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The six C's of successful higher education-industry collaboration in engineering education: a systematic literature review

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ABSTRACT
This systematic literature review provides an overview of how higher education in engineering, in collaboration with industry, supports student transitions to work life. A qualitative content analysis of 36 articles published between 2013 and 2023 indicated that this collaboration provides numerous benefits for all stakeholders; however, challenges can impede or even halt those efforts. The reviewed articles address curricula, motivation, and professional aspects and demonstrate evidence of international research collaborations. Common collaboration patterns include problem-solving, product development, and assisting students in transitioning from academia to the professional sphere. While the benefits of collaboration are evident for all parties involved, challenges and hindering factors like time and resource constraints do exist. In the discussion, we introduce the six C's: key factors for successful collaboration between higher education and industry; namely, clarity, communication, commonality, commitment, continuity, and confidence. A framework outlining potential success factors for higher education–industry collaboration is proposed.

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Higher education; industry; collaboration; engineering; conceptual framework; systematic literature review

1. Introduction

The transition from higher education (HE) to work life is a critical phase in which educational background, work environment, learning abilities, skills, and social networks all play significant roles in graduates' success and integration into a sustainable career (Blokker et al. 2023; De Schepper, Clycq, and Kyndt 2023; Grosemans, Coertjens, and Kyndt 2017). Graduates lacking the competencies and knowledge relevant to the workplace face a disadvantage compared to their peers when searching for employment (e.g. Ang 2015). There have thus far been mixed findings concerning whether and how well education prepares students for and supports them in school-to-work transitions: some reports suggest low levels of preparedness (e.g. Bax et al. 2023; Gawrycka, Kujawska, and Tomczak 2020; Prikshat et al. 2020; Winterton and Turner 2019), while others claim that students are generally well equipped for their work (e.g. Ali et al. 2017; Deters, Paretti, and Ott 2020; García-Aracil, Monteiro, and Almeida 2018). There is a need for a research synthesis of how HE supports this crucial life event.

The focus of this review is to synthesise the research on how engineering HE, in collaboration with industry, supports student transitions to work life. Recent studies have emphasised the significance

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of collaborative efforts between HE and industry (Arcelay et al. 2021; Arthur-Mensah 2020; Husin et al. 2022; Romero-Gázquez, Cañavate-Cruzado, and Bueno-Delgado 2022), which can promote knowledge exchange, leading to advancements in innovative products, research and development (R&D) projects, and services (Ankrah and Al-Tabbaa 2015; Bastos, Sengik, and Tello-Gamarra 2021; Zhang and Chen 2023). Other benefits include students' practical work experiences, improved learning outcomes, study motivation, and preparedness for the transition to work life (Bennett, Knight, and Li 2023; García-Aracil, Monteiro, and Almeida 2018; Sabry, Gardner, and Hadgraft 2021; Thune and Støren 2015). Moreover, work life experience during studies may reduce dropout rates for students who struggle to see the relevance of their studies by helping them apply theoretical knowledge in practical settings, increasing their comprehension and interest (Hovdhaugen 2015).

HE–industry collaborations have increased globally (Cohen and Eyal 2021; Husin et al. 2022). For example, Taiwan's Ministry of Education has been promoting strategies like introducing industrial resources via collaborative teaching and dual teaching systems (Do et al. 2023), while Canada has leveraged cross-sectoral collaborations to provide work-integrated learning opportunities (Cukier 2019). In Europe, innovative training actions like IN4WOOD have proven to be practical tools for students, employees, and managers to learn about emerging technologies (Romero-Gázquez, Cañavate-Cruzado, and Bueno-Delgado 2022). The PoDoCo (n.d.) and Demola (n.d.) programs aim to enhance Finnish companies' competitiveness and provide students with industry-relevant skills, emphasising the meaningful creation of HE–industry networks (Kunttu, Neuvo, and Tikkanen 2022). Studies in Turkey, China, and the United States have showcased the global recognition of HE–industry collaborations as bridging skill gaps and enhancing students' competencies for employment (Akdur 2021; Babic et al. 2022; Qiu, Xu, and Omojokun 2020; Zheng and Shi 2022).

The transition from HE to ever-evolving work life can pose challenges for graduates, as it is often marked by competition, mismatches, and instability (Alpaydin and Kültür 2022; De Schepper, Clycq, and Kyndt 2023; Figueiredo et al. 2017; Grosemans, Coertjens, and Kyndt 2017; Tomlinson 2023). Enhancing the transition phase and improving the employability of engineering graduates through stronger HE–industry collaboration can include internships, on-the-job training, capstone projects, and work-integrated learning opportunities (Brooks and Youngson 2016; Ford et al. 2019; Jackson and Bridgstock 2021; Winberg et al. 2020). The transition from HE to work life represents just the beginning of a graduate's career path (Karaca-Atik et al. 2023). Moreover, transition processes vary among graduates; for example, in fields with high employee demand, there is a growing expectation for students to start working before finishing their degrees (Béduwé and Giret 2021; Hovdhaugen 2015).

The interdisciplinary foundation of engineering places various demands on engineering curricula, pedagogical arrangements, and students themselves. Fostering students' abilities to learn across disciplines and boundaries, collaborate effectively, and engage in co-creation have all been identified as essential elements in enhancing employability and work readiness (Fortuin et al. 2023; Oonk et al. 2022; Striolo, Jones, and Styan 2023). Hains-Wesson and Ji (2020) found that interdisciplinary study tours not only broadened students' capacity to navigate complexity but also facilitated knowledge sharing across different fields of study, fostering the development of creativity. Communication skills, the ability to innovate, and possession of social and cultural awareness to collaborate with diverse groups of people are examples of skills needed in future work life (Jackson and Bridgstock 2021; Karaca-Atik et al. 2023; Lauder and Mayhew 2020). HE should not only equip students for their initial months or years of work life but also focus on fostering the skills required for their careers.

While there are several best practices for successful collaboration, these are often scattered throughout the literature, with some focusing on specific aspects such as technology transfer or problem-solving (Awasthy et al. 2020). As a result, collaborations between HE and industry are often insufficient and lack effectiveness (Marijan and Gotlieb 2020), leading industry partners to question the potential return on their investment (Alhamrouni et al. 2016). Potential investment risks can significantly influence the strategic motives, intentions, and decisions of industry partners (Todeva and Knoke 2005). The success of collaborations is unlikely without a shared goal that is interesting and beneficial for both HE and industry (Garousi et al. 2019). Hence, the realm of collaboration presents its own set of challenges. However, it also offers significant potential benefits for all stakeholders (El Hadidi and Kirby 2017). It is crucial to identify the most effective practices to foster strong HE–industry relationships (Cukier 2019) to benefit all the key stakeholders: students, HE institutions and staff, and industry (Shah and Gillen 2023). To this end, the purpose of this systematic literature review is to examine how engineering HE, in collaboration with industry, supports student transitions to work life. Thus, the aim is to explore various collaborative approaches that could help students transition into work life. To achieve this goal, the following three research questions (RQs) are addressed:

RQ1. What is the current state of research and scientific research networks on HE–industry collaboration in engineering education?

RQ2. In what ways is collaboration between HE and industry manifested?

RQ3. What are the benefits and hindering factors of collaboration for the stakeholders (students, HE institutions and staff, and industry)?

The article is divided into five main sections. The second section outlines the methodology employed, the third section discusses the findings of the systematic review, the fourth section discusses the results by proposing a framework for successful collaboration between HE and industry, and the final section gives the concluding remarks.

2. Methods

A bibliometric analysis and systematic literature review were carried out to address the research questions by providing insights into scholarly collaboration in engineering education and synthesising previous research to inform better practices and identify important directions for research and practice in engineering education (e.g. Borrego, Foster, and Froyd 2014; Xian and Madhavan 2014).

For the first research question, a bibliometric analysis was used to provide a visual overview of scientific collaboration across countries and author–keyword co-occurrences depicting the central themes among the articles found in the systematic search. The bibliometric analysis, which was conducted using R and its *bibliometrix* package (Aria and Cuccurullo 2017), provided a systematic view of the regional aspects of the research collaboration and illustrated the interconnectedness of related keywords.

To answer the second and third research questions, a systematic literature review was undertaken. Following recommendations by Borrego, Foster, and Froyd (2014), the search and selection process was adapted from Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al. 2009; Page et al. 2021) and consisted of five steps: (1) defining inclusion criteria, (2) database searching, (3) title and abstract screening, (4) full-text screening and appraisal, and (5) synthesising. The methodological quality of the included studies was appraised by using the Mixed Methods Appraisal Tool (MMAT) by Hong et al. (2018). Content analysis, a commonly employed qualitative research method for deriving meaning from textual content (Hsieh and Shannon 2005), was used for the synthesis.

