practitioners as part of the emerging recommendations.

For each research question, we identified various common features shared across multiple studies and used these as codes to categorise each study, in accordance with the content analysis process described by Borrego, Foster, and Froyd (2014). It is these codes that were used to answer our research questions and they represent the focus of the results presented in this review.

It is worth mentioning that our content analysis methodology differed from usual analysis procedures for grounded data, which often combine codes into 'concepts' and subsequently combine these into 'categories', such that these categories and concepts interrelate to form theory (Corbin and Strauss 2014). Since the purpose of this review is to capture existing literature rather than to develop theory from it, the use of codes was sufficient to organise the data.

2.7. Research quality

'Consistency and transparency' are drivers of quality in systematic literature reviews (Borrego, Foster, and Froyd 2014, 63). Working towards these goals, we carefully detail our methodological approach within this paper, including inclusion criteria, search terms, and databases used. A complete catalogue of papers included in this study is also available upon request. In addition, we held regular debriefing meetings to review ongoing work and add validity to the process (Creswell 2014). Borrego, Foster, and Froyd (2014) also states that collaboration improves reliability in literature reviews. Throughout the analysis process, we conferred interpretations between researchers (Creswell 2014).

2.8. Limitations

This review is limited by the biases introduced as part of the inclusion criteria for our selected works. Firstly, by considering only peer-reviewed sources written in English, we excluded potentially contributive theses and dissertations, non-English studies, non-academic reports, perspective articles and opinion pieces as well as all forms of grey literature not published by commercial publishers.

Secondly, owing to the large number of results generated, we had to narrow our scoping study by only considering subject-specific databases, thereby excluding more general databases such as Wiley, Scopus and JSTOR.

As an additional consequence of the extensive results obtained, we also had to limit our geographical focus to papers documenting only US/UK-based university-industry partnerships. Despite their relevance to our research questions, several studies featuring university-industry collaborations from countries such as Norway, South Africa, Brazil, China, Germany, Spain, India, Ireland, Denmark and Australia had to be omitted. While the focus on including works featuring case studies at US/UK universities may narrow the focus of the work, this enabled us to complete the review, since widening the scope would have made the number of relevant results unfeasible for analysis. This was a scoping decision we made following the large number of results we obtained across a wider demographic when deciding on our inclusion criteria and research questions.

Finally, since our work focused exclusively on teaching and education-related forms of university-industry partnerships for undergraduate engineering students, we did not consider the various forms of research-based collaborations that exist between universities and companies, particularly those involving academic faculty and graduate students. Based on our scoping study, we realised that focusing on university-industry collaborations for graduate student education alone constitutes enough data to merit a separate systematic literature review study of its own and represents a valuable source for potential future work in this area.

While it could be argued that these limitations impact the quality of the research produced, they were also a necessary part of scoping the process. Moreover, such shortcomings are often unacknowledged in published reviews. In being transparent about our limitations, we hope to instil further confidence in our results.

3. Findings

The appendix table lists all 28 selected studies, along with the codes used to categorise each of them for each of the specific research questions. The findings subsections below provide a detailed analysis to answer each of our proposed research questions.

3.1. What are the purposes/goals of university-industry collaborations for education?

Twenty five of the 28 papers identified specific purposes for educational partnerships between universities and industries within the context of their case studies. The remaining 3 studies (Burns et al. 2018; Shooter and Buffinton 1999; Tener 1996) did not explicitly discuss any overarching goals motivating such forms of collaboration. Some of the general benefits of such partnerships for the various stakeholders involved, as noted by the majority of our studies, comprised the following: solutions to complex projects with the help of additional resources at low cost (for industrial companies), acquisition of real-world problem-solving skills and professional experience (for students) and potential to keep up to date with disciplinary knowledge from industrial perspective (for academic faculty). The specific purposes governing these types of collaborations are provided within the subsections below in further detail.

3.1.1. Promoting industrial involvement in senior/final-year capstone design project courses (11 studies)

Over a third of our studies cited increasing participation of industrial companies within the development and implementation of senior/final-year capstone design projects as one of the primary motivators behind university-industry partnerships. Collaborations of this nature were found to be mutually beneficial in fulfilling the needs of both students and industrial partners (Trent Jr and Todd 2014), through industry involvement as curriculum advisors, project mentors and guest lectures offered within final-year capstone design courses (Goldberg et al. 2014).

We found several instances of industry participation within final-year undergraduate capstone design courses documented in the form of case studies among our selected papers. These featured the inclusion of an integrated product development (IPD) component for bioengineering students (Herz et al. 2011), an evaluation of industrial and business mentorship in mechanical engineering projects (Abu-Mulaweh and Abu-Mulaweh 2019; Demetry 1997; Na Zhu 2018), the implementation of a collaborative problem-based learning (PBL) framework through execution of Lean Six Sigma (LSS) projects in industrial engineering programmes (Martínez León 2019) and the development of a new aluminium engineering design course for mechanical engineering students (Pai and DeBlasio 1997).

A more non-traditional form of industry involvement within project-based design courses through the less-demanding route of podcasting and use of multimedia content was discussed in Ruikar and Demian's (2013) study. Alexander et al. (2015) identified best practices for administering capstone programmes, while Shaul Norback et al. (2014) captured a snapshot of students' experiences and perspectives of industry involvement in such courses.

3.1.2. Preparing graduating students with employability skills (6 studies)

Several of the works also considered the goal of university-industry partnerships to be centred around providing engineering graduates with the necessary skills required to be successful in the workplace. This was achieved through integrating elements of design, manufacturing and business as part of a practice-based engineering curriculum known as the learning factory (Lamancusa, Jorgensen, and Zayas-Castro 1997), incorporating cooperative education practices within electrical and computer engineering programmes (Duwart et al. 1997) and creating a common standard design framework across multiple senior capstone projects (Estell and Hurtig 2014).

Some of the case studies highlighted how industry involvement led to undergraduate students acquiring a host of authentic learning skills relevant to current industrial practices. These arose from establishing a learning environment for advanced energy storage technology within laboratory-based engineering courses (Gene Liao, Young, and Moss 2013), providing students in project-based design courses with opportunities to create tangible user interfaces (TUIs) with local small and medium-sized enterprise (SME) companies (Conradie et al. 2016) and using building information modelling (BIM) and IPD concepts in architectural engineering courses (Solnosky, Parfitt, and Holland 2014).

3.1.3. Providing students with short-term industrial internships and work-placements (4 studies)

A few authors focused on the short-term internships and work placement opportunities offered by sponsoring companies to university students as extracurricular activities taking place beyond the classroom outside the standard academic terms. Durkin (2016) presented a case study on the implementation of experiential learning techniques, within which students were able to apply their existing knowledge through summer industrial projects, while Murray, Hendry, and McQuade (2020) showcased how students achieved the same through co-curricular evening workshops established in conjunction with practising civil engineers.

The efficacy of such forms of internship programmes was measured by assessing alignment with the programme criteria set out by the Accreditation Board for Engineering and Technology (ABET) (Haag, Guilbeau, and Goble 2006) and documenting industrial work placement statistics to ascertain the engagement of civil engineering undergraduate students (Tennant et al. 2018).

3.1.4. Bespoke goals – not aligned to a common theme (4 studies)

We noted that there were some studies whose identified purposes for university-industry partnerships were uniquely suited to the context of their individual case studies and consequently did not fit any of the common themes mentioned above. Examples of the motivating factors driving industry involvement included promoting retention of female students in STEM and technology-related careers (Wasburn and Miller 2007) as well as enhancing student knowledge and attitudes towards corporate social responsibility (CSR) (Smith et al. 2018).

Wade (2013), for instance, noted instances of strategic university-industry partnerships in which companies provided technical support to universities to help manage their resource and technology platforms for engineering education. Industrial companies have also been known to provide sponsorship funding to undergraduate students to complete their degree studies, as a form of financial support designed to assist in the initial training of future engineers (Soltani, Twigg, and Dickens 2012).

3.2. What theories/lenses have been used to guide the study?

The case studies from 20 of the 28 papers were guided by a sound theoretical foundation comprising references to existing learning frameworks as well as to past literature sources on university-industry partnerships. The remaining 8 studies (Demetry 1997; Estell and Hurtig 2014; Gene Liao, Young, and Moss 2013; Haag, Guilbeau, and Goble 2006; Herz et al. 2011; Shooter and Buffinton 1999; Trent Jr and Todd 2014; Wade 2013) were characterised by the absence of any such theoretical backbone underpinning their work. This was often because these were never explicitly mentioned or delved into in sufficient detail by the authors. Consequently, this raised an important concern about the prevalence of studies documenting university-industry collaborations, devoid of any theoretical lens whatsoever (discussed further in Section 4). The subsections below highlight the specific sources of the theories that guided the majority of the studies.

3.2.1. Guidance from existing theoretical learning frameworks (10 studies)

Over a third of our papers featured case studies that were largely guided by a variety of existing learning theories, which have been systematically listed alongside each corresponding paper in Table 3.

3.2.2. Guidance from prior literature calling for greater university-industry collaboration (7 studies)

A quarter of our studies featured case studies that were guided by several prior literature sources that emphasised the need for increased collaboration between universities and industry and these have been compiled and listed in Table 4.

3.2.3. Bespoke theoretical guidance – not aligned to a common theme (3 studies)

There were also a few studies whose work was guided by literature sources citing theoretical concepts that did not identify with any of the common themes presented above. Na Zhu's paper (Na Zhu 2018), for instance, evaluated the effectiveness of mentoring by industry and business professionals within a senior mechanical engineering capstone design course. The author discusses how the development of such capstone courses by universities are based on different methods such as the iterative model of continuous improvement (Mirzamoghadam and Harding 2013), the impact of group projects and teamwork (Stettina et al. 2013; Wilbarger and Howe 2006) and the

Table 3. Theoretical learning frameworks guiding the study of university-industry partnerships.

