



Using communities of practice to investigate work-integrated learning in engineering education: a grounded theory approach

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Abstract

Industry worldwide calls for highly qualified STEM graduates that are ready to work. Work-integrated learning (WIL) has been implemented to address this need. WIL is a strategy to bridge the gap between theory and practice, and emphasize “employability.” However, students often perceive a confusing disconnect between their training and their workplace experience. This paper reports on a study of a graduate engineering course that uses a Communities of Practice (CoP) lens and a grounded theory approach to reconceptualize WIL. Data sources from 2017 to 2022 include 27 students’ responses from an open-ended survey and fourteen interviews with students, alumni, and employees from different construction sites that hosted students. Findings show that the articulations of the universities and companies should be centered on creating critical boundary objects and developing skills to allow students to become effective brokers. Furthermore, our analysis revealed that WIL is a bidirectional bridge where students can transfer their expertise through *boundary objects* from the company to the class and vice versa, becoming *brokers* who can participate in and mediate across the two communities. Companies should provide opportunities for *Legitimate Peripheral Participation* (LPP), where students can negotiate their increasing participation from peripheral to full members. The roles of universities, industries, students, and instructors in connecting the university and the workplace are described.

Keywords Communities of Practice · Work Integrated Learning · Graduate engineering students · Grounded theory approach

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Introduction

Several global policy documents emphasize the importance of aligning student training with industry needs, increasing participation in STEM careers, and addressing demographic biases in the STEM workforce (ABET, 2014; Engineers Australia, 2022; National Science Foundation, 2020). For instance, the National Science Foundation (NSF) highlighted in 2020 that “Urgent actions and long-term investments are needed in STEM Education and Workforce Development Research to establish an educational infrastructure that is modern and attracts, retains, and develops the diverse STEM talent.” (National Science Foundation, 2020, p.29). Similarly, Engineers Australia (2022) states, “Australia’s ability to train, develop and maintain a local engineering workforce needs to be significantly improved” (p.16). Integrating workplace activities into the curriculum has emerged as a crucial strategy to improve the training and match the industry needs in higher education. Unfortunately, research shows that graduate education does not prepare students to “translate their knowledge into impact” (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018, p.1). As a result, employers perceive that the skills of graduate students do not match their needs (Blom & Saeki, 2011; Ramadi et al., 2016); students feel unprepared because they lack field experience or competencies in their training (Pažur Aničić et al., 2023; Atkinson and Pennington, 2012), creating anxiety and a sense of not belonging at the beginning of their professional career (Jackson, 2014; Kolmos & Holgaard, 2019).

Several pedagogical approaches have been developed to better align the competencies developed in higher education with the needs of industry, notably work-integrated learning (WIL). WIL principles have been applied to design experiences that allow students to combine their classroom knowledge with practical skills needed for their job (Jackson, 2017; Jackson & Collings, 2018). WIL involves “splitting students’ education into on-campus training and placement-based training off-campus” (Björck, 2021, p. 308). This strategy was originally developed in Australia and has since spread widely, e.g., Switzerland (Schedin & Hassan, 2016), the UK (Ponikwer & Patel, 2021), and Canada (Dorland et al., 2020).

While WIL is a promising approach to produce better-prepared students, it requires further development, particularly at the theoretical level. Furthermore, research on WIL among engineering students has placed primary emphasis on employment outcomes and has thus focused on evaluating and measuring rates of employability produced by WIL experiences (e.g., Meglio et al., 2022; Callanan & Benzing, 2004; Bilsland et al., 2019; Ponikwer and Patel, 2021). Employability is conceptualized as preparation to carry out a profession’s daily practices and adapt to professional life (Björck, 2020, p. 310). Standard WIL approaches tend to be interpreted by students as implying a separation between theory and practice, academia and the real world, and studying and working, which then creates a gap that needs to be bridged (Björck and Johansson, 2019, Björck, 2021). Experts have called for a non-dualistic account of graduate employability that transcends these conceptual distinctions and polarization (e.g., Björck, 2021; Björck & Johansson, 2019; Orr, 2002).

In the WIL experience, two communities interact: companies and universities. Wenger’s Communities of Practice (CoP; Lave & Wenger, 1991; Wenger, 1998) provides theoretical tools to analyze how two communities of practice interact. Lave and Wenger (1991) state that “A community of practice is a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping Communities of practices.” (p.

98). CoPs develop where a group of individuals comes together around a common interest or purpose; participants become progressively more skilled in the practices of that community.

CoP theory provides a theoretical lens to re-conceptualize the purpose of WIL from preparing students to become employable (i.e., participants in the workforce) to providing a mechanism for greater interaction of two CoPs, with students learning to participate in both, becoming capable of becoming brokers across the two CoPs. In this process, boundary objects—tools, terminology, procedures used in both CoPs, albeit in different ways—play a key role. To empirically examine this process, we conducted a grounded theory analysis of 27 students' course evaluations and 14 interviews with students, former students, and employees of construction companies that hosted students, from a graduate engineering course. This research investigates WIL practices using the lens of CoP to conceptualize how the university and workplace function in WIL learning experiences. This paper is guided by the following question:

How do students, former students, and employees in a WIL course perceive the relationship between class learning and job site learning?

By answering this question, we aim to offer an alternative understanding of how workplace experiences can be effectively integrated into the curriculum, addressing the concerns raised by other researchers (Björck, 2020, 2021), and providing a better understanding of the role students, instructors, and companies play to implement effective WIL experiences. Using CoP, we valorize active student participation in the workplace to foster valuable and meaningful learning outcomes applicable in both the classroom and the company rather than solely preparing students for employment. Our study will also shed light on the significant roles played by students, workers, and instructors who are immersed in WIL programs.

Background

Definition of WIL

The definition of WIL is “Where structured and purposefully designed learning and assessment activities integrate theory with the practice of work” (Australian Government Tertiary Education Quality and Standards Agency, TESQA, 2022, p.1). WIL usually involves placing students in professional company environments, forming an interface between universities and industry that allows students to practice their disciplinary knowledge in a supervised and enriching work environment (Jackson, 2017). WIL is an umbrella term for approaches including UK's Higher Degree Apprenticeship (HDA) and Work-Based Learning (WBL) (Hughes & Saieva, 2019) and cooperative education (Co-op) developed in North America (Sovilla & Varty, 2011). In fact, TEQSA (2022) describes that WIL includes a wide variety of activities and duration, and some of the activities most commonly used are an internship, fieldwork, practicums, industry-partnered projects, etc. Co-op involves a partnership between an academic institution and employers to engage students in practical work through job rotations with full-time employment and formal classroom study (Main et al., 2021).