2.1. Inclusion criteria

This study focuses on HE–industry collaboration, especially how that collaboration supports students' transitions to work life. All authors collaboratively defined inclusion criteria to include academic papers focusing on collaboration or the transition from HE to work life in the engineering education context. Peer-reviewed articles published since 2013 were selected because the engineering profession and discipline has grown and transformed a great deal in the last 10 years and to reflect the current state of literature. Only articles published in English were included. Studies

Table 1. Inclusion and exclusion criteria.

Inclusion	Exclusion
Peer-reviewed journal and conference articles accessible with full text written in English and published since 2013. Studies with empirical evidence that focused on the collaborative actions and interactions between HE and work life or industry or the transition from HE to work life in the context of engineering education. Articles which proposed or evaluated models or frameworks related to HE–industry collaboration or the transition from HE to work life.	Studies that had an irrelevant topic or focus (e.g. not related to engineering or engineering education, HE–industry collaboration, or the transition from HE to work life). Studies that concentrated only on minorities or the high school or middle school levels. Studies that were dissertations, theses, conference abstracts, books, editorial letters, policy reports, or book reviews. Non-peer-reviewed articles. Articles in a language other than English. Duplicate results.

were not limited to specific methodological approaches or forms of HE-industry collaboration. The aim was to thoroughly understand the collaborative actions and interactions encompassing diverse research-focused, education-focused, and knowledge-exchange approaches. Furthermore, relevant full-length conference papers were included; conference abstracts were excluded. Table 1 presents the full inclusion and exclusion criteria.

2.2. Database search

An extensive literature search (through early October 2023) for publications published since 2013 was conducted in three databases: Web of Science (WoS), Scopus, and Google Scholar. Information specialists were consulted for support in designing systematic review search strategy and database selection as suggested in earlier literature (Gusenbauer and Haddaway 2020). The databases were chosen for their interdisciplinary focus, which corresponds well with the diverse nature of engineering. Furthermore, Scopus and Web of Science have the best visualisation of documents and a robust query engine, with Scopus being the most comprehensive repository indexing articles not covered by some other databases (Valente et al. 2022). Google Scholar, in turn, provides a powerful addition to other traditional search methods (Haddaway et al. 2015), although criticised for not being as complete as the other data repositories (Valente et al. 2022). The authors agreed to select these databases during an initial planning meeting in early September 2023, acknowledging that the choice of the databases could narrow the viewpoint to some extent.

Based on RQ2 and RQ3, various keywords were defined for the transition from school to work life and the collaboration between HE and industry. These terms are all actively used among scholars. All authors discussed the search terms and research questions to ensure relevant keywords were identified. The first author sought expert advice from a librarian on searching and keywords. The terms used included ‘boundary crossing,’ ‘work-integration,’ ‘industry-academia cooperation,’ ‘industry-academia liaison,’ ‘industry-academia collaboration,’ and ‘career transition’. The Boolean operators AND, OR, and NOT were used to refine search results for engineering education and HE. Table 2 provides an overview of the search terms, filters, and search hits per database. Snowball sampling (e.g. Wohlin et al. 2022) was also used to identify additional articles beyond the initial comprehensive search.

2.3. Selection of studies

After conducting database searches, a total of 13,578 articles were found and imported into the Zotero reference management software. A review of 478 titles and abstracts revealed decreasing relevance in search results from Google Scholar after the first 200 hits. This result was expected because, for example, Haddaway et al. (2015) recommended that Google Scholar searches of article titles should focus on the first 200 or 300 results. In cases where the information gathered from the title and abstract review was inadequate, the articles’ results sections were examined to ensure thorough comprehension. After removing duplicates, 461 articles remained. From this list,

Table 2. Search strategies.

Databases	Search string*	The total number of studies returned from the database ($N = 13,578$)
Web of Science	ALL (“Engineering education”) AND (“Higher education” OR “College” OR “university”) AND (“Industry Cooperation” OR “Industry Liaison” OR “Industry collaboration” OR “Business cooperation” OR “Business liaison” OR “Work integration” OR “Boundary Crossing” OR “Transition to workforce” OR “Transition to labor market” OR “Career Transition” OR “Drop out”) NOT (“High school” OR “middle school” OR “secondary school”) (all fields) Timespan: 2013-01-01 to 2023-15-10 (publication date)	47
Scopus	TITLE-ABS-KEY (“Engineering education”) AND (“Higher education” OR “College” OR “university”) AND (“Industry Cooperation” OR “Industry Liaison” OR “Industry collaboration” OR “Business cooperation” OR “Business liaison” OR “Work integration” OR “Boundary Crossing” OR “Transition to workforce” OR “Transition to labor market” OR “Career transition” OR “Drop out”) AND NOT (“High school” OR “middle school” OR “secondary school”) PUBYEAR >2013	231
Google Scholar	Anywhere in the article (“Engineering education”) AND (“Higher education” OR “College” OR “university”) AND (“Industry Cooperation” OR “Industry Liaison” OR “Industry collaboration” OR “Business cooperation” OR “Business liaison” OR “Work integration” OR “Boundary Crossing” OR “Transition to workforce” OR “Transition to labor market” OR “Career transition” OR “Drop out”) NOT (“High school” OR “middle school” OR “secondary school”) (Anywhere in the article) Timespan: 2013–2023 (publication date)	13,300

*NOTE: The search strings were adapted for each search engine.

53 articles were selected after excluding studies based on inclusion and exclusion criteria. Thus, excluding studies that did not focus on the transition from HE to work life in the context of engineering education or on the collaboration between HE and industry. The titles, authors, and digital object identifiers (DOIs) of the 53 articles were compiled in an Excel spreadsheet, with columns for screening decisions added to the table.

The first, second, and fifth authors independently screened the titles and abstracts of the 53 articles using the inclusion and exclusion criteria (see Table 1) and the Excel spreadsheet. The first author reviewed all 53 articles, while the second author reviewed 24 and the fifth author 29; each assessed inclusion with a ‘no,’ ‘maybe,’ or ‘yes’. A ‘no’ meant that a source did not meet the inclusion criteria, while those marked ‘yes’ or ‘maybe’ were moved on to full-text screening. The authors’ estimates were generally in agreement, with slight differences in the interpretation of nine research papers. After an independent rating and comparison of decisions, consensus was reached through consultation. The percent level of consensus between the first and second authors was 83.3%, and between the first and fifth authors was 82.6%. The consensus percentages were calculated by dividing the number of identical evaluations between authors by the total number of items evaluated, then multiplying by 100 to obtain a percentage. One additional author provided input on conflicting decisions on two articles. A calculation of the Cohens Kappa revealed an inter-rater reliability of first and second author $\kappa = (p = 0.60\%)$ and first and third author $\kappa = (p = 0.60\%)$ indicating a substantial agreement according to Landis and Koch (1977). Limited access prevented two articles from being thoroughly reviewed, potentially leading to missed information. A total of 36 articles were included after the full-text screening process, with one additional article (i.e. Pogatsnik 2018) identified through snowballing. Figure 1 presents a PRISMA flow diagram of the study selection process.