Paper	Framework used
Ruikar and Demian (2013)	• Accommodation of several learning styles and abilities (Fry et al., 2009; Horgan 2009; Ramsden 2003) by multimedia podcasting approach based on **Gardner's theory of multiple intelligence** (Gardner 1983) • Adoption of an **active learning-based approach** (Gibbs, Habeshaw, and Habeshaw 1998) to encourage greater student interest and involvement
Conradie et al. (2016)	• Emergence of new user-experience design paradigm (Moczarny, de Villiers, and van Biljon 2012) with the notion of empathic design (Kouprie and Visser 2009) and TUIs with the notion of interactivity (Satyanarayanan 2001) requires a **PBL approach** facilitating **contextual and experiential learning** (Dahlgren 2003; Frank, Lavy, and Elata 2003) based on **Kolb's educational model** (Kolb 1984)
Duwart et al. (1997)	• Purpose of higher education is driven by students' cognitive, behavioural and affective needs (Chickering 1969) • **ABET Engineering Criteria** (*Engineering Criteria 2000*, 1995) used to pinpoint key skills expected from all graduates of engineering programmes
Murray, Hendry, and McQuade (2020)	• Need for an **authentic curriculum** to contextualise student learning as alluded to by Watts (2006), Lowden et al. (2011) and Pegg et al. (2012) • Use of inductive learning through **PBL** (Prince and Felder 2006) and its alignment with **social constructivism** through the importance of **collaborative and peer-led learning** (Ashwin and McVitty 2015)
Martínez León (2019)	• **PBL approach** (Bell 2010; Borror et al. 2012) used to bridge the gap between theory and practice, while the **LSS methodologies** used for curriculum development (Anderson-Cook, Patterson, and Hoerl 2005; Mitra 2004)
Tennant et al. (2018)	• Guided by the benefits of industrial placements with regard to **academic and situated cognition** (Murray and Tennant 2014), **identity formation in a community of practice** (Johri and Olds 2011) and **contextual learning** through authentic work experience (Pegg et al. 2012)
Pai and DeBlasio (1997)	• Adult learning philosophies such as the **pillars of adult learning** (Knowles 1980) used to design the course in which students had substantial input through self-evaluation activities, with professors acting as facilitators
Durkin (2016)	• Guided by **experiential learning theory (ELT)** in which students acquire and apply knowledge gained through prior experiences (Dewey 1963; Kolb 1984) • Integration of ELT with teamwork and peer interaction through reflective conservation, team learning and functional leadership (Kayes, Kayes, and Kolb 2005)
Lamancusa, Jorgensen, and Zayas-Castro (1997)	• References to **cognitive processes and behavioural psychology** citing limitations of lecture-based teaching approaches (Koen 1994; Mestre 2001; Wankat and Oreovicz 1994) • Allusions to **visual learning** and importance of practical hands-on experience in engineering education (Felder and Silverman 1988)
Wasburn and Miller (2007)	• Design of intervention programmes based on theoretical concepts from literature explaining male-female gender gap such as testing-based, biological determination and cognitive/learning differences and **socio-psychological theories** (Clewell and Campbell 2002) • **Female retention-enhancing strategies** based on theoretical framework by Tinto (1975) that students' decision to remain or withdraw from a course is based on their academic and social experiences within the university

importance of capstone projects in facilitating a smooth transition from academic study to practical engineering (Hanna and Sullivan 2005; Magleby et al. 2001).

Smith's study (Smith et al. 2018) focusing on CSR arising within industry-university partnerships was guided by engineering students' sense of social responsibility (Layton 1986; Noble 1979; Wisnioski 2012) and discussions of previous sources highlighting the importance of CSR in the engineering workplace (Blowfield and Frynas 2005; Ekwo 2013; Loureiro, Dias Sardinha, and Reijnders 2012).

Finally, the case study by Solnosky, Parfitt, and Holland (2014) outlined the implementation of an architectural engineering capstone course designed to address the needs of the architecture, engineering and construction (AEC) industry. This made use of BIM and IPD in education settings to simulate an integrated industry process in academia as well as the differences between educational objectives and educational outcomes (Jestrab, Jahren, and Walters 2009) and aspects of team-based learning (Fong 2010).

Table 4. Past literature studies highlighting the need for greater university-industry collaboration.

Paper	Literature studies used
Goldberg et al. (2014)	Guided by references to the importance of industry involvement in capstone design courses as stated in Farr et al. (2001) and Pembridge and Paretti (2010)
Alexander et al. (2015)	Needs and values of all stakeholders (students, faculty, industry, institution) in capstone design programmes established with the help of the study by Todd and Magleby (2004) and resources such as contract accords and researcher guidebooks published by the University-Industry Demonstration Partnership (UIDP 2012a; 2012b)
Shaul Norback et al. (2014)	Detailed literature review of over 1900 capstone design papers between 1997 and 2012 including those by Cheville and Welch (2009), Helbling et al. (2007) and Shaul Norback, Leeds, and Kulkarni (2010) revealed that student experiences and inputs on capstone projects had never been captured
Abu-Mulaweh and Abu-Mulaweh (2019)	References made to studies by Hamelink (1994), Karimi (2003) and Todd, Sorenson, and Magleby (1993) highlighting the importance of industry involvement in senior design projects
Soltani, Twigg, and Dickens (2012)	Need for closer collaboration between industry and university engineering departments as stated in The Lambert Review (Lambert 2003) and reports published by the Royal Academy of Engineering (*Educating Engineers for the 21st Century* 2007) and the Department of Education and Skills (*The Future of Higher Education*, 2003)
Tener (1996)	Calls for more effective partnerships between universities and industries as mentioned in reports by The Business Roundtable (*Management Education and Academic Relations*, 1982), Matthews & Norgard (1984) and the American Society of Engineering Education (*Engineering Education for a Changing World*, 1994)
Burns et al. (2018)	Six aspects of student learning from industry engagement activities drawn from previously validated surveys from literature sources (Haag, Guilbeau, and Goble 2006; Metrejean, Pittman, and Zarzeski 2002; Rodrigues 2004; Watson and Lyons 2011)

3.3. What are the methods that have been used in the study of university-industry partnerships?

Investigating the specific methods of data collection and data analysis employed by each paper to study university-industry partnerships helped us propose changes in methodology which future works on this topic could take into consideration (discussed further in Section 4). Seven studies in particular (Conradie et al. 2016; Duwart et al. 1997; Goldberg et al. 2014; Lamancusa, Jorgensen, and Zayas-Castro 1997; Shooter and Buffinton 1999; Tener 1996; Wade 2013) failed to either adopt or explicitly mention the concrete methodology approach used to derive the conclusions for their work. Consequently, this raised an important consideration for future studies to incorporate, with regard to including a specific methods section within their work as well as documenting their techniques of data collection and analysis in sufficient detail. The subsections below explore, in more detail, the different types of methods used by the remaining set of studies.

3.3.1. Qualitative methods (11 studies)

The majority of papers made use of qualitative methods of data collection comprising surveys, questionnaires and feedback assessment forms provided to each of the key stakeholders (students, faculty, industry sponsors) in order to gauge the effectiveness of university-industry partnerships within the context of their own case studies. These have been summarised in greater detail in Table 5.

It is also worth mentioning however, that while most of the studies listed in Table 5, stated their methods of data collection, they often did not mention the specific qualitative data analysis techniques employed within their work. The few studies that did so primarily used thematic analysis techniques inspired by Braun and Clarke (2006) to analyse the results from surveys and questionnaires. Moreover, while Table 5 principally records the various qualitative data collection methods comprising surveys, interviews and questionnaires employed by the selected works, some of these data collection methods did also contain quantitative aspects within them, but on the whole they can still be categorised to be qualitative.

Table 5. Qualitative data collection methods used.

Paper	Data collection method used
Y. Gene Liao, Young, and Moss (2013)	**End-of-semester surveys** used to gauge mastery of learning outcomes by students in new courses and **face-to-face focus group interviews** conducted by external evaluators asking students to respond to specific questions
Trent Jr. and Todd (2014)	**Surveys** used to collect data to understand needs and expectations of industry with regard to new engineering graduates, also sent to industry sponsors for feedback to make necessary course adjustments
Alexander et al. (2015)	**Web surveys** and **literature review** used as data collection methods to sample baseline of current administrative practices and identify challenges in implementing capstone programmes
Murray, Hendry, and McQuade (2020)	**Free text questionnaires** used to gain verbatim student feedback
Abu-Mulaweh and Abu-Mulaweh (2019)	**Feedback assessment forms** provided to industry sponsors, faculty and students to evaluate effectiveness of university-industry partnership
Smith et al. (2018)	**Surveys** provided to students both before and after a petroleum engineering field session course to assess changes in their knowledge, skills and attitudes towards CSR and the engineering profession
Solnosky, Parfitt, and Holland (2014)	**Verbal/written grades feedback** from faculty used to evaluate course objectives, compare them with student performance and confirm if course outcomes were met
Martínez León (2019)	**Student feedback surveys** from completion of an engineering and management capstone design course used to assess bridging of the gap between theory and practice
Tennant et al. (2018)	**Peer-reviewed placement questionnaires** using a five-point Likert scale provided to students as a means of gathering data
Pai and DeBlasio (1997)	**Formative and summative course evaluations** carried out by students used to improve course content for future sessions with the summative evaluation performed using four levels of evaluation guidelines (Kirkpatrick 1994)
Durkin (2016)	**Student essays and feedback** used to evaluate learning experiences and project success from university-industry partnership

3.3.2. Quantitative methods (2 studies)

We found only two studies from our selection set that made exclusive use of quantitative methods to study university-industry partnerships. For data collection, Na Zhu (2018) designed two modes of assessment types (course materials and a capstone project) to measure and compare student outcomes with and without industrial or business mentorship involvement. On the other hand, Burns et al. (2018) developed a questionnaire-based survey using a seven-point Likert-type scale (Finstad 2010) conducted using the online software Qualtrics to gauge student perceptions of different industry engagement activities.