WIL in higher education: empirical research

To evaluate the impact generated by WIL, researchers have focused on the analysis of employability definitions and employment outcomes, nature and quality of work placements, types of skills developed, and co-construction of higher education coursework between faculty and practitioners in the field (Bilsland et al., 2019; Callanan & Benzing, 2004; Dacre Pool & Sewell, 2007; Ponikwer and Patel, 2021). For example, paid internships in the final year were found to increase full-time employment and improve employment quality (Jackson & Collings, 2018). More recently, Jackson (2024), analyzing an extensive data set from an Australian national survey ($n=152,226$), found that students' employment is influenced by work experience activities that universities arrange for students.

Participating in WIL further promotes the development of discipline-specific (e.g., programming) and professional skills, including communication and time management (Jackson and Bridgstock, 2021; Jackson & Collings, 2018). The environment created when different companies share a common space (usually referred to as a co-working space) in small to medium enterprises (SMEs) enhanced business students' enterprise skills (Jackson and Bridgstock, 2021). Social and cultural capital influence the quality of WIL experiences, highlighting the need for support for students from low socio-economic groups and marginalized communities (Clerke et al., 2021).

An alternative WIL approach simulates a professional environment in the classroom. Ponikwer and Patel (2021) utilized WIL principles to create an environment where students act as employees and entrepreneurs, selling chemistry products. Their longitudinal study on 109 chemistry students who participated in a 1-week WIL experience within the classroom showed a positive impact on students' communication, teamwork, and creativity. This experience enhanced their employability and satisfaction after graduation.

Supervisors in WIL experiences play a critical role (Jackson, 2024) as mentors but also because they are responsible for assessing students (Boud et al., 2023). Even though employers recognize WIL as a learning experience for themselves, it can demand much of their time. Additionally, Crawford, Brimble, and Freudenberg (2024) found that lack of communication and clarity of the purpose of WIL can negatively impact the participation of employers.

Theoretical bases of WIL

Despite the positive results and abundance of WIL studies, few papers explicitly use a theoretical or conceptual framework. Papers about the use of WIL in STEM disciplines (e.g., Ponikwer & Patel, 2021; Wilton, 2012) typically introduce WIL as the research framework and used labor-centric data such as industry needs for more workers, employability in recent graduates, and better salaries. Papers that do use a theoretical framework for WIL mainly use a framework that does not explicitly address the relationship between workplace and classroom learning. For example, both the work of Jones et al. (2017) and Carbone et al. (2020) draw on experiential learning (Kolb, 1984) to interpret the views of participants. Such frameworks do not incorporate explanations for how students learn to use professional tools or terminology or learn to participate in the academic and workplace settings, and only support improving skills that make students more employable but do not shed light on important processes or support fine-grained analyses (Díaz et al., 2022b).

Other studies, by contrast, have been built on theoretical frameworks closely related to the students' effect of participating in WIL. For example, Jackson and Dean (2022) draw on Bourdieu's (1986) conceptualizations of social and cultural capital to understand why participation in employability-related activities may vary across student groups. Similarly, Paull et al. (2019) use the social theory of practice frames (Bourdieu's (1977, 1990; Tomlinson, 2017) to understand how the five interdependent types of capital (human, social, cultural, identity, and psychological) influence students' access to a WIL experience. Finally, other investigations use WIL as a pedagogical methodology (e.g., Perez-Encinas & Berbegal-Mirabent, 2023) distinguished by earlier exposure to real environments.

More specific theoretical frameworks for the WIL study come from economic theory, especially the interpretation and study of employability (e.g., Björck, 2020; Wang, 2008; Young et al., 2021). For example, Björck studies how companies' neoliberal perspectives on the definition of employability introduced in the early 1980s continue to be present in the discourses promoting the use of WIL strategies. The author used a Foucauldian approach (1972) to evaluate discourse and power under the WIL description. Similarly, Zemblyas (2006) used the Foucauldian approach to analyze the accommodation of students' power in a WIL experience. In sum, a multiplicity of theoretical and practical perspectives have informed WIL, but papers on WIL in STEM disciplines have failed to fully explicate the processes that enable students to become more prepared for the workplace, what preparation for work actually means, how students must adapt to organization dynamics and cultures, and none have the specificity and granularity to inform the design of effective WIL experiences based on student's aspiration, motivation, and potential work (Lester & Costley, 2010).

Practical challenges associated with the implementation of WIL strategies include the lack of evaluation tools (McNamara, 2013), the impracticality of current approaches to assess student performance (Ajjawi et al., 2020; Ferns & Zegwaard, 2014; Higgs, 2014), and lack of guidance for the principled design of authentic learning experiences (Ajjawi et al., 2020). In addition, fundamental issues of conceptualization remain unresolved. For example, WIL papers frequently aim to eliminate a perceived *gap* between theory and practice between the university and industry (e.g., Jackson & Collings, 2018; Immerstein et al., 2019; Bilsland et al., 2019; Ponikwer and Patel, 2021). However, this viewpoint has been extensively criticized as it created a discourse where knowledge learned in universities is purely theoretical (Allan & Evans, 2019; Baldvinsdottir et al., 2010; Björck & Johansson, 2019; Orr, 2002). Students are the most affected by this confusing discourse because they interpret the knowledge acquired in the university as knowledge devoid of practice and infer that the universities are only a source of theory (Björck, 2020, 2021).

Moreover, merely being in a workplace does not ensure significant and meaningful student learning (Sadler, 2009). We share the perspective that learning is situated: "...learning is not merely situated in practice... learning is an integrated part of generative social practice in the lived-in world" (Lave & Wenger, 1991, p.35). Sadler (2009) highlights that even though students, by practicing in professional CoPs, can learn tools or software used in the professional CoP, they may operate those tools mechanically. If students just use those tools to complete a task, they may fail to understand the tool and the meaning of the tool for the community, nor will they be able to leverage the concepts and theories learned in the university to enable more creative, productive, and principled use of those tools. Thus, WIL experiences that focus on learning-to-operate tools do not help students bring new ideas to the industry or the class. Unfortunately, the distinction between operational learning and the critical conceptual/theoretical aspect of learning has been very limited in the discussion of WIL (Ajjawi et al., 2020).