The first and the fifth authors critically appraised the methodological quality of the included studies by using Hong et al.’s (2018) MMAT, which addresses the challenge of critically appraising reviews with different methods: quantitative, qualitative, and mixed methods. The MMAT checklists include screening questions and items corresponding to different methodological domains. The

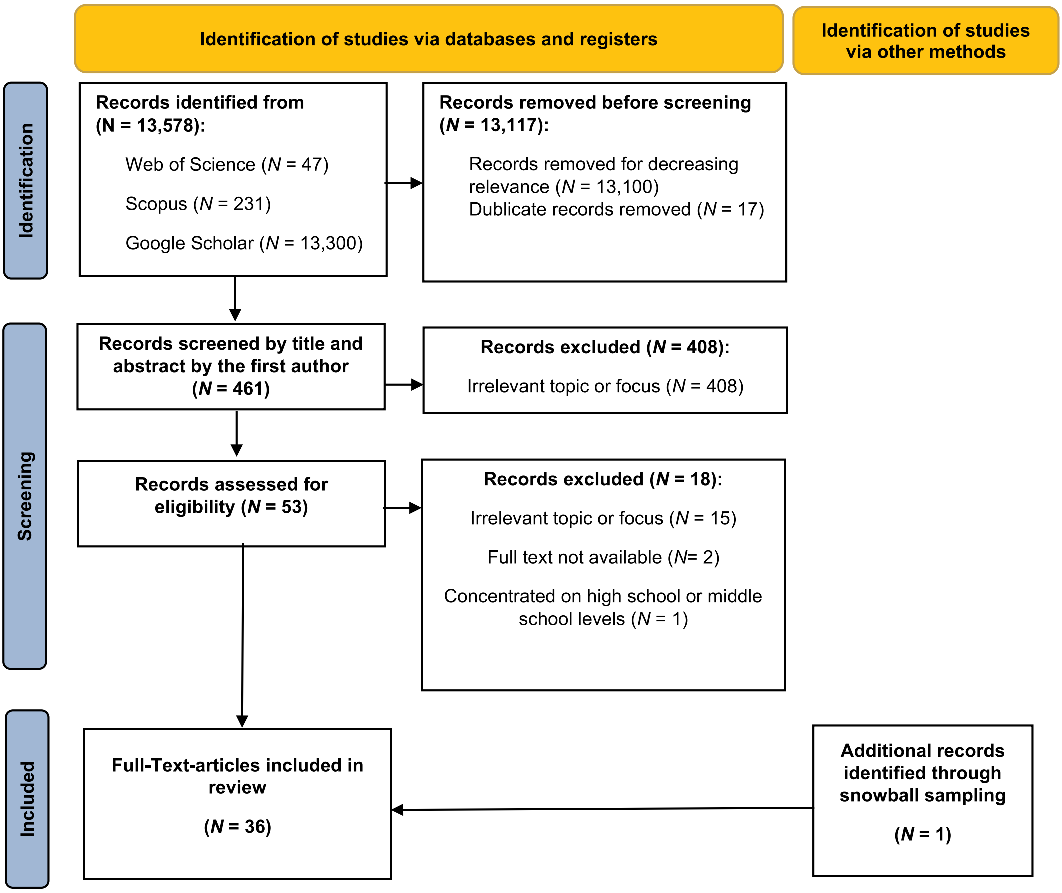

Figure 1. PRISMA Flow Diagram (adapted from Page et al. 2021).

assessment scale is 'yes,' 'no,' or 'cannot say'. Seventeen studies, a notable number of which were case studies, lacked clear research questions or a detailed methodology. However, fifteen studies had suitable methods to answer their research questions. The quality assessment through MMAT informed the conclusions drawn and was complemented by triangulation in the research process to minimise potential bias. Weekly meetings were held to assess the synthesis and conclusions for possible misconceptions and biases. The quality assessment tool and results are detailed in the supplementary material (Appendix A, Table A.1).

2.4. Synthesis

The following information was extracted in the Microsoft Excel coding form from the full text: (a) author(s), (b) DOI, (c) title, (d) publication rating, (e) country of origin, (f) field (e.g. electrical engineering), (g) research type, (h) student transition and transition support, (i) key findings, (j) benefits and challenges about what happens in the workplace, (k) suggested ideas for future research, and (l) limitations. Data were independently collected from half the articles by the second and fifth authors, while the first author collected data from all 36 articles. The initial data collection phase included a discussion among those three authors to ensure the standardisation of coding annotations.

After all authors were consulted, additional information was collected from the included studies: (a) pedagogical model; (b) theoretical background; (c) perspective (e.g. university, industry, or students); (d) research design; (e) data analysis; and (f) unit of analysis. The second part of data collection was conducted in the same manner as the first by the same three authors.

The analysis involved 36 articles. A qualitative content analysis approach (Hsieh and Shannon 2005) was adopted, building on previous studies to develop the initial coding framework and identifying additional codes as the analysis progressed. The findings and coding framework were discussed with all authors after independent coding, with the first author performing the final evidence synthesis using the collected data. This collaborative approach to the data collection and analysis process allowed for a comprehensive examination of the literature.

3. Findings

This section is structured around the three RQs. First, the current state of research and scientific networks on HE–industry collaboration in engineering is presented. Following this, the focus is on collaboration between HE and industry. Finally, the benefits and hindering factors related to collaboration for the stakeholders are highlighted. From a future perspective, it is particularly interesting to understand when collaboration succeeds. Therefore, in the discussion section, the focus is on the key success factors of collaboration between HE and industry.

3.1. Current state of research and scientific networks on HE–industry collaboration in engineering

The selected literature (Table 3) revealed that most of the studies included were published in 2022 ($N = 7$), 2016 ($N = 6$), and 2020 ($N = 5$). The results revealed interesting geographical variations. Most of the included studies were published in Europe ($N = 14$) or Asia ($N = 8$); two studies did not specify where the research took place. Methodologies included qualitative ($N = 11$), quantitative ($N = 7$), and mixed methods ($N = 8$), while 10 studies did not have a clearly specified methodology. A wide range of engineering disciplines were represented (see Table 3). Note that the letter P and the coding number (issued in alphabetical order) are used to identify specific papers in supplementary materials appendix 1A, 2A and 3A.

Figures 2 and 3 visualise the regional aspects of the country-scientific collaboration network and the interconnectedness of the most frequently occurring related keywords. Based on the affiliations of the co-authors (Figure 2), five blocks of collaboration between different countries emerged: (1) China, Hong Kong, Singapore, and the Unites States; (2) South Africa, Namibia, Malawi, and Algeria; (3) Sweden and Ireland; (4) Japan and Thailand; and (5) Brazil and Italy. Because of the differences in educational systems between countries and the notion that engineering as a practice encompasses different cultures, geographical areas, and organisations (e.g. Mahadevan 2014), intercultural scientific collaborations have the potential to provide diverse perspectives and innovative approaches to research (Fu et al. 2022; Ozdemir et al. 2023).

The keyword co-occurrence network in Figure 3 shows which words appearing more than once occurred as a keyword with other keywords in the selected articles. The central keywords among the selected articles were 'engineering education,' 'students,' 'university–industry collaboration,' and 'curricula'. Clustering the network using the Walktrap algorithm (Aria and Cuccurullo 2017; Pons and Latapy 2006) identified three clusters of keywords relating to (1) the central keywords, (2) semi-structured interviews and motivation, and (3) professional aspects.

The most relevant sources were the European Journal of Engineering Education (5 articles), Proceedings of the IEEE Frontiers in Education (FIE) (4 articles), and the International Journal of Engineering Education (3 articles). Other sources provided only single articles. There were no recurring authorships and no co-authoring between articles (Table 3). The number of articles published annually showed a slight increase (Figure 4). Except for two active years 2013 and 2018, the average total citation count per year remained relatively low (Figure 5). Overall, the results suggest that the topic showed a slightly increasing interest and some cross-national collaboration,

Table 3. Studies included in this review.

Paper code	Author(s)	Year	Study Region	Field	Methodology
P1	Al-Atroush & Ibrahim	2022	Ireland	Engineering management construction	Quantitative
P2	Alhamrouni, et al.	2016	US	Technology	Qualitative
P3	Asplund & Bengtsson	2020	Sweden	Multiple engineering fields	Quantitative
P4	Bodas Freitas, Marques & Silva	2013	Brazil	Science and engineering department	Mixed methods
P5	Cao, Tang & Case	2022	China	Science and technology and electrical engineering	Qualitative
P6	Carbone, et al.	2020	Australia	Engineering	Mixed methods
P7	Chen, Lu & Wang	2020	China	Computer Engineering	Mixed methods
P8	Chew, et al.	2021	Malaysia	Soil and Groundwater Remediation and Membrane Technology	Quantitative
P9	Conradie, et al.	2016	Not specified	Industrial Design and Electronics students	Not specified
P10	Cruz & Dominguez	2016	Portugal	Mechanics engineering	Mixed methods
P11	Dieck-Assad, Ávila-Ortega & González Peña	2021	Mexico	Automotive industry	Quantitative
P12	Falcone, et al.	2014	Spain	Electrical and Electronic Engineering	Not specified
P13	Fortuin., et al.	2023	Not specified	Multiple fields	Not specified
P14	Friesel	2019	Denmark	Engineering	Not specified
P15	Jiravansirikul, Dheandhanoo & Chantamas	2017	Thailand/US	Game industry	Qualitative
P16	Johanyak	2016	Hungary	Software engineering	Not specified
P17	Juvane, et al.	2020	Mozambique	Software industry	Qualitative
P18	Kauppila, Majava & Kropsu-Vehkaperä	2016	Finland	Industrial engineering and management	Qualitative
P19	Lahdenperä, et al.	2022	Finland	ICT	Qualitative
P20	Lautala	2013	USA/EU	Railroad Industry	Not specified
P21	Morgan & O'Gorman	2017	Northern Ireland	Multiple engineering programs	Quantitative
P22	Ngonda, Nkhoma & Falayi	2023	Southern Africa	Engineering education	Qualitative
P23	Ozor, Achebe & Sukdeo	2022	Nigeria	Not specified	Qualitative
P24	Pantzos, et al.	2022	Sweden	Engineering	Qualitative
P25	Pogatsnik	2018	Hungary	Mechanical engineering, technical management	Mixed methods
P26	Pyrhönen, Niiranen & Pajarre	2020	Finland	Multiple engineering fields	Mixed methods
P27	Rampersad	2015	Australia	Science and engineering	Qualitative
P28	Rawboon, et al.	2019	Thailand/ Japan	Engineering	Not specified
P29	Scachitti & Higley	2023	USA	Engineering technology programs	Not specified
P30	Sedano & Vasankari	2021	Finland	Computing	Mixed methods
P31	Shin, et al.	2013	South Korea	Computer science and engineering	Not specified
P32	Ståhl, Sandahl & Buffoni	2022	Sweden	Software engineering	Mixed methods
P33	Valentine, Marinelli & Male	2022	Australia	Multiple fields	Qualitative
P34	Venson, et al.	2016	Brazil	Software Engineering	Not specified
P35	Xi, Shen & Chen	2022	China	Computer Engineering	Quantitative
P36	Yuen & Wong	2021	Singapore	Data Science Education	Quantitative