Both of the works above made use of statistical methods to analyse the quantitative data obtained, with Na Zhu (2018) making use of data analysis techniques to calculate the mean and standard deviation scores for different groups of students and Burns et al. (2018) adopting the respondent selection technique to choose the key sampling group and evaluating the hypotheses using the multivariate analysis of variance (MANOVA) method to compare student perception scores across different activities.

3.3.3. Mixed methods (8 studies)

Several of our studies also made use of mixed methods, consisting mainly of qualitative as well as quantitative data collection tools such as surveys and questionnaires, combined with quantitative metric-based, statistical data analysis methodologies. Within their case studies, Estell and Hurtig (2014) and Soltani, Twigg, and Dickens (2012), for instance, employed both qualitative (surveys, interviews, document reviews) and quantitative (course evaluation questionnaires) methods to capture feedback and reflections from students, alumni, academic staff and industry partners. Demetry (1997) and Haag, Guilbeau, and Goble (2006) made use of similar types of surveys to ascertain the fulfilment of the goals of university-industry partnerships from the viewpoint of each of the key stakeholders. To analyse their data, all of the works mentioned above utilised statistical analysis techniques such as conservative Mann–Whitney non-parametric tests (Haag, Guilbeau, and Goble 2006) to determine whether the differences in responses between various stakeholder groups was statistically significant or not.

In order to evaluate the benefits of and assess students' learning from the use of podcasting in final year design projects featuring industry involvement, Ruikar and Demian (2013) made use of quantitative metrics to analyse data collected from qualitative questionnaires and interactive discussions. Similarly, Herz et al. (2011) provided surveys to students to gauge their response to a new bioengineering programme as well as to employers to assess the performance of students in industrial summer internships, which were subsequently analysed by assigning rubric score metrics.

We also found that many of our selected papers, barring two of the studies, failed to use literature-informed measures of quality such as triangulation to improve the credibility and validity of their research findings. The work by Shaul Norback et al. (2014) proved to be particularly notable for corroborating its results by using the classical content analysis methodology (Krippendorff 2012) which consisted of human analysts coding transcriptions from the responses of student panel discussions into content themes using a meta-thematic framework, in conjunction with analysis performed by a computer-based program (QDA MINER).

As part of their case study, Wasburn and Miller (2007) conducted a statistical analysis of pre- and post-seminar surveys provided to students to evaluate their attitudes and beliefs towards women in technology-related disciplines. They too made use of the triangulation method (Patton 1990), which involved combining multiple methodologies including a review of the literature on women in technology and on freshman seminars with comments obtained from end-of-year student feedback forms, to boost the validity of their findings.

3.4. What are the major findings/conclusions from such studies and what evidence-based best practices have been identified?

The large majority of our selected studies (24 out of 28 papers) presented critical, overarching findings from their work, which also formed the basis for recommendations for evidence-based best practices for university-industry partnerships. While some authors listed these explicitly, we found that in most cases, the identification of best practices to be adopted would only be implicitly contained within the findings (discussed further in Section 4). While the remaining four papers (Demetry 1997; Gene Liao, Young, and Moss 2013; Pai and DeBlasio 1997; Shooter and Buffinton 1999) did list their conclusions, these were not deemed relevant for the present research question, as the findings were too specific to the context of the individual case studies. The subsections below present, in more detail, the findings and best practices identified by our chosen works.

3.4.1. Findings related to industry involvement in senior/final-year capstone design project courses (10 studies)

A substantial proportion of the studies contained conclusions dedicated to industry partnerships arising within final-year capstone design projects, which was to be expected, considering the fact that several works identified these to be one of the principal purposes of collaborations between universities and industries, as mentioned in Section 3.1.1. These have been collated and summarised together in Table 6, along with the recommended forms of best practice.

3.4.2. Findings related to industry-focused authentic learning opportunities (6 studies)

Some of the studies also generated findings emerging from authentic learning opportunities featuring industry involvement, in which students were able to work on relevant problems motivated by real-world projects and applications. Duwart et al. (1997) received positive feedback from the cooperative education community and division of the American Society of Engineering Education (ASEE) on their curriculum model combining classroom-based education with practical work experience as part of an electrical and computer engineering programme.

Table 6. Summary of findings for industry involvement in capstone design courses.

Paper	Findings and identified best practices
Estell and Hurtig (2014)	• capstone design projects led to improvement in students' project management skills, confidence and design experience and provided valuable preparation for alumni for their future careers • best practices to improve the capstone project experience include the application of a corporate management standard, use of project management documentation, assessment using specialised rubrics and use of project review boards
Goldberg et al. (2014)	• capstone courses resulted in highly positive benefits for industry, students and faculty involved, though industry sponsorship was identified as the major challenge • recommendations for best practice include choosing specific projects that meet the needs of both industry sponsors as well as students, setting clear expectations, deliverables and roles when seeking industry sponsors, recruiting good-quality industrial guest speakers and creating an industrial advisory board
Trent Jr. and Todd (2014)	• working on a capstone project offers great value in preparing students for what to expect in industry • the evaluation and assessment of a project can be very challenging and difficult for industry sponsors due to the elements of subjectivity involved • placing students into teams and stressing the importance of collaboration can address the perceived weaknesses of new graduates in industry
Alexander et al. (2015)	• sampling of current baseline practices indicated a lack of consistency in the administration of capstone programmes across institutions • recommended forms of best practice include enabling transparency in administrative paperwork to help faculty recruit industry sponsors for projects and devoting increased time and attention to drafting externally sponsored capstone programme agreements
Shaul Norback et al. (2014)	• students were found to have a different perception of capstone design projects as compared to faculty and industry sponsors • student reflection and feedback on capstone design projects not captured by literature is of vital importance and cannot be overlooked
Herz et al. (2011)	• positive reception from students to the incorporation of IPD in a capstone design course led to its being made a mandatory requirement, as opposed to an optional component of the course • inclusion of IPD within the programme led to an overall improvement in the experiential learning component of the bioengineering curriculum, while also successfully meeting the ABET's capstone design requirements
Abu-Mulaweh and Abu-Mulaweh (2019)	• industry sponsors were extremely satisfied with their involvement in the capstone project partnership and keen to continue sponsoring projects • student feedback indicated that they were well prepared for the job market following their exposure to real-world design problems
Na Zhu (2018)	• engagement with industry professionals acts as a stimulant for student by making them pay more attention to courses • frequent weekly meetings with industry professionals led to a temporary negative impact on course assessment tests
Solnosky, Parfitt, and Holland (2014)	• implementation of a multidisciplinary pilot programme within an IPD and BIM senior capstone course is an excellent tool for training young engineers entering the workplace • generation of such a programme in an academic environment is feasible, with its course objectives being both relevant and effective to meet industry needs
Martínez León (2019)	• students taking the enhanced LSS capstone course had an enhanced learning experience accompanied by a growth in their self-confidence, theoretical and practical knowledge and preparedness for work environments • engaging in meaningful, collaborative industry projects prepared students to solve real-world problems and transition to the workplace more easily

Meanwhile, Murray, Hendry, and McQuade (2020) also acquired positive responses from students, industry speakers and workshop facilitators on the establishment of co-curricular learning initiatives featuring evening workshops between practising engineers and civil engineering undergraduate students. Their findings confirmed that, within such settings, relevant learning did indeed take place as students working in teams on real-world problems were able to identify crucial links and gaps within material presented in the curriculum and in the workshops.

Industry-led internship programmes were found to be beneficial to students as they led to attainment of high levels of technical competence, confidence and engagement (Durkin 2016) as well as industry members who were extremely satisfied with the performance of student interns (Haag, Guilbeau, and Goble 2006). While Haag, Guilbeau, and Goble (2006) commented on how student interns were able to imbibe a majority of the skills from the ABET criteria, Durkin (2016) noted how summer internships enabled the partnering university to achieve its objective of increasing STEM graduates, with all students graduating successfully within their chosen undergraduate degrees.

A study by Tennant et al. (2018) while highlighting positive student satisfaction feedback from their experiences on industrial placements, also emphasised students' lack of structured reflective analysis and thinking and signposted opportunities for university faculty to prepare and support students better through the placement experience. From their case study introducing the development of a new, practice-based engineering curriculum known as the learning factory, Lamancusa, Jorgensen, and Zayas-Castro (1997) pinpointed several recommendations for best practice methods to implement these successfully. These included facilitating cross-university development and sharing of course materials, promoting industry sponsored senior design projects, creating industrial advisory boards and encouraging student participation in course development.

3.4.3. Findings related to other forms of industry engagement (8 studies)

The remaining 8 papers contained findings and recommendations pertaining to other, more bespoke modes of industry partnerships that did not identify with any of the common themes presented above. These have been discussed in more detail in Table 7, however, it is

Table 7. Summary of findings for bespoke forms of industry involvement.