Communities of practice

Lave and Wenger (1991) presented the idea of a community of practice as a group of people who share purposes and methods. The CoP framework emerged from situated contexts where people can engage in an activity: they negotiate, participate and share different meanings, tools, symbols, concepts, procedures, criteria, etc. (Wenger, 1998). The process in which students join a new community and develop learning is called *Legitimate Peripheral Participation* (LPP): “mastery of knowledge and skill requires newcomers to move toward full participation in the social-cultural practices of a community.” (Wenger, 1998, p. 29).

Lave and Wenger (1991) posit that learning does not involve the absorption or construction of general, abstract schemas, but rather manifests in activity. *Learning* is an outcome of involvement, engagement, participation, and practice in social activities. This paper will use the term *learning* to cover both traditional understandings of increased knowledge and CoP perspectives of expanded participation.

The interaction between two communities of practice is mediated by *brokers* and *boundary objects* (Wenger, 1998). A *broker* participates in two communities and can introduce elements from one to the other. The task of individuals connecting two communities is challenging since they must adapt the language, align perspectives between communities, coordinate tasks, etc. (Baas et al., 2023). The effectiveness of a *broker* is also determined by the degree of participation in both communities. For example, an individual fully involved in both communities can transfer more ideas and disseminate effectively within and across both communities.

Boundary objects are artifacts, documents, terms, procedures, and concepts through which CoPs organize their connections and lay the foundation for their practice. To facilitate students’ transfer between the university and industry, curriculum learning outcomes must align with the industry’s work and make explicit connections by promoting the same tools, procedures, and concepts.

In order to fruitfully establish coordination and connections between academic and professional CoPs, Ajjawi et al. (2020) suggest that *boundary objects* and *brokers* are critical: “we can conceptualize the university and work setting placement as two ‘communities’ ... connections can be made through boundary objects and brokering” (p.313). In the next section, we will respond to this call and expand the conceptualization of WIL through a CoP lens.

Describing WIL through the lens of CoP

WIL programs involve two CoPs: one CoP centered on the workplace and another centered around the university course. Both the broader university and the entire company have multiple communities of practice; for example, the university has departments and courses that likely host many communities themselves, and many communities may extend across departments. Every community has its own objects, which are interpreted in their context. However, when two communities have the same objects but use them for different purposes, they are called *boundary objects*. In order to connect an academic CoP with an industry CoP, it is essential that they have some shared tools, software, procedures, etc., even if they are used in different manners.

From a theory–practice perspective, students learn new practical tools by participating in the WIL experience. Following CoP theory, students will instead need to *reinterpret* and

redefine each boundary object according to context. The generalized and abstract knowledge gained in the classroom allows greater understanding and adaptability when using these in a concrete setting. Students will not only go to companies to learn *practice*; using the CoP lens, students actively develop *brokerage* skills by transferring ideas, concepts, etc., from the university to the workplace and vice versa, as well as learning to contextualize shared *boundary objects* according to the specific CoP. CoP theory enables us to interpret and explain the WIL experience with greater granularity, supporting a better understanding of the role of students, and allowing a full description of the relationship between a university course and companies that avoids the dualistic discourse commonly featured in WIL. Figure 1 shows interactions and connections between the university and the company using the theory–practice perspective other authors have used (Fig. 1a) and using CoP to reconceptualize the connections between universities and companies by boundary objects and brokers (Fig. 1b). Through the CoP lens, learning is described as an outcome of active participation in a social environment. Differences in learning across companies and universities may in fact occur, but those are because the objects are different (rather than practice–theory differences). To become a central member in an industry setting, students must master objects (procedures, software) commonly used in companies that may not be used in university practices. WIL experiences aim to connect classes and companies through those critical objects that are not in universities and provide opportunities for students to participate in real social environments that require those objects for participation (which leads to learning outcomes).

WIL implementations currently may not provide structures or mechanisms to support students and ensure their *participation*. Mechanics of support are essential to avoid and reduce the different risks involved in having students in the workplace (Odlin et al., 2022). Although students can observe the workplace activities, or learn how to use software or new procedures, this alone does not have significance or meaning from the students' perspective if they are not engaging (Sadler, 2009). However, it is critical that companies and universities offer a *Legitimate Peripheral Participation* (LPP) where students can negotiate their participation and become more central members. Without an LPP, no matter how much time students spend in the companies, WIL will not create the desired connection and articulation. Their LPPs may be impacted by, and the degree and type of support may vary based on, students' ethnicity, social-economic class, and gender as well (Wang, 2008).

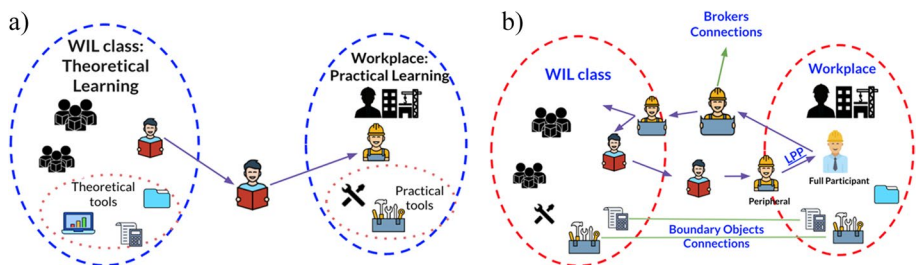


Fig. 1 Diagram of interaction in a WIL experience. **a** Theory–practice perspective: “Theoretical” ideas, tools, terms, procedures learned in academic settings by students; student then arrives at the workplace where these are used differently if at all, resulting in a “gap” and the need for “practical” learning on the job. **b** WIL through CoP lens: ideas, tools, terms, and procedures disseminate across both CoPs, through *brokers* who are participating members of both CoPs

In summary, as CoP highlights, it is necessary to successfully support students as they learn to participate in both university and industry, i.e., to prepare and support novices to move from peripheral members to core members of a professional community, to learn to use *boundary objects* in both contexts appropriately and develop *brokerages* skills to transfer their knowledge from one community-context to another effectively. Instructors may select a workplace where students must use professional *boundary objects* in common between both CoPs but reinterpreted in their CoP context. Conceptualizing WIL through the CoP lens provides specific, actionable directions and mindsets (e.g., the student can bring ideas and tools from the workplace back into the classroom) and responds to the issues highlighted in the literature of dualistic discourse on graduate employability and the gap between theory–practice prevalent in WIL literature (e.g., Björck, 2020, 2021).