but isolated research work regarding authorship, and only three publication sources showing recurrent activity. Thus, this study provided a significant contribution by systematically synthesising prior research results.

3.2. Collaboration between HE and industry

Collaboration between HE and industry involves an industry partner or partners, students, teaching staff, and/or other members of the HE institution (see Figure 6 and supplementary material Appendix 2A for an overview). Sometimes collaboration only occurs between students, HE staff, and the industry partner(s) without a clear definition of the role of HE institutions (Alhamrouni et al. 2016; Lahdenperä et al. 2022). It is also common for individual members of HE institutions or firms in industry to initiate such partnerships. In 12 of the studies reviewed, there was no clear description of the role

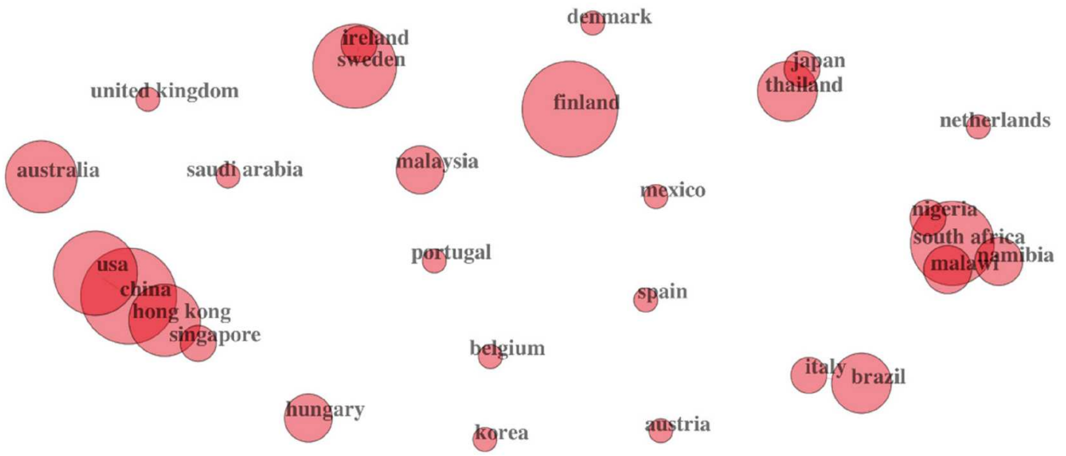

Figure 2. Scientific productivity and collaboration between countries based on authors' affiliations.

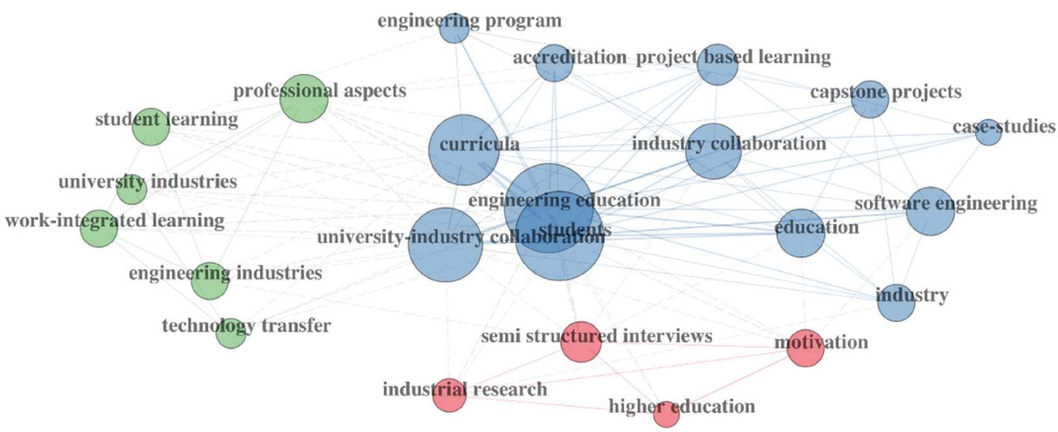

Figure 3. Keyword co-occurrence network for keyword frequency $n > 1$.

played by academic staff in collaborations between HE and industry. This challenge regarding their role was evident in studies focusing on R&D in HE and industry collaboration (Lautala 2013; Valentine, Marinelli, and Male 2022). From this perspective, collaboration requires clear roles, objectives, and assignments, thus **clarity**. The literature indicated that objectives and approaches are versatile and somewhat ambiguous in addition to roles.

The forms of collaboration between HE and industry varied widely in the studies reviewed (see Figure 6 and supplementary material Appendix 2A for an overview). Nine of the studies reviewed discussed work placements, such as internships as a key component of HE-industry partnerships (Friesel 2019; Rampersad 2015). Internships other forms of work placements in a HEI's partner company are perhaps the most direct forms of collaboration, where HE students are placed in industry environments to gain hands-on experience. Such placements often result in a thesis or project directly tied to the work conducted at the industry partner's facility (Asplund and Bengtsson 2020; Ngonda, Nkhoma, and Falayi 2023). The duration of these work placements varied in the included studies, with the longest lasting up to one semester (e.g. Falcone et al. 2014; Ngonda, Nkhoma, and Falayi 2023). There were also differences in how the placements were implemented in the academic year. For instance, Pogatsnik (2018) describes a dual-education model in which

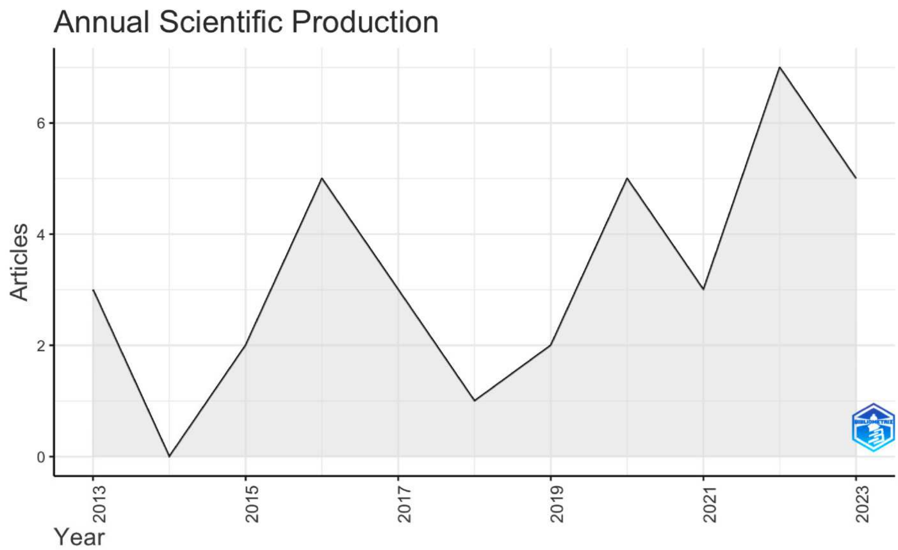

Figure 4. The number of articles per year showed a slight increase.