Paper	Findings
Ruikar and Demian (2013)	• there is great potential for using audio-visual podcasts in project-based learning as it promotes motivation and learner engagement • podcasting accommodates most learning styles, facilitates self-paced learning, encourages active student participation and augments synergies between industry and academia
Conradie et al. (2016)	• collaboration with industry for prototyping TUIs through involvement with SME companies was enriching for students working on open-ended real-world design problems • integration of TUI into the curriculum was difficult due to the inflexible educational system, the challenges of working in multidisciplinary teams and the wariness of companies in involving users at an early stage of product development
Wasburn and Miller (2007)	• students involved in the first-year freshman seminar for women formulated as a result of a university-industry partnership were more favourable to technology careers than those in other freshman courses • freshman seminars of this kind can make a difference in student attitudes as evidenced by the universal positive feedback received regarding the course
Smith et al. (2018)	• industry-university partnerships through field-based learning imparted students with a more holistic understanding of CSR • increase in students' capacity to understand CSR prepared them better to successfully navigate responsibilities in the industrial workplace
Burns et al. (2018)	• students perceived some industry engagement activities such as internships, tours, guest speakers and projects as being the most effective at enhancing their learning
Wade (2013)	• embedding platform and tools provided by the industry partner for a first year electrical engineering practical course led to improvements in student engagement and a boost in student satisfaction survey results • technology support provided by the industry partner for final year capstone courses resulted in successful industrial projects, with students invited to present their work at global conferences
Soltani, Twigg, and Dickens (2012)	• students found that the industrial sponsorship of their studies resulted in long term benefits such as the development of skills like project management, leadership, data analysis, communication, teamwork and application of learning to real-life situations • employers also agreed that such sponsorship added value and provided them with positive opportunities to influence the curriculum, which in turn would improve the quality of engineering graduates
Tener (1996)	• the general characteristics and elements of a beneficial university-industry partnership within an engineering programme were found to comprise effective joint strategic planning, a committed industrial advisory committee, a student internship programme, faculty with industrial experience and the use of outcome-based indicators of success

worth mentioning that none of these works explicitly identify any recommendations for specific forms of best practice.

3.5. What are the areas of future work that need to be explored further?

Twenty one of the 28 papers suggested areas of future work for forthcoming studies on university-industry partnerships to explore further. While in most cases, we found the recommendations to be broadly generic and easily transferable to other institutions, we also noted that 7 papers (Abu-Mulaweh and Abu-Mulaweh 2019; Demetry 1997; Gene Liao, Young, and Moss 2013; Goldberg et al. 2014; Martínez León 2019; Na Pai and DeBlasio 1997; Zhu 2018) identified areas of future work whose scope was limited simply to extending the context of their own case studies. Since these suggestions were found to lack meaningfully transferable or generalisable suggestions, they were not included within the areas of future work discussed in detail within the subsections below.

3.5.1. Future work pertaining to industry involvement in senior/final-year capstone design project courses (7 studies)

Considering the sizable number of works with findings dedicated to industry engagement in final-year capstone design projects as stated in Section 3.4.1, we expected to have studies identifying avenues for future work within this area. Estell and Hurtig (2014) for example, discuss ways of extending their case study to other universities by adopting best-practice methods such as introducing multi-year projects, incorporating customer-stakeholder relationships and performing more progress reviews within capstone courses.

Trent Jr and Todd (2014) emphasised the need for promoting industry partnerships through capstone design courses in order to improve students' learning experience, while Shooter and Buffinton (1999) noted that future projects could be improved by setting realistically attainable goals, establishing clear objectives and engaging in a cycle of continuous iteration for courses.

The recommendation to improve the transparency of administrative paperwork provided by Alexander et al. (2015) within their case study can be put into practice by drafting externally sponsored capstone programme agreements at other institutions to ensure effective execution of project outcomes.

Avenues for further work also include encouraging faculty and industry sponsors of such courses to embed student and alumni input gathered through focus groups, panels and conferences (Shaul Norback et al. 2014) as well as focusing on how to incorporate larger teams or student groups comprised of multiple disciplines within capstone courses (Solnosky, Parfitt, and Holland 2014). Finally, Herz et al. (2011) also examined the expansion of their ongoing interdisciplinary undergraduate bioengineering programme by fostering additional commercial partnerships and launching a new graduate programme with a similar interdisciplinary focus.

3.5.2. Future work pertaining to industry-focused authentic learning opportunities (6 studies)

Following on from Section 3.4.2, some studies discussed possibilities for exploring future work related to industry-focused authentic learning opportunities such as placements, internships and other cooperative education initiatives. While Duwart et al. (1997) offered suggestions to apply the concepts and practices of the cooperative education model to curricula within other universities and countries, Murray, Hendry, and McQuade (2020) considered expanding their co-curricular learning initiative featuring evening workshops for civil engineering undergraduate students to the daytime curriculum. The latter also noted how students' exposure to industrial engineering can be enhanced through mentoring by graduate engineers and through the introduction of degree apprenticeship programmes.

Haag, Guilbeau, and Goble (2006) highlighted the need to further examine improving the provision of skills such as planning, preparing, report-writing and presenting, which students from their engineering internship programme were found to lack. This was similarly echoed by Durkin (2016) as part of

Table 8. Summary of future work identified for bespoke forms of industry involvement.

Paper	Areas for future work
Ruikar and Demian (2013)	practitioners are recommended to explore podcasting opportunities within project-based learning featuring industry involvement, while pedagogic researchers are encouraged to develop and assess these from a learning context
Conradie et al. (2016)	SME companies should be more involved in project-based courses as this allows students to experience working as professionals under budget and time constraints, while being part of multidisciplinary teams
Wasburn and Miller (2007)	results from the current study on female-focused freshman seminars led by industry can be made more statistically significant by conducting future research using a larger, randomly drawn sample of both male and female students
Smith et al. (2018)	future work can be aimed at comparing the efficacy of the petroleum engineering field sessions with ongoing classroom-based learning in both social science and engineering courses that include content on CSR
Burns et al. (2018)	current study focused on the perception of senior engineering students to various industry engagement activities can be expanded to gauge the differences in the student learning perceptions of sophomore and senior year students
Wade (2013)	the case studies presented highlighted the need for more universities to pursue mutually beneficial partnerships with industrial technology providers through involvement in sponsored summer internships, employability workshops and graduate placement opportunities
Soltani, Twigg, and Dickens (2012)	further longitudinal and cross-section studies of industry sponsorship schemes should be carried out over a longer timescale to include a larger survey sample covering other universities, programmes and industry sectors and to also increase student awareness of such sponsorship schemes through publicity material
Tener (1996)	more universities and industry companies should come together to emphasise the stature and prestige of a construction engineering degree by demonstrating the rigour and professional training it provides to its graduates

the author's summer internship case study, which suggested that experiential learning processes should be embedded in engineering technology education. The benefits of short-term industrial placements also motivated Tennant et al. (2018) to emphasise the need to further develop similar academic-industry partnerships by exploring closer collaboration and increased opportunities.

Finally, as part of their future work, Lamancusa, Jorgensen, and Zayas-Castro (1997) concluded that their case study on the manufacturing engineering education partnership featuring the development of a practice-based engineering curriculum (the learning factory) should be continued and accompanied in the future by the reporting of detailed assessment results of the project's outcomes and deliverables.

3.5.3. Future work pertaining to other forms of industry engagement (8 studies)

The remaining papers, similar to those from Section 3.4.3, presented avenues for future work dedicated to other forms of industry engagement that did not identify with the common themes identified thus far and these have been summarised in more detail in Table 8 below.

4. Discussion & recommendations

4.1. Opportunities for new areas of focus in university-industry collaborations

Over one-third of the studies identified the development and implementation of senior/final-year capstone design projects as the primary purpose of university-industry partnerships. This is unsurprising as a main characteristic of capstone design teaching is to promote employability, including forming connections with potential employers in industry (Pembridge and Paretti 2019).

While capstone lends itself to industry partnership, this finding demonstrates the need for future work in university-industry partnerships centred around the earlier years of the undergraduate engineering curriculum. As more and more first-year engineering programs crop up that emphasise design thinking, a unique opportunity for industry collaboration is available for motivated educators. Beyond capstone and first-year, the middle years of engineering education have been neglected when it comes to design teaching (Lord and Chen 2014). Research exploring industry connections as it pertains to design teaching in the middle years is another opportunity for development.

4.2. The role of theory in partnership studies

Just over a quarter of the studies had no theoretical framework/foundation to serve as the guide behind their work. This was often absent or never explicitly mentioned in sufficient detail for the reader. This could be an indication of a lack of theoretical underpinnings for the study of university-industry partnerships or that this area of study is still in its relative infancy compared to other areas in engineering education. Future works would benefit from a strong theoretical backbone drawing from other fields, or at least references to past literature/existing theories. Additionally, there appears to be an opportunity for grounded approaches that seek to develop theoretical frameworks. However, 'no single theoretical perspective provides an adequate foundation for a general theory of collaboration' (Gray and Wood 1991, 3), so any theoretical advancements would lend themselves to being context-dependent.

4.3. The value of research methods in the study of educational partnerships

Notably, several studies do not apply a concrete methodology to derive conclusions for their work, and in particular, data analysis techniques were often not mentioned. As with the absence of a theoretical underpinning, the lack of methods indicates underdevelopment of research in university-industry partnerships in engineering education. Most studies have employed unnamed/non-specific qualitative methods of data collection and analysis, with just a few works that explore quantitative methods. Future studies should seek to include a specific methods section within their research work documenting the overarching method type (e.g. qualitative, quantitative approach) as well as describing their sources of data collection and data analysis. Shaul Norback et al. (2014) model this well by applying content analysis techniques from Krippendorff (2012).

More concerningly, in most of the studies reviewed, there were no obvious measures of research quality (i.e. promoting validity, reliability, trustworthiness, etc), with the notable exception of Wasburn and Miller (2007) who make use of triangulation (Patton 1990). While there are many resources for promoting quantitative research quality, qualitative research quality in engineering education has been primarily guided by trustworthiness as outlined by Lincoln & Guba (1985) and the newer framework from Walther, Sochacka, and Kellam (2013).