Methods

Research context

This research used data collected between 2017 and 2022 in the course Building Information Modeling (BIM) in construction. This course is offered to graduate engineering students (master's and Ph.D. level) at a public, research-intensive mid-Atlantic American university. The course objective is to use BIM to support practices of construction management. BIM software can visualize construction progress (what happened) and plans (what will happen) using 3D, 4D (adding time as a variable), and 5D (adding time and cost as variables) in the entire project. The BIM tools taught in classes were Revit and Navisworks (Autodesk application, Architecture, Engineering & Construction Collection). In the course, small groups of students were assigned and placed physically at workplaces—ongoing construction sites. In some but not all cases, companies were already using BIM software. Placement sites were carefully selected by the instructor based on multiple characteristics, including availability, distance from university to construction site, and stage of construction. Participating companies varied from year to year based on the same characteristics.

Participant

Every fall semester BIM course receives around 21 students on average. The highest number of students was in 2017, with 30 graduate engineering students, and the lowest in 2021, with 18 students. In 2020, the course was suspended due to the COVID-19 pandemic. The historical university record reveals that 85% of the students are from India or Central Asia, 6% are Hispanic, 6% are from East Asia, and 3% are White US students. Additionally, the university records show that 78% of the students are identified as male and 22% as female (only binary gender descriptions were available).

Data sources

Course evaluations

Seventy-seven students' anonymous course evaluations, which measured students' perceptions at the end of the course in fall 2017, 2018, and 2019, were analyzed. The course instructor designed the evaluations without a specific educational theoretical framework but with help from a STEM Education faculty member. The survey consists primarily of open-ended questions around the axes of experience with on-site visits, company interaction, site-course alignment, and reflection on the course. Additionally, the instrument has two closed questions about dedication and if they had previous experience in on-site work. The course evaluation is provided in Appendix 1.

Students' interviews at the end of the semester

We interviewed five students who took the course in 2021, individually and over Zoom. The course structure, learning outcomes, delivery, and instructor did not change between 2017 and 2021, but the companies and projects that students were assigned to change every semester based on company availability and willingness to participate in the course. In 2020, the course was not offered because of COVID-19 restrictions. The interviews were carried out in November and December 2021. The interviews were semi-structured, and the protocol was built based on the preliminary analysis of the course evaluations as well as CoP theory. The full semi-structured protocol is in Appendix 2.

Former students' interviews

Five former students who took the course between 2017 and 2019 were individually interviewed 3–5 years after graduation. They were all working in the construction industry after graduation. They were participants of the aforementioned course evaluations. University academic information and LinkedIn were used to get the student's contact information. The semi-structured interviews lasted between 45 and 60 min and were conducted in March 2022 via Zoom. An interview protocol was developed using the analysis of course evaluations, CoP theory, and interviews conducted with the students who took the course in 2021. The full semi-structured protocol is in Appendix 3. These interviews provided insight into the role of the course in preparing students for the workplace.

Employees' interviews

Four company workers who hosted the students in fall 2017, 2018, and 2019 were interviewed. They are BIM coordinators, superintendents, or project engineers. Contacting company workers was difficult because many had already changed companies. Interviews were carried out in March and April 2022 after the interviews with the former students were completed. None of the five workers interviewed participated in hosting students in the 2021 version of the course. The full semi-structured protocol, developed in a similar manner as the other protocols, is in Appendix 4. These interviews shed light on the workplace CoP and whether and how students engaged in LPP and brokering.

For all interviews, the automatic transcript of the interview provided by Zoom was corrected to ensure accuracy by the second author of this paper, a Ph.D. and native English speaker.

Class material and instructor perspective

The materials generated from the course were analyzed. For example, students' weekly reports and mid-term and final reports and presentations were used in the analysis. Those documents provide a summary of students' progress, problems faced by students, and a full description of the company's projects. The instructor is part of the research team and one of the authors of this paper. The instructor's perception and notes that he collected during all versions of this course were used to illuminate and interpret the emerging themes. The instructor's perspective helps understand the technical details students describe during the interview or other material analyzed. We did not code the instructor's informal observation as a whole; we just came to them with specific questions that helped to interpret the results thoroughly.

Data collection flow

A grounded theory approach was used to analyze the 5-year data from the WIL course. The data were collected and analyzed in a series of iterative stages. The analysis started with the 77 course evaluations and then incorporated the interviews with students, former students, and employees. Figure 2 shows the flow of the data collection and analysis.

Data analysis

This study followed a constant comparative method (Strauss & Corbin, 1998) for data analysis. The data were collected and analyzed in iterative stages (see Fig. 3). Initially, the analysis started with the course evaluation, where the data was broken down into dimensions (i.e., on-site visits, company interaction). Open coding was used by examining the data closely and comparing for similarities and differences. This examination resulted in the generation of sentences or small paragraphs of text, which were then assigned labels such as company benefits, and soft skills. Then axial coding takes place by associating the previous labels with concepts from the WIL framework. For instance, if students commented that the course helped them understand real construction practices, times, and how problems appear in real construction, these findings were categorized as *field experience*. Based on the results of this preliminary analysis, an interview protocol was developed for students at the end of the course.

Students' interviews were analyzed as open books. First, using open coding, the text was broken down into paragraphs, and each section was assigned a code aligned with relevant concepts from the WIL literature. For example, text describing company benefits were associated with the code *win-win*, as it represents a situation where both the company and the university derive benefits. The results of this preliminary analysis were consolidated into a preliminary codebook (Codebook V1 in Fig. 3), which informed the development of an interview protocol for former students and employees.

The analysis of employee and former student interviews followed the same procedure as the student interviews. During this analysis, new codes emerged that were not directly supported by the existing WIL concepts. For instance, while students mentioned learning

software in the company (initially coded as a *discipline/technical skill*), they did not reflect on how it related to the course outcomes. However, former students described how some of those tools were also available in the course but had different uses or meanings within the company. Drawing support from the CoP theory, these tools were recoded as *boundary objects*, indicating their role in connecting different CoPs.

After the initial codes were generated, we looked for associations between them, merging similar ones as well as generating subcategories for others. For example, connections can be distinguished between connections made by objects (connections by *boundary objects*) and people (connections by *brokers*), so we generated those two subcategories of connection. On the other hand, the code *Technical skills* and the code *Personal skills* were merged under the umbrella term *Employability skills*. All new codes (including sub-codes) were consolidated into Codebook Version 2.

To ensure we extracted all information from the data, a second coder reviewed a small sample of the data independently. This analysis aimed to saturate the information and ensure that no further emergent themes were present. The inclusion of two coders was intended to strengthen the saturation process. The same coder was also used to improve the reliability as described in the next section.

To improve the codebook, CoP and WIL concepts, definitions, descriptions, and exemplary examples were used. This leads to a final version of the codebook (see Appendix 5. Table 1).