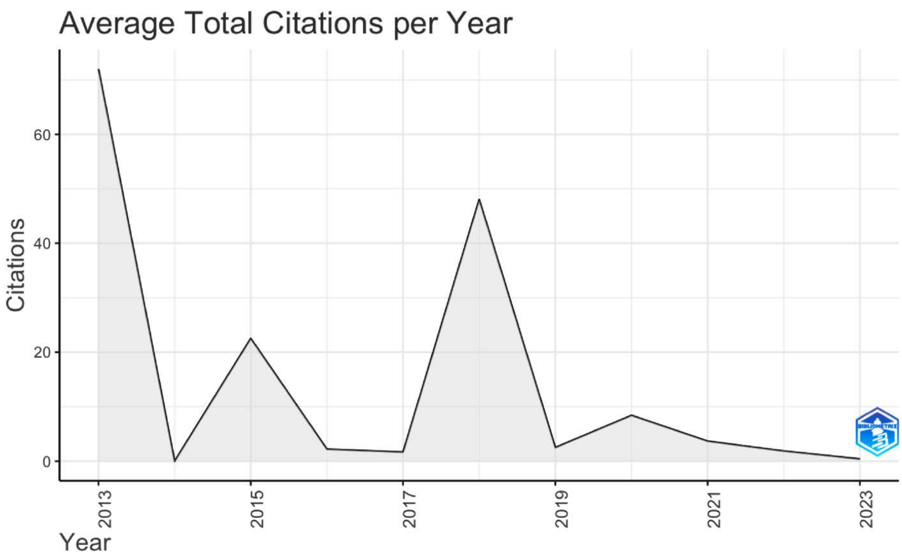

Figure 5. The average total citations per year.

HE students spent 14 weeks in an academic semester during the autumn, followed by an 8-week corporate placement in the winter. In the spring, students returned to another 14-week academic period, followed by a 16-week corporate placement over the summer. Work placements potentially led to the employment of the students (e.g. Alhamrouni et al. 2016; Asplund and Bengtsson 2020), or at least clearer career paths (Pantzos et al. 2022; Shin et al. 2013). These forms of collaboration call for **continuity, commitment** and **confidence** in other stakeholders and in the collaboration process itself, as they're often long-lasting and reoccurring.

Six of the included research examined site visits as means to provide students with an immersive experience, allowing them to observe industry operations firsthand (Morgan and O'Gorman 2017; Rawboon et al. 2019). These visits help students contextualise theoretical knowledge and better

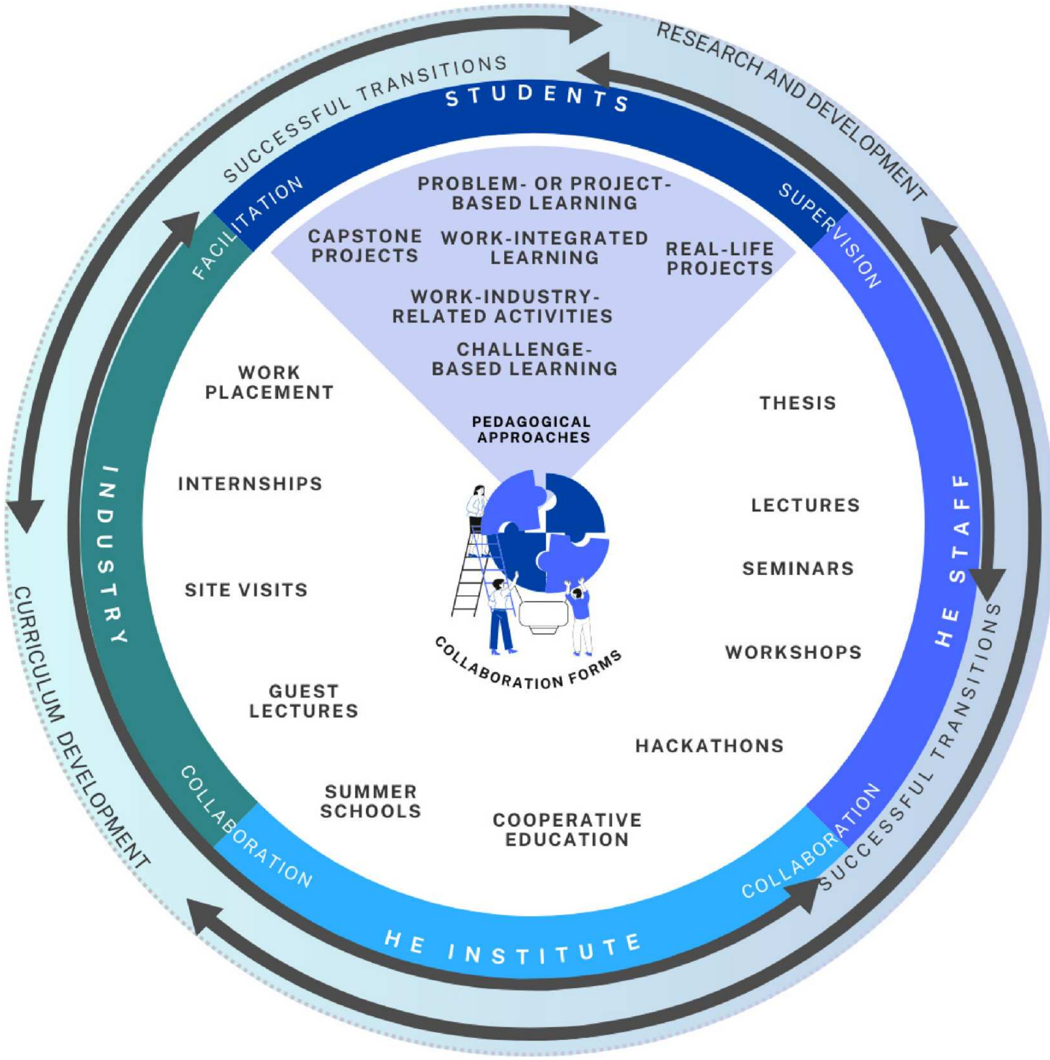

Figure 6. The main HE-industry collaboration forms, stakeholders and the pedagogical approaches.

understand the practical realities of their field (Carbone et al. 2020; Morgan and O'Gorman 2017). One form of collaboration identified in the included studies was inviting guest lecturers from the industry (Chew et al. 2021; Cruz and Dominguez 2016; Jiravansirikul, Dheandhanoo, and Chantamas 2017). These forms of collaboration allowed for professionals to bring real-world perspectives into the classroom, enriching the curriculum with current trends and challenges from the industry (Al-Atroush and Ibrahim 2022; Johanyak 2016).

In addition to these common formats, our review also identified more specialised collaboration forms, such as co-developing curricula and joint R&D. The most common approach in this section was curriculum co-development, aimed at enriching learning processes through various industry collaborations. For instance, course module design in collaboration with industry helps teachers to adjust their teaching content and methods. It provided opportunities to introduce current trends from the industry to HE staff and students, while also granting industry partners to get a sense of the training of future engineers (Sedano and Vasankari 2021; Xi, Shen, and Chen 2022). Approaches to co-development of curriculums included designing workshops (Chen, Lu, and Wang 2020), modules (Dieck-Assad, Ávila-Ortega, and Peña 2021), courses (Sedano and Vasankari 2021; Xi, Shen, and Chen 2022), and programs (Pantzos et al. 2022), as well as providing real-world examples and problems from industry to HE staff and students (Johanyak 2016; Kauppila, Majava, and Kropsu-Vehkaperä 2016; Lahdenperä et al. 2022) and aligning course objectives with industry demands (Dieck-Assad, Ávila-Ortega, and Peña 2021; Lahdenperä et al. 2022). Approaches such as the forementioned emphasised having common goals among stakeholders to further improve the future engineering and engineers, thus **commonality**.

In the studies we examined, active learning theories were prevalent (see supplementary material Appendix 2A for an overview), with project- or problem-based learning (PBL) being among the most common pedagogical approaches, with some form or characteristics being present in 12 of the included studies (Cruz and Dominguez 2016; Rawboon et al. 2019). These studies described their objective as applying students' knowledge in a meaningful context related to their future profession by exposing various design processes with projects (Conradie et al. 2016; Jiravansirikul, Dheandhanoo, and Chantamas 2017; Rawboon et al. 2019). Approaches such as PBL motivated students or improved their self-confidence in solving real-world problems (Cruz and Dominguez 2016; Friesel 2019) and further expanded interest towards their studies and/or field (Ståhl, Sandahl, and Buffoni 2022).