4.4. The need to highlight evidence-based best practices

While not all studies explicitly stated the evidence-based practices to be adopted in university-industry partnerships arising from within their own findings, many could be inferred from closer scrutiny and interpretation of their conclusions. We recommend that future work make a more direct link in their specific findings to key overarching recommendations for practitioners of partnership. Given that many scholars in the field of engineering education are practitioner-researchers, this becomes particularly salient.

4.5. The need to emphasise future work beyond study-specific contexts

Several papers identified areas of future work whose scope was limited simply to extending their own case studies by adopting or incorporating a recommended form of best practice. While this is certainly helpful locally, future studies should also comment on the future directions that their work could take within the larger context of engineering education and how it might broadly inform the scholarly literature on the subject (preferably by providing recommendations both to practitioners and researchers).

5. Concluding remarks

Through this systematic literature review, we documented the recent history leading to the current state of the research around university-industry partnerships in engineering education. In doing so, we identified purposes for collaborations, theories used, research methods, evidence-based practices identified, and areas of future work. This paper can be used as a starting point for researchers looking to contribute to the growing body of knowledge on educational partnerships as well as practitioners looking to implement evidence-based approaches. While there is a significant body of work being developed, there is still a major need to conduct more robust research in this area as evidenced by the limited nature of the theoretical underpinnings, methodologies, and measures of research quality employed. Without this, future work will be limited in the conclusions it can draw.

List of Acronyms Used

Acronym	Full Form
STEM	Science, Technology, Engineering and Mathematics
ERIC	Education Resources Information Centre
JSTOR	Journal Storage
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
IEEE	Institute of Electrical and Electronics Engineers
IPD	Integrated Product Development
PBL	Problem/Project-Based Learning
LSS	Lean Six Sigma
TUI	Tangible User Interface
SME	Small and Medium-Sized Enterprise
BIM	Building Information Modelling
ABET	Accreditation Board for Engineering and Technology
ELT	Experiential Learning Theory
UIDP	University-Industry Demonstration Partnership
AEC	Architecture, Engineering and Construction
MANOVA	Multivariate Analysis of Variance

Disclosure statement

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

Notes on contributors

Dr. Rehan Shah is a Lecturer in Mathematics and Engineering Education at Queen Mary University of London. He has a PhD in Applied Mathematics (Nonlinear Dynamics) from University College London (UCL), an MSc in Applied Mathematics from the University of Oxford (St. Anne's College) and a BEng in Mechanical Engineering with Business Finance from University College London (UCL) with the London School of Economics (LSE).

Dr. Andrew L. Gillen is an Assistant Teaching Professor in the First Year Engineering Program at Northeastern University. He has a PhD in Engineering Education from Virginia Tech and B.S. in Civil Engineering from Northeastern University.

ORCID

R. Shah http://orcid.org/0000-0002-5025-3503
A.L. Gillen http://orcid.org/0000-0001-8021-6108

References

*Asterisks indicate studies indicated as part of the systematic review.

Abdul Jabbar, A. I., and P. Felicia. 2015. "Gameplay Engagement and Learning in Game-Based Learning: A Systematic Review." *Review of Educational Research* 85 (4): 740–779. https://doi.org/10.3102/0034654315577210.

*Abu-Mulaweh, H. I., and N. A. Abu-Mulaweh. 2019. “Case Study: Industry-Sponsored Mechanical Engineering Capstone Senior Design Program.” *International Journal of Mechanical Engineering Education* 47 (4): 371–381. https://doi.org/10.1177/0306419018791975.

Acharya, S., P. Manohar, P. Wu, and W. Schilling. 2017. “Using Academia-Industry Partnerships to Enhance Software Verification & Validation Education via Active Learning Tools.” *Journal of Education and Learning* 6 (2): 69–84. https://doi.org/10.5539/jel.v6n2p69.

*Alexander, D., G. Watkins, S. Beyerlein, and S. Metlen. 2015. “Processes to Formalise Sponsored Educational Activity Agreements Between Industry and Universities Related to Capstone Design Projects.” *International Journal of Engineering Education* 31 (6B): 1881–1891.

Anderson-Cook, C. M., A. Patterson, and R. Hoerl. 2005. “A Structured Problem-Solving Course for Graduate Students: Exposing Students to Six Sigma as Part of Their University Training.” *Quality and Reliability Engineering International* 21 (3): 249–256. https://doi.org/10.1002/qre.666.

Ashwin, P., and D. McVitty. 2015. “The Meanings of Student Engagement: Implications for Policies and Practices.” In The European Higher Education Area, edited by A. Curaj, L. Matei, R. Pricopie, J. Salmi, and P. Scott, 343–359. Cham: Springer. https://doi.org/10.1007/978-3-319-20877-0.

Bell, S. 2010. “Project-Based Learning for the 21st Century: Skills for the Future.” *The Clearing House: A Journal of Educational Strategies, Issues and Ideas* 83 (2): 39–43. https://doi.org/10.1080/00098650903505415.

Blowfield, M., and J. G. Frynas. 2005. “Setting New Agendas: Critical Perspectives on Corporate Social Responsibility in the Developing World.” *International Affairs* 81 (3): 499–513. https://doi.org/10.1111/j.1468-2346.2005.00465.x.

Borrego, M., M. J. Foster, and J. E. Froyd. 2014. “Systematic Literature Reviews in Engineering Education and Other Developing Interdisciplinary Fields.” *Systematic Literature Reviews in Engineering Education. Journal of Engineering Education* 103 (1): 45–76. https://doi.org/10.1002/jee.20038.

Borror, C. M., R. L. Berger, S. LaFond, and M. Stull. 2012. “Undergraduate Statistics Curriculum: A Large, Unstructured, Complex Problem.” *Quality Engineering* 24 (2): 201–214. https://doi.org/10.1080/08982112.2011.652005.

Braun, V., and V. Clarke. 2006. “Using Thematic Analysis in Psychology.” *Qualitative Research in Psychology* 3 (2): 77–101. https://doi.org/10.1191/1478088706qp063oa.

Brown, P. R., R. E. McCord, H. M. Matusovich, and R. L. Kajfez. 2015. “The use of Motivation Theory in Engineering Education Research: A Systematic Review of Literature.” *European Journal of Engineering Education* 40 (2): 186–205. https://doi.org/10.1080/03043797.2014.941339.

*Burns, C., S. Chopra, M. Shelley, and G. Mosher. 2018. “Utilising Multivariate Analysis for Assessing Student Learning Through Effective College-Industry Partnerships.” *Journal of STEM Education: Innovations and Research* 19 (3): 27–32.

Cheville, A., and S. Welch. 2009. “The Impact Of Scaffolding On Student Success In A Pre Capstone Design Course.” *2009 Annual Conference & Exposition Proceedings*, 14.1224.1–14.1224.14. https://doi.org/10.18260/1-2–5449.

Chickering, A. W. 1969. *Education and Identity*. 1st ed. San Francisco, CA: Jossey-Bass.

Clewell, B. C., and P. B. Campbell. 2002. “Taking Stock: Where We’ve Been, Where We Are, Where We’re Going.” *Journal of Women and Minorities in Science and Engineering* 8 (3–4): 30. https://doi.org/10.1615/JWomenMinorScienEng.v8.i3-4.20.

*Conradie, P. D., C. Vandevelde, J. De Ville, and J. Saldien. 2016. “Prototyping Tangible User Interfaces: Case Study of the Collaboration Between Academia and Industry.” *International Journal of Engineering Education* 32 (2A): 726–737.

Cook, D. A., and C. P. West. 2012. “Conducting Systematic Reviews in Medical Education: A Stepwise Approach.” *Medical Education* 46: 943–952. https://doi.org/10.1111/j.1365-2923.2012.04328.x.

Corbin, J., and A. Strauss. 2014. *Basics of Qualitative Research (4th ed.): Techniques and Procedures for Developing Grounded Theory*. 4th ed. Los Angeles, CA: Sage Publications. https://doi.org/10.4135/9781452230153.

Creswell, J. W. 2014. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 4th ed. Thousand Oaks, CA: SAGE Publications.

Dahlgren, M. A. 2003. “PBL Through the Looking-Glass: Comparing Applications in Computer Engineering, Psychology and Physiotherapy.” *International Journal of Engineering Education* 19 (5): 672–681.

Day, R., and J. V. Day. 1977. “A Review of the Current State of Negotiated Order Theory: An Appreciation and a Critique.” *The Sociological Quarterly* 18 (1): 126–142. https://doi.org/10.1111/j.1533-8525.1977.tb02165.x.

*Demetry, C. 1997. “A University-Industry Partnership in US Undergraduate Education. The WPI-Norton Company Project Center.” *Industry and Higher Education* 11 (4): 218–223. https://doi.org/10.1177/095042229701100405.

Dewey, J. 1963. *Experience and Education*. New York, NY: Collier Books. https://www.schoolofeducators.com/wp-content/uploads/2011/12/EXPERIENCE-EDUCATION-JOHN-DEWEY.pdf.

*Durkin, R. J. 2016. “Experiential Learning in Engineering Technology: A Case Study on Problem Solving in Project-Based Learning at the Undergraduate Level.” *Journal of Engineering Technology* 33 (1): 22–29.

*Duwart, E. J., R. L. Canale, Ellen J. Duwart, and Richard L. Canale. 1997. “Re-engineering Cooperative Education Learning.” *Industry & Higher Education* 11 (4): 229–235. https://doi.org/10.1177/095042229701100407.

Eberhardt, A. W., O. L. Johnson, W. B. Kirkland, J. H. Dobbs, and L. G. Moradi. 2016. “Team-Based Development of Medical Devices: An Engineering-Business Collaborative.” *Journal of Biomechanical Engineering* 138 (7): 0708031–5. https://doi.org/10.1115/1.4032805.

Educating Engineers for the 21st Century. 2006. Royal Academy of Engineering.