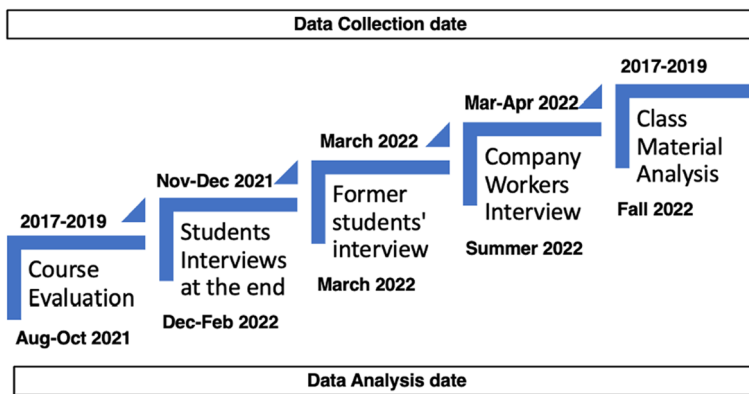


Fig. 2 Data collection flow and data analysis

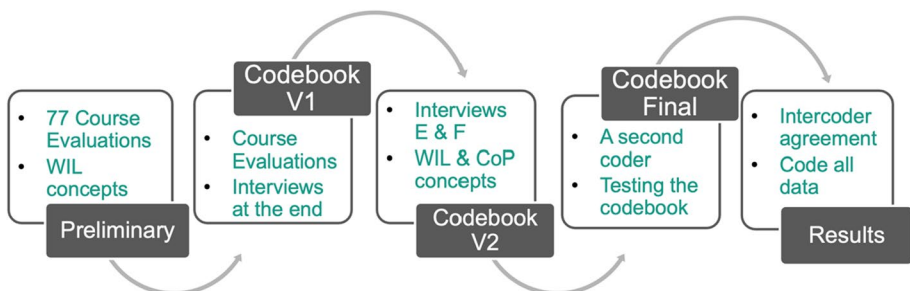


Fig. 3 Data analysis process. Note: E, employees' interviews; F, former students' interviews

Validity and reliability

The class evaluations were designed by the course instructor with the guidance of a Ph. D.-level science educator and the second author of this paper. Interview protocols were designed with the research team, including the PIs and the research assistant, all authors of this article. Our previous study (Díaz et al., 2022a) assessed the instruments used, finding that interviews and course evaluation offer accurate, informative, and appropriate results.

To evaluate the reliability of the analysis, we followed the description of Guest et al. (2012) “Two analysts, using the same codebook, independently apply codes to a section of text. In most cases, this will be a few transcripts from in-depth interviews or focus groups” (p.13). Furthermore, the final codebook was applied with two independent coders using five course evaluations, one student interview, and one company worker interview. These data were selected as a representative sample of total data resources. Using two independent coders improves reliability. An intercoder agreement (ICA) metric was calculated according to the procedure described by Guest et al., (2012, p.13) to evaluate the reliability of the analysis and interpretation, obtaining over 85% agreement. Then, all the data was coded by one coder using the final codebook and Taguette system (Rampin & Rampin, 2021).

Results

Students’ perspective at the end of the course

Boundary objects

From the analysis of the course evaluations, 57 students (74% of total responses) highlighted that the central relationship and connection between the class and the workplace is the opportunity to use tools or software (e.g., Naviswork and Revit). One commented, in response to the question “Please identify areas where the course lectures and exercises aligned well with actual practices on the construction site by giving examples”:

3D modeling, Navisworks scheduling (4D BIM), Clean Detection practices (Student #8, 2017).

Softwares we learned in class were same as company was using. (Student 60, 2019)

In CoP terms, these 57 students see the relationship between the class and the workplace as based on *boundary objects* (the software). One student mentioned, “it was nice to learn a software then utilize it on site” (Student #34, 2018). Other students reflected on how those *boundary objects* may be used differently depending on the context, “During our site visit in [deleted] company, we interacted with the project engineer...told us how they plan construct and control the project, *how BIM implemented in the project*, Through discussion with them. I had a better understanding of BIM” (Student #42, 2018, emphasis added). Similarly, some students encountered 5D (i.e., space, time, and cost) software being used on the construction sites, whereas only 3D and 4D software were covered in the class.

Brokers

The students also had an opportunity to present and share their experiences from the workplace with the class. For example, student #52: “I do felt I connected both the group. We implemented teaching from course into the jobsite and learning from jobsite into the course work (2018).” This student describes how this course experience allows them to develop a bi-directional brokerage skill to connect the learning goals from the class to the company and vice-versa. Indeed, their experience included new ideas, workflows, and technologies they helped their companies implement. A team talked about how they observed drones being used by company workers to scan the construction site. Another team presented the use of a new mobile application their company wanted them to try, which the company ended up using even after the course was over. Class presentation facilitates the effective transfer of knowledge and ideas between the company and the class, creating a bidirectional exchange. The instructor of the course also benefits from this bidirectional dissemination, as he can use these examples as effective case studies for future students.

Finally, some students mentioned disseminating tools and ideas from class to the workplace, noting that they introduced Navisworks (software taught in class) to the company:

Yes, we [student and company workers] talked this idea [implementing Navisworks] to [company name deleted] company. They thought it is a great idea to improve productivity, currently, they do not use Navisworks to do facility management and they may adopt it in their next project. (Student #42, 2018)

Those multiple examples show that tools and ideas were transferred in various possible directions: introduction from class to workplace; from workplace to class; and where present in both, with differences in application depending on context.

Participation

All the 77 students (100%) felt welcome to the construction project. For example: “Yes, every time we went on-site, our project engineer welcomed us warmly” (Student #68, 2019). Additionally, 72% of students describe feeling welcome and able to interact with other company workers, as one student remarked, “we did spend time with subcontractors to learn different challenges on other projects as well.” (Student #32, 2018). The other 38% did not explain why they felt welcome; the typical response to the question “Did you feel welcomed?” was only “Yes” (Student #1, 2017).

Forty-seven students (61% of total responses) disclosed that they spent extra time in the companies to be more involved in the company, its organization, and get to know more workers (not only their supervisor), which helped them obtain more knowledge. “Talking about the problems and progress beyond the assignment. For instance, once we discussed the lack of [company name deleted] subcontractor at [company information deleted].” (Student #64, 2019). Using CoP concepts, the students became more central members of the company (“insiders”).