Work-integrated learning (WIL) emerged in five of the studies included in this review as an approach for facilitating authentic learning experiences by linking theoretical knowledge with practical application (Carbone et al. 2020; Ngonda, Nkhoma, and Falayi 2023). These studies emphasised that WIL and work-integrated activities (WIA) allow students to engage in real-life problems in an actual or simulated work environment, providing deeper insights into career opportunities and enhancing their prospects for employment or securing an internship position (Ngonda, Nkhoma, and Falayi 2023; Rampersad 2015).

Capstone, and other forms of final-year projects were highlighted as pedagogical approaches in the included research (Alhamrouni et al. 2016; Shin et al. 2013; Venson et al. 2016). These included projects such as final degree projects and research activities such as bachelor's, master's or doctoral thesis (Alhamrouni et al. 2016). In most cases, completion of these projects was required for the graduation of engineering students (Alhamrouni et al. 2016; Scachitti and Higley 2023; Shin et al. 2013). The purpose of these approaches was to provide more opportunities for engineering students to contribute to various projects, gain hands-on experience, deepen their knowledge (Alhamrouni et al. 2016; Venson et al. 2016), and eventually evaluate their abilities in addressing complex engineering tasks (Alhamrouni et al. 2016). Figure 6 visualises the main HE-industry collaboration forms, stakeholders and the pedagogical approaches in the studies included in this review.

3.3. Benefits and hindering factors related to collaboration for the stakeholders

The various stakeholders in HE–industry collaboration each play distinct roles. Figure 6 and appendix 2A illustrate these participants, including industry partners, students, HE institution and HE staff. Industry partners or company representatives were involved as participant stakeholders in all but one of the studies (Fortuin et al. 2023), while students participated in 33 out of 36 studies. HE institutions participated in 30 studies, and the role of HE staff as participants was noted in 24 of 36 studies. Table 4 presents the benefits and hindering factors of collaboration from stakeholder perspectives. Supplementary material appendix 3A provides a full list of references from the articles reviewed in this study for each benefit or hindering factor.

Benefits clearly highlighted the importance of **commonality**, thus, the shared expectations, goals, and aims of collaboration between HE and industry partners. The results revealed various reasons for the involvement of industry partners, who mentioned benefits such as recruiting new talent, influencing academic programs in 30 studies (Al-Atroush and Ibrahim 2022; Friesel 2019), reputation gains in 11 studies (Chen, Lu, and Wang 2020; Valentine, Marinelli, and Male 2022), obtaining new insights

Table 4. Benefits and hindering factors of HE–industry collaboration for different stakeholders.

Stakeholder	Benefits	Hindering factors
Students	• Deepens and broadens the understanding of the field • Provides authentic learning opportunities (integration of theory and practice) • Students develop skills and professional identity for their future work – Improvements in self-efficacy • Employment outcomes and career plans are improved (employability) • Attitude towards studies improves (motivation)	• Assignments are more complex; requirements might be too strenuous • Limited availability or relatively short duration of suitable projects or placements • Low priority for industry partner, lack of support, supervision, or help
HE (as an institute)	• Access to funding and real data or issues (R&D – joint research); Transfer of knowledge • Getting feedback from industry, improving engineering curricula • Availability of student placements (e.g. master's thesis, internship) • Improved student outcomes • Brand visibility	• Limited funding for, e.g. staff supervision time – Lack of resources • Requires planning and skilled employees in, e.g. assessment of assignments and supervision • Complexity is much greater when working with an industry partner • Difficult to connect with willing companies – Collaboration takes commitment
HE staff	• Staff obtains a sense of the industry needs and problems • Access to collaboration in research projects and education • More skilled and motivated students	• Lack of time or resources for, e.g. supervision time • Attracting partners takes commitment – Collaborating is too much work • Challenges with curriculum planning, assessments, etc.
Industry partners	• Transfer of knowledge: Access to new methods at low cost (R& D – joint research) • Recruiting new talent for job placements and employment • Provides solutions to and new views on their problems at low risk • Reputation gains, brand image visibility • Possibility to affect academic programs or student learning outcomes – More skilled workers in the future	• Benefits of collaboration might be unclear, which raises bar for participating in joint efforts • Communication between industry and HE is not constant and clear • Collaboration is seen as too much work • Unclear to industry partners how they can help students and HE

and solutions to their problems in 23 studies (Conradie et al. 2016; Shin et al. 2013), and accessing new methods and joint research in 18 studies (Carbone et al. 2020; Ozor, Achebe, and Sukdeo 2022).

HE institutions' benefits from collaboration with industry included access to funding or joint research opportunities as well as access to real data or issues (Cao, Tang, and Case 2022; Juvane et al. 2020). Obtaining feedback from industry was also considered a benefit in 16 studies, leading to potential modifications and improvements in engineering curricula or individual course modules (Cruz and Dominguez 2016; Falcone et al. 2014). Additionally, reputation gains were reported as a benefit for HE institutions in four studies (Alhamrouni et al. 2016; Chew et al. 2021; Pogatsnik 2018; Yuen and Wong 2021). For HE staff such as researchers and educators, access to collaboration in research projects or education and gaining a sense of industry needs and challenges were the main benefits in 22 studies (Johanyak 2016; Rawboon et al. 2019; Xi, Shen, and Chen 2022).

Students benefit from HE–industry collaboration in several ways. Gaining the opportunity to learn in an authentic environment, developing skills for future employment, and improving their career prospects were the main benefits for students in 33 studies (Carbone et al. 2020; Rampersad 2015; Xi, Shen, and Chen 2022). Obtaining internship positions and seeing improved student learning outcomes and employability were also viewed as benefits for HE institutes and staff. In 25 of the research included, students' self-confidence, self-efficacy, or attitudes towards their studies were reported to have improved because of HE–industry collaboration (Dieck-Assad, Ávila-Ortega, and Peña 2021; Yuen and Wong 2021).

The hindering factors, on the other hand, highlighted the importance of **commonality**, **commitment**, **communication**, and **continuity**. For industry partners, factors hindering collaboration between HE and industry include a lack of clarity of its benefits, student involvement, and communication gaps. Collaboration was also perceived as requiring too much effort and a significant investment of time and resources to achieve the desired results in 22 studies (Lautala 2013; Venson et al. 2016). On the other hand, in Valente et al. (2022) industry representatives expressed a desire for more extensive and comprehensive engagement with HE, rather than just occasional one-time visits.

Collaborating with industry partners can be challenging for HE institutions due to hindering factors like a lack of resources and the perception that it requires a significant commitment as reported in 24 included studies (Asplund and Bengtsson 2020; Scachitti and Higley 2023). Other common challenges include dealing with greater complexity, attracting willing companies, and meeting the increased collaboration requirements placed on HE staff (Conradie et al. 2016; Sedano and Vasankari 2021). These difficulties also became evident in areas like pedagogical design, student supervision, and assessment in 23 studies (Alhamrouni et al. 2016; Venson et al. 2016). Two studies highlighted the increased workload for HE staff due to collaboration (Dieck-Assad, Ávila-Ortega, and Peña 2021; Sedano and Vasankari 2021).

HE students often face hindering factors like the limited availability or short duration of industrial placements, internships, or projects as reported in 13 of the included research (Carbone et al. 2020; Friesel 2019). Collaboration with industry stakeholders is more complex, raising the skill requirements and expected outcomes from student stakeholders (Pyrhönen, Niiranen, and Pajarre 2020; Ståhl, Sandahl, and Buffoni 2022). In 8 of the included studies, there was a clear perception of inadequate communication, support or guidance for HE students from industry stakeholders (Lahdenperä et al. 2022; Shin et al. 2013).

4. Discussion

The findings highlight the positive outcomes of HE–industry collaboration in engineering for students, institutions, staff, and industry partners. While there are clearly benefits for all the involved parties, challenges and hindering factors like time and resource constraints do exist. Collaboration between stakeholders has various benefits, including joint research opportunities and the ability for industry partners to influence academic programs. Common collaboration patterns include problem-solving, product development, and assisting students in transitioning from academia to the professional sphere.

Clarity, communication, commonality, commitment, continuity, and confidence – the six C's – emerged as key factors for successful collaboration between HE and industry (see Figure 7). These themes, all of which were identified in the articles reviewed in this study (see Appendix 3A for an overview), play a vital role in fostering effective collaboration between HE and industry stakeholders.