Educating Engineers for the 21st Century. 2007. Royal Academy of Engineering.

Ekwo, U. S. 2013. "Sustainability Through Collaboration-Based Corporate Social Responsibility." *AEI 2013*, 633–642. https://doi.org/10.1061/9780784412909.062.

Engineering Criteria 2000. 1995. Accreditation Board for Engineering Education (ABET). https://user.eng.umd.edu/~zhang/414_97/abet.html.

Engineering Education for a Changing World. 1994. American Society of Engineering Education. https://files.eric.ed.gov/fulltext/ED382447.pdf.

*Estell, J. K., and J. K. Hurtig. 2014. "Adopting Best Corporate Practices for Capstone Courses: A Case Study at Ohio Northern University." *International Journal of Engineering Education* 30 (1): 20–30.

Evidence for Policy and Practice Information and Co-Ordinating Centre (EPPI-Centre). 2010. *EPPI-Centre Methods for Conducting Systematic Reviews*. London: University of London.

Farr, J. V., M. A. Lee, R. A. Metro, and J. P. Sutton. 2001. "Using a Systematic Engineering Design Process to Conduct Undergraduate Engineering Management Capstone Projects." *Journal of Engineering Education* 90 (2): 193–197. https://doi.org/10.1002/j.2168-9830.2001.tb00590.x.

Felder, R. M., and L. K. Silverman. 1988. "Learning and Teaching Styles in Engineering Education." *Engineering Education* 78 (7): 674–681.

Fielding, E. A., J. R. McCardle, B. Eynard, N. Hartman, and A. Fraser. 2014. "Product Lifecycle Management in Design and Engineering Education: International Perspectives." *Concurrent Engineering* 22 (2): 123–134. https://doi.org/10.1177/1063293X13520316.

Finstad, K. 2010. "Response Interpolation and Scale Sensitivity: Evidence Against 5-Point Scales." *Journal of Usability Studies* 5 (3): 104–110.

Fong, P. S. 2010. "Building Teams That Learn: Study of Learning Effects in Engineering Student Teams." *Journal of Professional Issues in Engineering Education and Practice* 136 (3): 121–127. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000017.

Frank, M., I. Lavy, and D. Elata. 2003. "Implementing the Project-Based Learning Approach in an Academic Engineering Course." *International Journal of Technology and Design Education* 13 (3): 273–288. https://doi.org/10.1023/A:1026192113732.

Fry, H., S. Ketteridge, and S. Marshall, eds. 2009. *A Handbook for Teaching and Learning in Higher Education: Enhancing Academic Practice*. 3rd ed. Oxford: Routledge.

Gardner, H. 1983. *Frames of Mind: The Theory of Multiple Intelligence*. New York, NY: Basic Books.

*Gene Liao, Y., Kwo Young, and G. F. Moss. 2013. "A University-Industry Partnership for Developing a Learning Environment for Advanced Energy Storage." *International Journal of Engineering Education* 29 (6): 1348–1361.

Gibbs, G., S. Habeshaw, and T. Habeshaw. 1998. *53 Interesting Things to Do in Your Lectures*. Wiltshire: Cromwell Press Ltd.

Gillen, A. L., J. R. Grohs, H. M. Matusovich, and G. R. Kirk. 2021. "A Multiple Case Study of an Interorganizational Collaboration: Exploring the First Year of an Industry Partnership Focused on Middle School Engineering Education." *Journal of Engineering Education* 110 (3): 545–571. https://doi.org/10.1002/jee.20403.

*Goldberg, J., V. Cariapa, G. Corliss, and K. Kaiser. 2014. "Benefits of Industry Involvement in Multidisciplinary Capstone Design Courses." *International Journal of Engineering Education* 30 (1): 6–13.

Gough, D. 2004. "Systematic Research Synthesis." In *Evidence-based Practice in Education*, edited by G. Thomas, and R. Pring, 44–62. Berkshire, UK: Open University Press.

Graham, R. 2012. *Achieving Excellence in Engineering Education: The Ingredients of Successful Change*. London: The Royal Academy of Engineering. https://raeng.org.uk/media/3cqlehy2/struggling_economy.pdf.

Gray, B. 1989. *Collaborating: Finding Common Ground for Multiparty Problems*. 1st ed. San Francisco, CA: Jossey-Bass. https://www.amazon.co.uk/Collaborating-Multiparty-Problems-Behavioural-Sciences/dp/1555421598.

Gray, B., and J. M. Purdy. 2018. *Collaborating for our Future: Multistakeholder Partnerships for Solving Complex Problems*. 1st ed. Oxford: Oxford University Press.

Gray, B., and D. Wood. 1991. "Collaborative Alliances: Moving from Practice to Theory." *Journal of Applied Behavioral Science* 27 (1): 3–22. https://doi.org/10.1177/0021886391271001.

*Haag, S., E. Guilbeau, and W. Goble. 2006. "Assessing Engineering Internship Efficacy: Industry's Perception of Student Performance." *International Journal of Engineering Education* 22 (2): 257–263.

Hamelink, J. H. 1994. "Industrial Oriented Senior Design Projects. A Key for Industrial Experience." *Proceedings of Advances in Capstone education conference*, 87–89. Provo, UT: Brigham Young University.

Hanna, A. S., and K. T. Sullivan. 2005. "Bridging the Gap Between Academics and Practice: A Capstone Design Experience." *Journal of Professional Issues in Engineering Education and Practice* 131 (1): 59–62. https://doi.org/10.1061/(ASCE)1052-3928(2005)131:1(59).

Helbling, J., D. Lanning, R. Madler, D. Marriott, and K. Siebold. 2007. "Impact Of New Facilities On Engineering Student Outcomes." *2007 Annual Conference & Exposition Proceedings*, 12.826.1–12.826.13. https://doi.org/10.18260/1-2–2945.

*Herz, L., M. J. Russo, H. D. Ou-Yang, M. El-Aasser, A. Jagota, S. Tatic-Lucic, and J. Ochs. 2011. "Development of an Interdisciplinary Undergraduate Bioengineering Program at Lehigh University." *Advances in Engineering Education* 2 (4): 1–31.

Hess, A., D. Rombach, R. Carbon, D. F. Murphy, M. Hoeh, and C. Bartolein. 2013. “The Role of Collaborative Capstone Projects-Experiences from Education, Research and Industry.” *International Journal of Engineering Education* 29 (5): 1088–1099.

Holloman, T. K., J. London, W. C. Lee, C. M. Pee, C. Hawkins Ash, and B. Watford. 2021. “Underrepresented and Overlooked: Insights from a Systematic Literature Review About Black Graduate Students in Engineering and Computer Science.” *International Journal of Engineering Education* 37: 497–511. https://www.ijee.ie/1atestissues/Vol37-2/18_ijee4045.pdf.

Horgan, J. 2009. “Lecturing for Learning.” In *A Handbook for Teaching and Learning in Higher Education: Enhancing Academic Practice*, edited by H. Fry, S. Ketteridge, and S. Marshall. 3rd ed. Oxford: Routledge.

Jestrab, E. M., C. T. Jahren, and R. C. Walters. 2009. “Integrating Industry Experts Into Engineering Education: Case Study.” *Journal of Professional Issues in Engineering Education and Practice* 135 (1): 4–10. https://doi.org/10.1061/(ASCE)1052-3928(2009)135:1(4).

Johri, A., and B. M. Olds. 2011. “Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences.” *Journal of Engineering Education* 100 (1): 151–185. https://doi.org/10.1002/j.2168-9830.2011.tb00007.x.

Jørgensen, U. 2007. “Historical Accounts Of Engineering Education.” In *Rethinking Engineering Education*, edited by E. F. Crawley, J. Malmqvist, S. Östlund, and D. R. Brodeur, 216–240. Boston, MA: Springer. https://doi.org/10.1007/978-0-387-38290-6_10.

Karimi, A. 2003. “Industrially Supported Projects In A Capstone Design Sequence.” *2003 Annual Conference Proceedings*, 8.698.1–8.698.10. https://doi.org/10.18260/1-2–12154.

Kayes, A. B., D. C. Kayes, and D. A. Kolb. 2005. “Experiential Learning in Teams.” *Simulation & Gaming* 36 (3): 330–354. https://doi.org/10.1177/1046878105279012.

Kernaghan, K. 1993. “Partnership and Public Administration: Conceptual and Practical Considerations.” *Canadian Public Administration* 36 (1): 57–76. https://doi.org/10.1111/j.1754-7121.1993.tb02166.x.

Kirkpatrick, D. 1994. *Evaluating Training Programmes—The Four Levels*. San Diego, CA: Berret-Koehler.

Knowles, M. 1980. *The Modern Practice of Adult Education*. New York, NY: Cambridge Books. https://www.umsl.edu/~henschkej/articles/a_The_%20Modern_Practice_of_Adult_Education.pdf.

Koen, B. V. 1994. “Toward a Strategy for Teaching Engineering Design.” *Engineering Education* 83: 193–201. https://doi.org/10.1002/j.2168-9830.1994.tb01104.x.

Kolb, D. A. 1984. *Experiential Learning: Experience as The Source of Learning and Development*. New Jersey, NJ: Prentice-Hall.

Kouprie, M., and F. S. Visser. 2009. “A Framework for Empathy in Design: Stepping Into and out of the User’s Life.” *Journal of Engineering Design* 20 (5): 437–448. https://doi.org/10.1080/09544820902875033.

Krippendorff, K. 2012. *Content Analysis: An Introduction to Its Methodology*. 3rd ed. Thousand Oaks, CA: Sage Publications. https://methods.sagepub.com/book/content-analysis-4e.