Only 28 students (36% of the total) described that they had previous work experience. Interestingly, five international students pointed out that on-site work allows seeing how things work in the US construction industry, for example: “Learn how US construction works like weekly meetings, terms of work.” (Students #16, 2017). They had previous experiences working with the software and in the industry back in their country; however, the techniques, procedures, and tools used in the US are different. Even though the course

includes a high number of international students, only those five students clearly stated that they had prior international experience.

Professional skills

Only four students (5% of the total) highlighted that the relationship between the class and the site offers the opportunity to develop professional skills, mentioning that the experience helped them to develop coordination and communication skills.

Communication. Expressing your opinions- Making yourself worthy to be heard. Coordination between various stakeholders. Understanding sequence of operations and sub-contractor issues. (Student 5, 2018).

Communicating with different people on-site from project manager to superintendent. (Student #71, 2019)

In summary, the relationship perceived by the students at the end of the BIM course was mainly an opportunity to transfer expertise through professional engineering tools learned in class to the real industry. Some students describe a bidirectionality of this connection. For CoP lens, the WIL strategy was related to transferring expertise by using *boundary objects* and developing *brokers'* skills in dealing between the class and the company. The student's perception of the WIL experience is related to their previous work experience. Indeed, 64% of the students who had not had previous work experience perceived benefits from being on-site compared to their peers with previous work experience. Students who had previous industry experience outside the US were also able to get the opportunity to reinterpret their previous experience in the US context.

Former students' perspective

Boundary objects

Similarly to students' perspective, all five former students highlight the connection between company and university based on *boundary objects*. Former students described adapting and transferring learning from one community to another:

we were able to do the animations then Navisworks and also we used to go on the field, which was very good, because I, to be honest, like, I came from India, so I had no. Knowledge about how the construction takes place in US... I was able to learn different softwares, and right now I was using, so we are using Naviswork to clash those. (Former Student #2)

Student #2 describes how Navisworks, software introduced in the class, works as a boundary object to connect the class to the company. In contrast, student #5 discussed a case of boundary objects from the company to the university:

I learned about the point cloud, I knew about IFC's but then we were asked to align the point cloud to the IFC files, so that was the first time I was getting exposed to it and the laser scanning. ... I have already done some laser scanning and I have helped the team to develop the scans that they needed and then, there was the sinker exercise that we did, It was a one class thing. (Former Student #5)

Industry Foundation Classes (IFC) is a file format used in different BIM software to interface architecture, engineering, and objects (e.g., walls, windows). The company asked the student to learn a technology (Laser Scanning) that had not yet been taught in class. The previous experience allowed her to support her classmates when this technique was taught in the classroom.

Participation and mentorship

Former students also described how their participation in the company was negotiated. For example, one former student said:

We were not aware of who we will be dealing with or who will be the people. But slowly and steadily we started talking and like we got engaged, we were made a part of the weekly meetings which used to happen on the side, so we got in touch with the project managers, we got in touch with the superintendent there. (Former student #1)

Students started as peripheral but legitimate participants and became insiders when they became more involved in the company, as by described by CoP.

An interesting case was a former international student whose first language is Spanish. He described that despite his initial limited English communication, he realized that speaking Spanish in construction is an advantage. He said:

I can tell you, like being a Latino in the construction is actually an advantage. You can talk with everyone so. (Former student #3)

In this case, the language gives him a membership which helps him to become a full participant. Interestingly, this student was hired by the company after the course. After 3 years, he is still working in the company.

Professional skills

All former students highlighted that this experience allowed them to use *boundary objects* (e.g., software), learn to participate and get to know old timers, and develop professional skills, similar to the students' opinions on the end-of-course evaluations. However, they also frequently mentioned working collaboratively with their peers, something that no students interviewed at the end of the course mentioned. From the perspective of having had the course 3–5 years earlier, former students valued collaboration, coordination, communication, and leadership skills:

I learned was teamwork. Because we were divided into groups of three ... the best thing that we learned was teamwork, how to work in a team and how to collaborate and bring something good out of there, ... the second thing comes was like communication and leadership, I would say. (Former student #1)

In summary, former student interviews followed a similar pattern as the course evaluations, with emphasis on *boundary objects*, participation, and professional skills, but highlighted collaboration, teamwork, and coordination. They described the experience as a good approximation of the real situation and traced their actual employment to the course in some cases. While being involved in their course project, students constantly negotiate their participation in the company. Companies need to offer a pathway to LPP to the students. Personal characteristics of the students (for example, speaking Spanish or prior

experience in the construction field) can facilitate their negotiation of participation and establishing relationships with other company workers as *brokers* among two classes of workers at the company. Students who successfully navigate the LPP in the companies can produce an impact on the company and be hired. *Brokers'* skills are transferable to other similar interactions between communities.

Employees' perspective

Bidirectional dissemination of ideas and win-win

Employees stated that they designed activities to be completed by the students without the input of the course instructor. We recommend closer coordination, with the instructor providing the course's learning goals to the company supervisor so activities can be designed accordingly. In most cases, the workers asked the students to learn and use new software that complements what students use in the class, positioning the software as a *boundary object*.

WIL posits that the relationship between the course and the company can and should be a win-win situation. The data used in this study show that the course's benefits consist of improving students' skills by practicing tools and skills learned in class in a professional environment. For example, company worker #2 mentioned that one of the values of this experience is gaining hands-on experience on-site "What I've seen, that was definitely very valuable to be able to let the students come on site and be able to get some, you know, hands on experience, if you will." Similarly, company worker #3 describes:

Students haven't even had that opportunity yet and this project [course project] is an opportunity for them to get a taste of it without actually, you know, walking into the job the first day and you know, being overwhelmed. So I think in that regard it's it's a good way to get themselves acclimated so (Company worker #3)

The benefits for companies can be to reduce time-demanding tasks for their administrators, learn new software that may be developing in academia, establish stronger connections with universities, recruit students, and test new tools. One worker talked about developing connections:

They [students] helped me get into contact with a couple people within the university ... they helped me with some things too as well as you know, developing my relationship with the university as well. (Company worker #3)

Another worker mentioned new developments in the field:

We had them [students] track some production values for us like ... if somebody does this activity, how long it takes and what is the amount of man hours that get spent that way we can get a better understanding of cost.. Multiple phases of construction work, so I think when we use them when they [students] worked with us during that semester, it was very helpful for us to understand some of the changes, a about the things happening in the field as well. (Company worker #4)

The impact on companies could take some years to appear. For example, employees asked to describe the students' impact on their company stated that the students, at the end of the experience, made several future-facing proposals that were interesting to them. Although it was not possible to implement them in the current project, they were implemented later:

the students gave their report ... we think that this is a cool tool, but there are a lot of glitches with it right now ... I went on to my next project.... I'm like, "well hold on hold on, we had a student group at [deleted] that ... do exactly what you're trying to achieve without all of this extra work" ... started using it, and it took off and now we're using it on like a national level. (Company worker #1)

This example shows how ideas that came from the course CoP then disseminated across the company's project engineer CoP.