Clarity encompasses well-defined stakeholder roles, expectations, collaboration guidelines, agreements on publications, patents, confidentiality, and communication methods (Jiravansirikul, Dheandhanoo, and Chantamas 2017; Yuen and Wong 2021). Understanding the expectations and objectives of other stakeholders from the outset of collaborative efforts, along with setting clear guidelines, communication channels, aims and goals, helped generate greater benefits or lowered the rim for stakeholders to participate and continue to participate in collaborative efforts (Sedano and Vasankari 2021; Ståhl, Sandahl, and Buffoni 2022). Juvane et al. (2020) noted in their study, that the industry members were uncertain about the university's capability to even conduct projects in collaboration. Having clarity in stakeholder roles was especially important in collaborative efforts, which involved HE studies and students (Dieck-Assad, Ávila-Ortega, and Peña 2021; Ngonda, Nkhoma, and Falayi 2023). For instance, in Chew et al. (2021), deliberations were undertaken to ensure that industrial practice examples were related to the theory that was taught in the engineering program. In contrast, Xi, Shen, and Chen (2022) found in their survey results that 34.1% of companies perceived a mismatch between HE courses and their developmental needs. Chen, Lu, and Wang (2020) stressed the importance of defining the learning outcomes from the outset and listed a balance between the industry's needs and theoretical goals in the course they studied. Alhamrouni et al. (2016) discussed whether industry partners should supervise final-year engineering

Figure 7. The Six C's of successful collaboration between HE and industry.

projects and stressed the importance of clear assessment criteria. In Valentine, Marinelli, and Male (2022) industry personnel were more motivated to invest time and effort into HE students' learning activities, when there was a clear possibility for on-going engagement e.g. in the form of delivering quest lectures.

Previous studies have also considered the importance of clarity in HE-industry collaboration. For instance, Awasthy et al. (2020) have proposed a framework for improving university-industry collaboration, highlighting the importance of several factors such as identifying the stakeholders, addressing intellectual property concerns, establishing efficient communication and setting basic principles for collaboration (Awasthy et al. 2020). Rybnicek and Königsgruber (2019) have also proposed in their review, that clarity between stakeholders is key aspect of ensuring industry-university collaboration has higher chances of being successful. Kauppila et al. (2015) also call for clear policies, roles and for example using key-performance indicators in monitoring and evaluating the collaboration. In Albats, Fiegenbaum, and Cunningham (2018) , clear division of roles and responsibilities contributed positively to efficiency of project delivery and the dynamics of the project.

Communication refers to the channels and methods that HE staff, students, and industry partners use to connect with one another. To ensure successful collaboration between HE institutions, industry partners, and other key stakeholders, it is vital to establish clear, efficient, and consistent communication channels (Cruz and Dominguez 2016; Juvane et al. 2020). Clear, efficient, consistent, and comprehensive communication is fundamental to successful collaborative efforts between HE and industry partners because it allows for feedback and provides further opportunities to enhance collaboration (Ngonda, Nkhoma, and Falayi 2023; Rampersad 2015). Collaboration between HE and industry partners may face obstacles, such as unclear initiation of contact and a failure to maintain communication networks among stakeholders (Bodas Freitas, Marques, and Silva 2013; Pantzos et al. 2022). Effective collaboration is dependent on strong communication channels and skills. For instance, students have been reported to have deficiencies in interpersonal skills during internships (Lahdenperä et al. 2022; Rawboon et al. 2019). However, in Ståhl, Sandahl, and Buffoni (2022), external partners commented that students were regarded as professional and dependable.

Earlier research, Kauppila et al. (2015) and Plewa et al. (2013B), for example, have expanded on communication as being key element of successful university-business collaboration. Kauppila et al. (2015) highlight the importance of using multiple effective channels for interaction and communication between partners, while Plewa et al. (2013B) stress the importance of communication in different phases of collaboration. Considering the fit of possible collaboration partner is also considered vital aspect of collaboration in earlier research (Awasthy et al. 2020; Kauppila et al. 2015).

Commonality involves the shared expectations, goals, and aims of collaboration between HE and industry partners. Mutual goals were found to be crucial for successful collaborative efforts in several studies, resulting in a win-win situation for both parties (Johanyak 2016; Kauppila, Majava, and Kropsu-Vehkaperä 2016). The most shared objectives include aligning the engineering curriculum of HE institutions to better meet industry needs, improve students' employability and skills, and foster closer collaboration between academics and industry professionals for knowledge transfer and R&D efforts. These shared objectives illustrate the importance of aligning the goals and aims of collaboration between HE institutions and industry partners (Cao, Tang, and Case 2022; Falcone et al. 2014).

Shared mission or goal between collaboration stakeholders has been also identified in earlier research as key element of successful collaboration (e.g. Awasthy et al. 2020; Kauppila et al. 2015; Thune 2011). Rybnicek and Königsgruber (2019) have also proposed certain levels of flexibility in institutional factors, as coping with change, aligning goals and visions for collaboration requires understanding and accepting e.g. cultural differences and adapting to collaboration rules. Fernandes et al. (2023) found in their review multiple critical success factors of university-industry R&D collaboration, including mutual understanding of partner's internal and external environment and needs.

Collaboration between HE and industry requires **commitment**. Obstacles to collaboration arise when stakeholders perceive the absence of an appropriate level of consistent buy-in from another party (Al-Atroush and Ibrahim 2022; Dieck-Assad, Ávila-Ortega, and Peña 2021). Collaboration requires time, resources, and effort to succeed (Carbone et al. 2020; Friesel 2019). Ambiguity in stakeholder roles and collaboration benefits, short-lived efforts, the failure to maintain partnerships, and inconsistent communication can hinder commitment (Scachitti and Higley 2023; Sedano and Vasankari 2021). Asplund and Bengtsson (2020) noted that initiating collaboration requires time and commitment, while Lautala's (2013) study revealed that industry members considered excessive time commitments to be the main reason for not collaborating with HE institutions.

In earlier research, Awasthy et al. (2020) have suggested committing to collaboration being one of the success factors of collaboration. The same authors recognise that commitment is often result of establishing clear strategy, which involves aspects such as legal framework, for collaboration (Awasthy et al. 2020). Kauppila et al. (2015) also stresses the importance of commitment to the collaboration especially from managers and leadership, while also noting the importance of evaluating and monitoring collaboration in a balanced way. Long-term perspective of collaboration, motivation of project members and senior management commitment were also identified in Fernandes et al. (2023) as being critical success factors of university-industry collaboration.

Continuity was emphasised as a key aspect in the success of HE–industry collaboration, with stakeholders recognising greater potential when collaborative efforts endured for longer periods. Even short-term collaborations like courses or site visits can be beneficial if collaboration continues (Cruz and Dominguez 2016; Valentine, Marinelli, and Male 2022). Collaborative efforts between HE and industry, such as internships and site visits, benefit students by helping them develop practical skills in an industry setting, gain a deeper understanding of engineering as a field, and even secure work offers (Juvane et al. 2020; Ozor, Achebe, and Sukdeo 2022). Longer collaborations have allowed for increased opportunities in research and in the development of new products for both HE institutions and industry partners (Johanyak 2016; Rampersad 2015). Additionally, these partnerships have facilitated the recruitment of new talent and provided visibility and image enhancements for industry partners (Morgan and O'Gorman 2017; Pogatsnik 2018). In addition, they have aided HEIs in further developing their curricula by addressing shortcomings and providing learning opportunities for staff members (Cao, Tang, and Case 2022; Rampersad 2015). The accumulation of collaborative experiences increases the chances of successful collaboration in the future (Kauppila, Majava, and Kropsu-Vehkaperä 2016).

Previous studies have found that HEIs' networking level and alumni for instance, are important connections for HEIs, in establishing and maintaining networks for future collaboration e.g. with local companies and adopting strategies or policies to encourage collaboration (Awasthy et al. 2020; Garcia et al. 2019; Johnston 2021). Rossoni, de Vasconcellos, and de Castilho Rossoni (2024) have suggested that one way of overcoming barriers for collaboration between HEIs and industry could be to start with smaller projects and gradually moving to more complex projects, which would prolong the partnership and generate benefits for stakeholders. Plewa et al. (2013B) have also addressed the crucial role of the people facilitating and maintaining collaboration in successful university-industry linkages, while Awasthy et al. (2020) also note that the characteristics of individuals and organisations influence the level of collaboration.