*Lamancusa, J. S., J. E. Jorgensen, and J. L. Zayas-Castro. 1997. “Learning Factory—A new Approach to Integrating Design and Manufacturing Into the Engineering Curriculum.” *Journal of Engineering Education* 86 (2): 103–112. https://doi.org/10.1002/j.2168-9830.1997.tb00272.x.

Lambert, R. 2003. *Lambert Review of Business-University Collaboration: Final Report*. London: HM Treasury.

Layton, E. T. 1986. *The Revolt of the Engineers: Social Responsibility and the American Engineering Profession*. Baltimore: John Hopkins University Press.

Liberati, A., D. G. Altman, J. Tetzlaff, C. Mulrow, P. C. Gotzsche, J. P. Ioannidis, and D. Moher. 2009. “The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Healthcare Interventions: Explanation and Elaboration.” *BMJ (Clinical Research Education)* 339: 2700. https://doi.org/10.1136/bmj.b2700.

Lincoln, Y. S., and E. G. Guba. 1985. *Naturalistic Inquiry*. Newbury Park, CA: Sage Publications.

Lord, S. M., and J. C. Chen. 2014. “Curriculum Design in the Middle Years.” In *Cambridge Handbook of Engineering Education Research*, edited by A. Johri, and B. M. Olds, 181–200. 1st ed. New York, NY: Cambridge University Press. https://doi.org/10.1017/CBO9781139013451.014.

Loureiro, S. M. C., I. M. Dias Sardinha, and L. Reijnders. 2012. “The Effect of Corporate Social Responsibility on Consumer Satisfaction and Perceived Value: The Case of the Automobile Industry Sector in Portugal.” *Journal of Cleaner Production* 37: 172–178. https://doi.org/10.1016/j.jclepro.2012.07.003.

Lowden, K., S. Hall, D. Elliot, and J. Lewin. 2011. *Employers’ Perceptions of the Employability Skills of new Graduates: Research Commissioned by the Edge Foundation*. London: Edge Foundation.

Magleby, S. P., R. H. Todd, D. L. Pugh, and C. D. Sorensen. 2001. “Selecting Appropriate Industrial Projects for Capstone Design Programs.” *International Journal of Engineering Education* 17: 400–405.

Management Education and Academic Relations. 1982. The Business Roundtable. https://mail.curt.org/pdf/139.pdf.

*Martínez León, H. C. 2019. “Bridging Theory and Practice with Lean Six Sigma Capstone Design Projects.” *Quality Assurance in Education: An International Perspective* 27 (1): 41–55. https://doi.org/10.1108/QAE-07-2018-0079.

Matthews, J. B., and R. Norgard. 1984. *Managing the Partnership Between Higher Education and Industry*. Boulder, CO: National Center for Higher Education Management Systems.

Mestre, J. 2001. "Cognitive Aspects of Learning and Teaching Science." In *Teacher Enhancement for Elementary and Secondary Science and Mathematics: Status, Issues, and Problems*, edited by S. J. Fitzsimmons, and L. C. Kerpelman, 1–20. Washington, DC: National Science Foundation. https://files.eric.ed.gov/fulltext/ED462268.pdf.

Metrejean, C., J. Pittman, and M. T. Zarzeski. 2002. "Guest Speakers: Reflections on the Role of Accountants in the Classroom." *Accounting Education* 11 (4): 347–364. https://doi.org/10.1080/0963928021000031466.

Mirzamoghadam, A. V., and J. C. Harding. 2013. "The Teaching Value of Defining Iterative Design Projects in Serving Capstone Engineering Undergraduate Education." *Journal of Engineering for Gas Turbines and Power* 135 (9): 091204. https://doi.org/10.1115/1.4024949.

Mitra, A. 2004. "Six Sigma Education: A Critical Role for Academia." *The TQM Magazine* 16 (4): 293–302. https://doi.org/10.1108/09544780410541963.

Moczarny, I. M., M. R. de Villiers, and J. A. van Biljon. 2012. "How Can Usability Contribute to User Experience?" *Proceedings of the South African Institute for Computer Scientists and Information Technologists Conference*, 216–225. https://doi.org/10.1145/2389836.2389862.

Morelock, J. R. 2017. "A Systematic Literature Review of Engineering Identity: Definitions, Factors, and Interventions Affecting Development, and Means of Measurement." *European Journal of Engineering Education* 42 (6): 1240–1262. https://doi.org/10.1080/03043797.2017.1287664.

*Murray, M., G. Hendry, and R. McQuade. 2020. "Civil Engineering 4 Real (CE4R): Co-Curricular Learning for Undergraduates." *European Journal of Engineering Education* 45 (1): 128–150. https://doi.org/10.1080/03043797.2019.1585762.

Murray, M., and S. Tennant. 2014. "New Civil Engineer: Introducing Undergraduate Civil Engineers to Construction Technology." *Engineering Education* 9 (1): 33–47. https://doi.org/10.11120/ened.2014.00024.

National Science Board. 2021. *The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers (Science and Engineering Indicators 2022)*. Alexandria, VA: National Science Foundation. https://ncses.nsf.gov/pubs/nsb20212.

Noble, D. F. 1979. *America by Design: Science, Technology, and the Rise of Corporate Capitalism*. Oxford: Oxford University Press.

*Pai, D. M., and R. A. DeBlasio. 1997. "Enhanced Learning from an Industry-University Partnership. Aluminum Engineering Course Design and Development." *Industry and Higher Education* 11 (4): 224–228.

Patton, M. Q. 1990. *Qualitative Evaluation and Research Methods*. 2nd ed. Newbury, CA: Sage Publications. https://psycnet.apa.org/record/1990-97369-000.

Pegg, A., J. Waldock, S. Hendy-Isaac, and R. Lawton. 2012. *Pedagogy for Employability*. York: The Higher Education Academy. https://s3.eu-west-2.amazonaws.com/assets.creode.advancehe-document-manager/documents/hea/private/pedagogy_for_employability_update_2012_1568036839.pdf.

Pembridge, J., and M. Paretti. 2010. "The Current State Of Capstone Design Pedagogy." *2010 Annual Conference & Exposition Proceedings*, 15.1217.1–15.1217.13. https://doi.org/10.18260/1-2–16141.

Pembridge, J., and M. Paretti. 2019. "Characterizing Capstone Design Teaching: A Functional Taxonomy." *Journal of Engineering Education* 108 (2): 197–219. https://doi.org/10.1002/jee.20259.

Prince, M. J., and R. M. Felder. 2006. "Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases." *Journal of Engineering Education* 95 (2): 123–138. https://doi.org/10.1002/j.2168-9830.2006.tb00884.x.

Ramsden, P. 2003. *Learning to Teach in Higher Education*. 2nd ed. London: Routledge.

Rodrigues, C. A. 2004. "The Importance Level of ten Teaching/Learning Techniques as Rated by University Business Students and Instructors." *Journal of Management Development* 23 (2): 169–182. https://doi.org/10.1108/02621710410517256.

*Ruikar, K., and P. Demian. 2013. "Podcasting to Engage Industry in Project-Based Learning." *International Journal of Engineering Education* 29 (6): 1410–1419.

Satyanarayanan, M. 2001. "Pervasive Computing: Vision and Challenges." *IEEE Personal Communications* 8 (4): 10–17. https://doi.org/10.1109/98.943998.

Shaul Norback, J., E. Leeds, and K. Kulkarni. 2010. "Integrating an Executive Panel on Communication Info an Engineering Curriculum." *IEEE Transactions on Professional Communication* 53 (4): 412–422. https://doi.org/10.1109/TPC.2010.2077413.

*Shaul Norback, J., P. F. Rhoad, S. Howe, and L. A. Riley. 2014. "Student Reflections on Capstone Design: Experiences with Industry-Sponsored Projects." *International Journal of Engineering Education* 30 (1): 39–47.

*Shooter, S. B., and K. W. Buffinton. 1999. "Design and Development of the Pik Rite Chilli Pepper Harvester: A Collaborative Project with the University, Industry, and Government." *29th Annual Frontiers in Education Conference: 'designing the Future of Science and Engineering Education', November 10, 1999 - November 13, 1999* 2: 12b4-19–12b4-24. https://doi.org/10.1109/FIE.1999.841587.

*Smith, N. M., J. M. Smith, L. A. Battalora, and B. A. Teschner. 2018. "Industry-university Partnerships: Engineering Education and Corporate Social Responsibility." *Journal of Professional Issues in Engineering Education and Practice* 144 (3): 04018002 (15 pp.). https://doi.org/10.1061/(ASCE)EI.1943-5541.0000367.

*Solnosky, R., M. K. Parfitt, and R. J. Holland. 2014. "IPD and BIM-Focused Capstone Course Based on AEC Industry Needs and Involvement." *Journal of Professional Issues in Engineering Education and Practice* 140 (4): A4013001 (11 pp.). https://doi.org/10.1061/(ASCE)EI.1943-5541.0000157.

*Soltani, F., D. Twigg, and J. Dickens. 2012. "Industry Input Into the Education of Undergraduate Engineering Students Through Sponsorship." *Design-Centric Engineering Education* 28 (4): 982–988.

Stettina, C. J., Zhao Zhou, T. Back, and B. Katzy. 2013. "Academic Education of Software Engineering Practices: Towards Planning and Improving Capstone Courses Based upon Intensive Coaching and Team Routines." *2013 26th International Conference on Software Engineering Education and Training (CSEE&T)*, 169–178. https://doi.org/10.1109/CSEET.2013.6595248.

Strauss, A. L. 1978. *Negotiations: Varieties, Contexts, Processes, and Social Order*. San Francisco, CA: Jossey-Bass.

Tashakkori, A., and J. W. Creswell. 2007. "Editorial: The New Era of Mixed Methods." *Journal of Mixed Methods Research* 1 (1): 3–7. https://doi.org/10.1177/2345678906293042.