Participation and mentorship

Employees see themselves as a mentor for students. However, only one of the four interviewees also showed a *sponsorship* relationship. *Sponsorship* is defined by Wenger (1998) as older learners who help newcomers by providing backup and support to become full participants in the community. While the other interviewees supported the students, they did not necessarily connect the students with other company members. Only having one company member interact with students positions the students as peripheral members; if they do not have contact with other members, they will not become full participants.

In summary, the relationship perceived by company workers is a win-win situation. University's benefits are providing students with an opportunity to practice their skills and knowledge in a real context. However, companies' benefits could take longer to manifest (2–3 years). For this reason, it is relevant to use a mid-long-term measure for the WIL experience. In addition, workers sometimes have a *broker* role where they personalize some class outcomes based on the company context and their experience, generating a more stimulating experience. Employees in charge of liaising with students should go beyond mentorship to sponsorship, encouraging and supporting the creation of ties to multiple company workers to support a pathway to LPP during WIL and beyond the course.

Merging students', alumni, and employees' perspectives

The primary relationship between the classroom and onsite learning is an opportunity to develop *boundary objects*. Software or construction technologies were the main aspects for students who had just finished the course. However, for former students, teamwork, communication, coordination, and the opportunity to generate new professional networks stood out more. The different perceptions of the WIL experience also were found by McManus and Rook (2021), where recent students value the development of specific skills rather than former students' emphasis on skills like teamwork or communication. Company workers sought to incorporate new objects for students to practice, which could benefit companies over a longer timeframe, with the impact potentially spreading from the specific construction site to the whole company.

Applying and transferring objects between communities, students developed *broker* skills. Students transfer new ideas, concepts, and software to companies, and these new ideas can benefit companies (Ajjawi et al., 2020). However, the situation can be bi-directional, with students learning about tools or procedures at the company that may then influence their individual learning or the course as a whole. To create a synergistic relationship between class and industry, there must be an overlap in the tools, procedures, terms, etc., that can be developed into boundary objects. Additionally, companies must provide an

LPP that allows students to become full members by negotiating their participation (Sadler, 2009).

Students who effectively become full participants will develop a sense of belonging to the company and will have more chances of creating direct benefits for the company. For example, former student #3 describes, “the benefit of the BIM course was that you were doing the whole semester, so it wasn’t one or two visits. It was actually every week. So that gave you I mean at the end of the day, feel like part of the company right, and you know the company felt from you, because every day, you know something.” (Former Student #3). In fact, companies are more likely to provide LPPs motivated by a win–win situation. Xia et al. (2015) also show that project-based WIL could create a win–win situation for companies, students, and academic institutions if all those stakeholders are engaged in the project and share similar expectations. Nevertheless, industries’ benefits can take years to show up.

Brokers’ capacities can be used in similar situations. Indeed, students who effectively transfer objects between the university and company, will use those skills when they need to have a broker role in other similar situations. For example, a former student said:

Who is handling the project, so it was really a good experience and also along with that I was able to learn different softwares, and right now I was using, so we are using Naviswork to clash those. During my vdc career I’m using Naviswork to clash, to run clashes on the model, so that was what also, I learned it from BIM course so it’s like a useful thing. (Former student #2)

Additionally, students will have a better transition and adjustment when they enter the workforce after graduation.

I had no experience about how to use Revit. So when I started taking instructions like when I started taking the CE 592 [BIM] course, so I was introduced to the software. And slowly and steadily like I went on to use Revit and modeling and learned its various functionalities, used different platforms like and or what the lectures, attended the lectures and everything. Went to job sites, and this helped me when I joined my company. I was allotted, I got asked to design a columbarium so I knew like this command does this, this command does this, and this helped me a lot. (Former student #1)

Additionally, as former student #3 commented, he was hired by the same company right at the end of the course, and after 5 years, he still works at the same company, showing that the *Broker* capabilities will allow them to get jobs and improve their adaptation process. While this may superficially sound like “increased employability,” the bi-directional nature of disseminating ideas, tools, etc., is better explained by the CoP lens.

Discussion

While the literature has discussed the empirical benefits of implementing work-integrated learning (WIL) in higher education, there have been critical issues surrounding the conceptualization of WIL strategies. For instance, Björck (2020, 2021) has criticized the dualistic discourse surrounding WIL as a strategy to bridge the theory–practice gap. Additionally, justifying WIL practice based on its situated learning nature does not guarantee that the learning experiences will be meaningful and significant for students (Sadler, 2009).

Furthermore, Ajjawi et al. (2020) discuss the importance of establishing clear connections between the curriculum and the activities students engage in within companies to ensure authentic WIL experiences. Similarly, according to Odlin et al. (2022), establishing clear connections and agreements between the university and workplace is key to mitigating the risks associated with internships, creating a safer environment that will be a more beneficial experience for the students.

Through data analysis of 27 course evaluations and 14 interviews with students, former students, and employees, this research demonstrates that this new conceptualization can address the issues highlighted in the literature.

Our conceptualization also takes into consideration the two factors proposed by Hagvall Svensson, Adawi, and Johansson (2022) for designing an authentic work experience: legitimacy and student participation. However, contrary to their findings, our interviews with former students showed that student engagement and participation contribute to enhancing critical thinking about engineering as a profession rather than limiting it. We attribute these differences to our conceptualization, wherein the instructor designs an experience that fosters bidirectional learning. Indeed, this bidirectional approach allows students to reflect on their participation in class and how the overall experience contributes to their professional development.

Furthermore, this conceptualization emphasizes the significant role of companies in offering *legitimate peripheral participation*, where students can reinterpret *boundary objects* and develop *broker* capacities (Ajjawi et al., 2020), as well as the framework in which students negotiate their participation (Wenger et al., 2002). The development of *boundary objects* in WIL experiences is also key. From the students' perspective, *boundary objects* mainly consist of professional artifacts (e.g., software) that can be learned in a company, while former students highlight the importance of professional skills (e.g., communication, teamwork, leadership) and their essential role in real-world environments. Additionally, successful WIL experiences should allow students to develop bidirectional *broker* skills by initially transferring ideas, knowledge, and concepts from the classroom to the company, and subsequently practicing and becoming more integrated members of the company, thus transferring knowledge from the company to the university. In a prior study by Baas et al. (2023), the essential role of brokers in fostering inter-institutional communities was described, with a specific focus on how teachers can facilitate connections between institutions. Building upon their research, we discovered that students can also effectively establish inter-institutional connections. However, we found that this is only possible when they receive appropriate support in both communities involved in the project.