Building trust and credibility is closely linked to **confidence** in collaboration partners, which is crucial for successful HE–industry collaboration (Chew et al. 2021; Valentine, Marinelli, and Male 2022). The absence of trust has been cited as a significant barrier to initiating collaboration, particularly for industry partners. This may be due to unclear benefits, the substantial investments required, or a perception that HE institutions and graduates are unwilling or unable to bring firms added value (Conradie et al. 2016; Ståhl, Sandahl, and Buffoni 2022).

In earlier research, Rybnicek and Königsgruber (2019) have identified trust between collaboration partners as a key element of successful collaboration. Similarly, Awasthy et al. (2020) highlighted social capital – including factors such as trust and mutual obligations – as essential for collaboration's success. Thune (2011) and Kauppila et al. (2015) have also considered the importance interorganisational trust between collaboration partners of being key aspect of collaboration's success. Plewa et al. (2013B) stress the importance of trust between stakeholders in different phases of collaboration, highlighting the importance of developing trust from the establishment point of collaboration. In their survey, Clauss, Kesting, and Franco (2024) found that formalising university-industry collaboration activities, led to less opportunism and strengthened the perceptions of trust and fairness.

Table 5 presents a complete list of potential success factors for different stakeholders based on the benefits and hindering factors of HE–industry collaboration in the articles reviewed for this study.

Earlier research has reported that solutions integrating work and studies often emerge in the later stages of academic programs, and that collaboration between HE and industry is often loose or occasional (Shah and Gillen 2023; Valiente Bermejo et al. 2022; Zhuang and Zhou 2023). Most of the studies in this review emphasised that collaboration takes time and resources for the various stakeholders to realise its benefits. Potential collaboration partners may have divergent expectations, goals, and definitions of success. Therefore, it is crucial to establish clear aims, a reasonable timeline, and the scope of collaboration to ensure mutual understanding, as previous research has also indicated (Fernandes et al. 2023; Plewa et al. 2013A; Thune 2011). Expanding on this, Rybnicek and Königsgruber (2019) have proposed that studying the environment in which collaboration takes place is advisable. The same authors stress the importance of awareness of e.g. current political or social developments. Atta-Owusu, Fitjar, and Rodriguez-Pose (2021) have also noted the importance of policies in encouraging HEIs and industry to collaborate. Building an environment and culture that

Table 5. Potential success factors for different stakeholders in HE and industry collaboration based on benefits and hindering factors of HE–industry collaboration.

Success factors	Explanation
Clarity	Clearly defined roles, objectives, assignments, policies, and rules of collaboration
Communication	Clear, efficient, transparent, and consistent communication channels
Commonality	Shared goals or mission
Commitment	Collaboration and success require effort, resources, and time to cultivate
Continuity	Regular and broad interactions, meetings, and planning
Confidence	Establishing trust between HE and industries while recognising their different strengths and weaknesses

promote and encourage companies and HEIs to collaborate might increase collaboration's chances of success.

Although collaboration between HE and industry has been studied in many countries, actual multinational collaboration in research was not extensively practiced in the studies included in this review. Instead, the research appeared to take place in separate blocks divided by continents. Two of the included studies reported how collaborative efforts rest solely on the shoulders of individuals (Bodas Freitas, Marques, and Silva 2013; Valentine, Marinelli, and Male 2022). It is worth considering whether collaboration should be managed at an organisational level to ensure its continuity after transitions like staff changes. Considering the framework suggested in this study might be one way of streamlining the collaboration process between HE and industry to better serve all stakeholders. Additionally, more comprehensive support, such as government funding, legislative regulations, and guidelines, is necessary for successful collaboration.

5. Conclusion, limitations and recommendations

Our findings delve into the dynamics of collaboration between HE and industry. The focus of the review was to synthesise research concerning how engineering HE, in collaboration with industry, supports students' transitions to work life. By scrutinising benefits and the factors that hinder HE–industry collaborations from the perspective of various stakeholders, this study has provided perspectives that can help refine and augment future collaborative endeavours. Furthermore, a framework outlining the critical success factors for HE–industry collaborations was introduced (see Section 4). This framework proposes key considerations for the effective planning and execution of such collaborations and paves the way for subsequent research to investigate the timing and nature of collaboration challenges, strategies for overcoming these obstacles, and the mechanisms through which solutions are implemented. Exploring the influence of individual stakeholders and the process of scaling collaboration from passionate individuals to the institutional level also offers a promising avenue for future inquiry.

The key practical contribution of this study is a framework that outlines potential success factors for higher education–industry collaboration. It serves as a tool for incorporating the six C's when establishing and maintaining collaborations. The framework is designed to be both comprehensive and adaptable, recognising that there is no one-size-fits-all solution; all elements should be considered when designing collaborative efforts. Our framework complements earlier research on critical success factors of HE–industry or university–industry collaboration e.g. Thune (2011), Kauppila et al. (2015), Fernandes et al. (2023). Our study was not limited to specific methodological approaches or forms of HE-industry collaboration. The aim was to thoroughly understand the collaborative actions and interactions encompassing diverse research-focused, education-focused, and knowledge-exchange approaches in the context of engineering. We propose that our framework has potential to be applicable in different contexts and approaches of collaboration between HE and industry. Our results call for action, highlighting a need in the field of engineering education for closer collaboration, including expanded shared international research, to advance the development of academia-industry partnerships.

Despite the pedagogical approach used (e.g. PBL), particular emphasis must be placed on the development of communication skills in education, as they are essential for effective collaboration across academic and industry settings. The framework has not been validated. Therefore, further evaluation and possibly further modifications are needed. Further research can help by examining individual factors and combinations of factors. Since we did not limit our study to just one or two continents or countries, future research could further explore global variations in collaboration and potentially apply the proposed framework within different contexts.

Some relevant studies may have been missed during the review process. First, the review was limited to the Scopus, Web of Science, and Google Scholar databases. Researchers seeking a more thorough examination of collaborations between HE and industry should consider expanding the

Table 6. List of used abbreviations.

HE	Higher education
HEI	Higher education institute
MMAT	Mixed Methods Appraisal Tool
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
R&D	Research and Development
RQ	Research question
WIA	Work-intergrated activity
WIL	Work-integrated learning
WoS	Web of Science

search to include additional databases, such as ERIC and Compendex. Second, in the initial screening phase, a single researcher selected the candidate studies. While all authors applied consistent inclusion criteria, having only one author conduct the initial screening may be a potential limitation. Furthermore, although consulting information specialists, creating a keyword search strategy for selected databases was challenging due to the absence of standardised procedures. The lack of standardisation made it necessary to construct search queries through trial and error, which might have created difficulties in conducting accurate searches. Google Scholar was chosen for its effective tools in improving the accuracy and precision of search terms and for assessing the relevance and effectiveness of search queries. We find that, although Google Scholar can retrieve a large amount of literature, it should not be relied upon as the sole source for systematic review searches due to decreasing relevance after 200 first papers. Since the review was limited to the first 200 search results, some valuable information may have been excluded. A variety of terms were used to enhance the search results and gain a deeper understanding of the research topic. Despite our best efforts, the broad scope of engineering, with its many subfields, may have led to the unintentional omission of some important articles. Additionally, two articles were excluded due to the lack of full-text availability.

The analysis of the articles required some interpretation in understanding the roles of different stakeholders in collaborative efforts. For example, if the role of HE staff was not clearly defined in collaborative efforts, but the paper topic referred to collaborating with industry partners to create a new course curriculum, it was assumed that teachers would also be involved. Similar interpretations were made when assessing benefits and hindering factors for different stakeholders, such as cases where HE institutions had difficulty finding suitable project placements for all students – seen as hindering factors for not only HE institutions but also for HE students.

Despite these limitations, our study has several strengths. The authors held weekly meetings to discuss the review's progress and resolve any ambiguities. The inclusion of studies from around the world enhances the comprehensiveness of our understanding of the research phenomena, facilitating geographic comparisons and underscoring the widespread interest in the topic. Moreover, by not restricting our database searches to specialised fields or methodologies such as qualitative studies of electronics engineering, we diversified our information sources. This strategy enriched our perspective, leading to a more expansive and nuanced comprehension of the topic.

The use of a risk-of-bias assessment improves the transparency of evidence synthesis. This transparency allows for a more detailed interpretation of the results, giving both researchers and readers a greater understanding of the evidence. In summary, the use of diverse sources, regular team meetings, and the inclusion of risk-of-bias assessments contributed to the robustness and thoroughness of our findings. Table 6 provides a list of abbreviations used in this study.

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