*Tener, R. K. 1996. "Industry-university Partnerships for Construction Engineering Education." *Journal of Professional Issues in Engineering Education and Practice* 122 (4): 156–162. https://doi.org/10.1061/(ASCE)1052-3928(1996)122:4(156).

*Tennant, S., M. Murray, B. Gilmour, and L. Brown. 2018. "Industrial Work Placement in Higher Education: A Study of Civil Engineering Student Engagement." *Industry and Higher Education* 32 (2): 108–118. https://doi.org/10.1177/0950422218756384.

The future of higher education. 2003. The Department for Education and Skills. http://www.educationengland.org.uk/documents/pdfs/2003-white-paper-higher-ed.pdf.

Thomson, A. M., and J. L. Perry. 2006. "Collaboration Processes: Inside the Black Box." *Public Administration Review* 66 (s1): 20–32. https://doi.org/10.1111/j.1540-6210.2006.00663.x.

Thomson, A. M., J. L. Perry, and T. K. Miller. 2007. "Conceptualizing and Measuring Collaboration." *Journal of Public Administration Research and Theory* 19 (1): 23–56. https://doi.org/10.1093/jopart/mum036.

Tinto, V. 1975. "Dropout from Higher Education: A Theoretical Synthesis of Recent Research." *Review of Educational Research* 45 (1): 89–125.

Todd, R. H., and S. P. Magleby. 2004. "Creating A Process To Design A Capstone Program That Considers Stakeholder Values." *2004 Annual Conference Proceedings*, 9.350.1–9.350.17. https://doi.org/10.18260/1-2–13554.

Todd, R. H., C. D. Sorenson, and S. P. Magleby. 1993. "Designing a Senior Capstone Course to Satisfy Industrial Customers." *Journal of Engineering Education* 82: 92–100. https://doi.org/10.1002/j.2168-9830.1993.tb00082.x.

Tranfield, D., D. Denyer, and P. Smart. 2003. "Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review." *British Journal of Management* 14 (3): 207–222. https://doi.org/10.1111/1467-8551.00375.

*Trent Jr., J. L., and R. H. Todd. 2014. "Bridging Capstone Design with Industry Needs Through Communication, Training and Involvement." *International Journal of Engineering Education* 30 (1): 14–19.

UIDP. 2012a. *Contract Accords for University Industry Sponsored Agreements*. Atlanta, GA: Georgia Tech Research Corporation.

UIDP. 2012b. *Researcher Guidebook: A Guide for Successful Institutional-Industrial Collaborations*. Atlanta, GA: Georgia Tech Research Corporation.

*Wade, H. 2013. "National Instruments and the University of Manchester, School of Electrical and Electronic Engineering: A Strategic Partnership for Engineering Education." *International Journal of Electrical Engineering and Education* 50 (3): 304–315. https://doi.org/10.7227/IJEEE.50.3.10.

Walther, J., N. W. Sochacka, and N. N. Kellam. 2013. "Quality in Interpretive Engineering Education Research: Reflections on an Example Study." *Journal of Engineering Education* 102 (4): 626–659. https://doi.org/10.1002/jee.20029.

Walz, K. A., M. Slowinski, and K. Alfano. 2016. "International Approaches To Renewable Energy Education – A Faculty Professional Development Case Study With Recommended Practices For STEM Educators." *American Journal of Engineering Education (AJEE)* 7 (2): 97–116. https://doi.org/10.19030/ajee.v7i2.9841.

Wang, Y., Y. Yu, M. Chen, X. Zhang, H. Wiedmann, and X. Feng. 2015. "Simulating Industry: A Holistic Approach for Bridging the gap Between Engineering Education and Industry. Part I: A Conceptual Framework and Methodology." *International Journal of Engineering Education* 31: 165–173.

Wankat, P. C., and F. Oreovicz. 1994. "A Different Way of Teaching." *ASEE Prism* 3 (5): 14–19.

*Wasburn, M. H., and S. G. Miller. 2007. "Keeping Women Students in Technology: Preliminary Evaluation of an Intervention." *Journal of College Student Retention: Research, Theory & Practice* 9 (2): 205–219. https://doi.org/10.2190/CS.9.2.e.

Watson, J., and J. Lyons. 2011. "Aligning Academic Preparation of Engineering Ph.D. Programs with the Needs of Industry." *International Journal of Engineering Education* 27 (6): 1394–1411.

Watts, A. G. 2006. *Career Development: Learning and Employability*. York: The Higher Education Academy. https://www.qualityresearchinternational.com/esecttools/esectpubs/watts%20career.pdf.

Wilbarger, J., and S. Howe. 2006. "Current Practices in Engineering Capstone Education: Further Results from a 2005 Nationwide Survey." *Proceedings. Frontiers in Education. 36th Annual Conference*, 5–10. https://doi.org/10.1109/FIE.2006.322616.

Wisnioski, M. 2012. *Engineers for Change: Competing Visions of Technology in 1960s America*. Cambridge, MA: MIT Press.

*Zhu, Na. 2018. "Effectiveness of Involving the Industrial and Business Professions Into Mechanical Engineering Capstone Course." *International Journal of Mechanical Engineering Education* 46 (1): 31–40. https://doi.org/10.1177/0306419017718920.

Appendix

Table A1. Summary of coded characteristics for each research question for the selected research studies.

Paper	RQ1: Purpose	RQ2: Theories	RQ3: Methods	RQ4: Findings	RQ5: Future work
Abu-Mulaweh and Abu-Mulaweh (2019)	Capstone design courses	Past literature studies	Qualitative	Industry involvement in capstone design courses	Limited scope for future work
Alexander et al. (2015)	Capstone design courses	Past literature studies	Qualitative	Industry involvement in capstone design courses	Industry involvement in capstone design courses
Burns et al. (2018)	Not specified	Past literature studies	Quantitative	Other forms of industry involvement	Other forms of industry involvement
Conradie et al. (2016)	Employability skills	Existing theoretical frameworks	Not mentioned	Other forms of industry involvement	Other forms of industry involvement
Demetry (1997)	Capstone design courses	None	Mixed	Limited to individual study	Limited scope for future work
Durkin (2016)	Internships and work placements	Existing theoretical frameworks	Qualitative	Industry-focused authentic learning opportunities	Industry-focused authentic learning opportunities
Duwart et al. (1997)	Employability skills	Existing theoretical frameworks	Not mentioned	Industry-focused authentic learning opportunities	Industry-focused authentic learning opportunities
Estell and Hurtig (2014)	Employability skills	None	Mixed	Industry involvement in capstone design courses	Industry involvement in capstone design courses
Gene Liao, Young, and Moss (2013)	Employability skills	None	Qualitative	Limited to individual study	Limited scope for future work
Goldberg et al. (2014)	Capstone design courses	Past literature studies	Not mentioned	Industry involvement in capstone design courses	Limited scope for future work
Haag, Guilbeau, and Goble (2006)	Internships and work placements	None	Mixed	Industry-focused authentic learning opportunities	Industry-focused authentic learning opportunities
Herz et al. (2011)	Capstone design courses	None	Mixed	Industry involvement in capstone design courses	Industry involvement in capstone design courses
Lamancusa, Jorgensen, and Zayas-Castro (1997)	Employability skills	Existing theoretical frameworks	Not mentioned	Industry-focused authentic learning opportunities	Industry-focused authentic learning opportunities
Martínez León (2019)	Capstone design courses	Existing theoretical frameworks	Qualitative	Industry involvement in capstone design courses	Limited scope for future work
Murray, Hendry, and McQuade (2020)	Internships and work placements	Existing theoretical frameworks	Qualitative	Industry-focused authentic learning opportunities	Industry-focused authentic learning opportunities
Na Zhu (2018)	Capstone design courses	Bespoke theoretical guidance	Quantitative	Industry involvement in capstone design courses	Limited scope for future work
Pai and DeBlasio (1997)	Capstone design courses	Existing theoretical frameworks	Qualitative	Limited to individual study	Limited scope for future work
Ruikar and Demian (2013)	Capstone design courses	Existing theoretical frameworks	Mixed	Other forms of industry involvement	Other forms of industry involvement
Shaul Norback et al. (2014)	Capstone design courses	Past literature studies	Mixed	Industry involvement in capstone design courses	Industry involvement in capstone design courses
Shooter and Buffinton (1999)	Not specified	None	Not mentioned	Limited to individual study	Industry involvement in capstone design courses
Smith et al. (2018)			Qualitative		

(*Continued*)

Table A1. Continued.

Paper	RQ1: Purpose	RQ2: Theories	RQ3: Methods	RQ4: Findings	RQ5: Future work
	Enhancing student attitudes towards CSR	Bespoke theoretical guidance		Other forms of industry involvement	Other forms of industry involvement
Solnosky, Parfitt, and Holland (2014)	Employability skills	Bespoke theoretical guidance	Qualitative	Industry involvement in capstone design courses	Industry involvement in capstone design courses
Soltani, Twigg, and Dickens (2012)	Sponsorship funding for students	Past literature studies	Mixed	Other forms of industry involvement	Other forms of industry involvement
Tener (1996)	Not specified	Past literature studies	Not mentioned	Other forms of industry involvement	Other forms of industry involvement
Tennant et al. (2018)	Internships and work placements	Existing theoretical frameworks	Qualitative	Industry-focused authentic learning opportunities	Industry-focused authentic learning opportunities
Trent Jr. and Todd (2014)	Capstone design courses	None	Qualitative	Industry involvement in capstone design courses	Industry involvement in capstone design courses
Wade (2013)	Technical resources support	None	Not mentioned	Other forms of industry involvement	Other forms of industry involvement
Wasburn and Miller (2007)	Female students retention in STEM	Existing theoretical frameworks	Mixed	Other forms of industry involvement	Other forms of industry involvement