An important discovery was made by analyzing retrospective interviews: students generated benefits to the company 2 to 3 years afterwards. Companies can hire students who finished the WIL programs and utilize students' new ideas for their internal benefit. Companies must have evaluation standards or procedures to assess their medium- and long-term benefits (Boud & Falchikov, 2006). Similarly, universities should use a mid-long term to evaluate WIL experiences. Conducting interviews 2 months afterwards, as done by Clegg and Diller (2019), may not capture these impacts. Evaluations should add follow-up student interviews after a year, or even longer where feasible.

Finally, WIL experiences should be evaluated in terms of the *boundary objects* involved; the LLP offered by companies, the student's capacity to bring new company objects to the course, and mid-long-term benefits to both the workplace and university. The design, evaluation, and research of a WIL course must consider and merge the perspectives of all actors (students, instructors, employees). We also expect that the interview protocols and codebook developed in this study can serve as helpful resources for other researchers.

Conclusions and future work

Drawing from the theoretical framework of the CoP, this research analyzes a graduate engineering course that aims to establish a connection between the university and local companies. Data collected from 27 students through open-ended surveys between 2017 and 2019, 14 interviews were conducted in 2021–2022 with current students, alumni, and company supervisors, and the instructor's notes, observations, and perceptions were analyzed using a grounded theory approach. Our results allowed us to reconceptualize WIL. Instead of viewing it as merely a way to bridge the gap between theory and practice, we now see WIL as a vehicle for bidirectional learning and teaching where students can reinterpret *boundary objects* and develop brokering capacity.

Companies must be encouraged to provide an environment that uses legitimate peripheral participation so that students can negotiate their participation and become full members of the company's community, fostering a sense of belonging through the field experience. Instructors should offer clear guidance and establish contacts with company workers to align their learning experiences with course outcomes. Companies can benefit from WIL experiences by potentially recruiting students, reducing costs, fostering connections with academia, learning about cutting-edge developments, etc. Supervisors in companies play a dual role as mentors and sponsors, introducing students to other workers who can help them develop further.

Developing *boundary objects* and *brokerage* skills in WIL is crucial. Former students' valued boundary objects as professional skills, and current students appreciate the relevance of professional artifacts acquired from companies or reinterpreted on-site. *Boundary objects* and *brokerage* skills development through WIL experience impact the future students' work experience.

Future work will look at the opportunity to expand and how we could adapt the results of this research to other disciplines. For instance, while the engineering construction course analyzed in this research highlights the importance of physically situating students in a construction project, other disciplines (e.g., computer science) may not require such physical placement in companies. Similarly, courses conducted during the COVID pandemic were frequently taken online. In such cases, the focus of an effective online WIL experience should be on promoting the development of new digital skills perceived that allow to bridging the gap perceived by recent graduates highlighted by Pažur Aničić et al. (2023). Indeed, to align WIL experiences with the learning outcomes and needs of other disciplines, a more effective approach would emphasize the connection of boundary objects rather than develop students' brokerage skills. Therefore, our future research will investigate how various arrangements between companies and universities can lead to different models for implementing WIL that match specific learning outcomes.

This research has primarily focused on understanding and conceptualizing how communities—companies, and universities—can be interconnected. However, government agencies also promote some arrangements aimed at connecting students to real-world environments. For instance, higher degree apprenticeships in the UK (Hughes & Saieva, 2019) and work-integrated learning (WIL) programs in Australia (Jackson, 2014) are strongly supported by government agencies. Future research could utilize a Triple Helix model (Etzkowitz & Leydesdorff, 2000) or Quadruple Helix (Carayannis & Campbell, 2009) to conceptualize and examine how government influence impacts the success of WIL experiences.

Contributions

Several policy documents emphasize the need for STEM education to incorporate real workplace experiences into the curriculum (Education Council Australia, 2018; National Science Foundation, 2020). However, universities' strategies (e.g., internships) do not fully address the perceived gap in the skills of recent graduates, as employers continue to express concerns about this issue. This paper addresses this problem by providing a comprehensive analysis of WIL. By emphasizing the student experience, this research study provides a fresh theoretical foundation for WIL that addresses the criticism often associated with the *theory vs. practice* discourse surrounding WIL (Allan & Evans, 2019; Baldvinsdottir et al., 2010; Björck & Johansson, 2019; Orr, 2002).

While some prior work has suggested that CoP could be used to address some of the challenges in WIL (e.g., Ajjawi et al., 2020), they often lack empirical evidence of how and what critical aspects should be considered through this new lens. This paper contributes to the field by providing an empirically driven analysis of WIL that leads to an in-depth understanding of the roles different stakeholders play.

This work highlights the importance of companies providing LPP, which is essential for addressing what Holyoak (2013) describes as the critical implicit assumption that all internship experiences are equally valuable for all students. Furthermore, this work underscores the need for LPP to be differentially adapted based on the characteristics of the students. An adaptation may be necessary for international students or those with prior work experience. In these varying scenarios, it is the joint responsibility of the university and companies to offer an appropriate LPP, rather than placing the sole burden of accommodation on the student. This perspective aligns with the observations made by Clerke et al. (2021), who point out that in the field of engineering, students in WIL are often tasked with finding their own workplaces, frequently disadvantaging minorities (Hewitt et al., 2018). Indeed, this paper distributes the responsibility among different stakeholders, not just students, which can help address the concern of Clerke et al. (2021).

Finally, our new conceptualization can help instructors and universities understand what aspect they should look at when selecting an appropriate workplace. For instance, instead of finding a workplace that offers practical knowledge for the students (as previous conceptualizations proposed), this work suggests that the instructor should select an appropriate workplace that offers common *boundary objects* that allow students to practice new relevant workplace objects and transfer them to the class, offer an LPP where students can negotiate their participation to become full members, and allow students to develop *brokers* skills by transferring knowledge in a bidirectionally way, resulting in a win–win situation.

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Data availability Interview protocols, analysis, and the codebook are available as supplementary information. Due to ethical approval restrictions, access to the dataset of interviews and course evaluations is not possible.

Declarations

Competing interests The authors declare no competing interests.

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