One foot in academia and one in work-life – the case of Swedish industrial PhD students

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Abstract

Purpose – The purpose of this study is to explore the benefits and barriers for learning in industrial PhD education through the perspectives of industrial PhD students. A work-integrated learning (WIL) approach is applied to highlight key issues that university and industry need to consider promoting mutual learning.

Design/methodology/approach – The empirical context is a Swedish university profiling WIL offering PhD programs in three disciplines for industrial PhD students from both the private and public sectors. Data was gathered using qualitative methods; 19 semistructured interviews with industrial PhD students.

Findings – Findings show that industrial PhD students are developing practical and transferable skills, hence, contributing to research of interest for academia and work–life. Identified benefits for learning include proximity and access to data, project and networks and contextual understanding and tacit knowledge. Barriers for learning are the perceived limited understanding of employers, the dilemma of balancing and switching between different roles, lack of belonging and identity, deficient collaboration agreements and ethical dilemmas.

Research limitations/implications – Contributes insights into an industrial PhD education transforming along with societal needs promoting a future workforce of researchers with skills, new work practices and learning capabilities applicable in the work–life of contemporary society.

Originality/value – This study contributes to the emerging field of studies of alternative doctoral educations by identifying benefits and barriers for learning and providing recommendations for how university and industry may promote learning in a resilient industrial PhD education collaboration.

Keywords Doctoral education, Industrial PhD student, Work-integrated learning, Workplace, University–industry collaboration, Sweden

Paper type Research paper

Introduction

The importance of doctoral education is recognized in contemporary society and there is an emerging interest for university–industry collaboration in doctoral education (Bernhard and Olsson, 2020; Bin *et al.*, 2016; Borrell-Damian *et al.*, 2010, 2015; Gustavsson *et al.*, 2016; Jones, 2018; Roolaht, 2015). Doctoral education has rapidly expanded, encouraged by higher education policies (Hasgall *et al.*, 2019; Santos and Patricio, 2020) and transformed along with societal needs and labor markets for PhDs, as doctoral education today does not merely aim for academic careers (Jones, 2018; Malfroy, 2011; Valencia-Forrester, 2019). The transition of doctoral education also reflects the ongoing transformation of higher education

institutions (HEI) toward an entrepreneurial approach with increased interaction and collaboration with industry, community and governments (Altbach *et al.*, 2019; Blessinger and Stockley, 2016; Giones, 2019; Gomes *et al.*, 2005; Klofsten *et al.*, 2019) often referred to as academic engagement (Perkmann *et al.*, 2021), strategic alliances (Elmuti *et al*, 2005) or industry alignment (Wildy *et al.*, 2015). Previous research emphasizes that when increasing industry involvement in doctoral education, there are issues to consider both for university and industry as expectations on research impact may differ (Caley *et al.*, 2021; Valentin and Shane, 2014). The traditional focus of knowledge creation in academia is gradually transitioned as the value of knowledge creation in and together with industry is acknowledged (Gomes *et al.*, 2005; Jones, 2018). Universities should act as a provider of trained researchers, although universities often struggle with low completion rates of traditional doctoral education, i.e. PhD (Littlefield *et al.*, 2015; Roos *et al.*, 2021). The doctorate degree covers skills and tools that are essential to all sectors of contemporary society (Cohen *et al.*, 2016; McCarthy and Wienk, 2019). There is, thus, an increased interest in collaborative doctoral education as industry employees need to expand their knowledge and skills (Borrell-Damian *et al.*, 2010, 2015; Gill and Mullarkey, 2015; Grimm, 2018; Jones, 2018; Roolaht, 2015) along with the continuous up-skilling demands of the workplace (Blessinger and Stockley, 2016). University–industry interactions in doctoral education are of importance for mutual life-long learning by integrating workplace learning and research redeveloping work practices related to new concepts, technologies and organizational principles (Bölling and Eriksson, 2016; Olsson *et al.*, 2021). The workplace is viewed as a learning space, in which interactions increase levels of knowledge, skills and expertise among employees (Billett, 2004). Accordingly, there is a rise of alternative forms of doctoral education based on collaboration between academia and work–life especially with focus on the workplace. Different concepts, and forms of doctoral education collaboration with industry exist world-wide e.g. professional doctorate (Fulton *et al.*, 2022; Jones, 2018; Lee *et al*, 2009; Wildy *et al*, 2015) business doctorate for executives (Gill and Mullarkey, 2015), hybrid trajectories of doctoral students (Santos and Patricio, 2020) and industrial PhD education (Berg and McKelvey, 2020; Bernhard and Olsson, 2020).

Recent academy adaptations of different hybridized models for doctoral education call for further research following the emerging new landscape of doctoral educations (Bernhard and Olsson, 2020; Borrell-Damian *et al.*, 2015; Jones, 2018; Lee *et al.*, 2009; Wildy *et al.*, 2015). The present study seeks to correspond to this research gap by exploring alternative doctoral educations in Sweden, here *industrial PhD students* referring to students who originate from and are fully employed in industry (company or organization) while pursuing their PhD education, i.e. the company is investing in an employee to become a PhD (Bernhard and Olsson, 2020). There are, hence, dual goals for industrial PhD education collaboration, i.e. individual skill and knowledge enhancements as well as increased organizational competence and access to contemporary research. Previous research stresses that industrial PhD students act as brokers of knowledge, spanning the boundaries between academia and industry networks, unlocking new research opportunities (Assbring and Nuur, 2017; Berg and McKelvey, 2020; Gustavsson *et al.*, 2016; Kunttu *et al.*, 2018; Lee *et al.*, 2009; Thune, 2009), while at the same time struggling with dual cultures and expectations (Kihlander *et al.*, 2011; Bernhard and Olsson, 2020). Industrial PhD students may be viewed as key stakeholders embodying the informing flows, i.e. interactions between industry and university and between industry and research, offering opportunities for validation and testing of empirical results and models (Bernhard and Olsson, 2020). Existing research applying the concept of *industrial PhD education* are e.g. programs in informatics and engineering in Sweden (Berg and McKelvey, 2020; Bernhard and Olsson, 2020; Kihlander *et al.*, 2011), engineering and health science in Portugal (Tavares *et al.*,

2020), engineering and automotive manufacturing in Germany (Grimm, 2018) and programs as policy tools for university–industry collaboration in Estonia and Denmark (Roolaht, 2015). However, research on industrial PhD education is limited and there are calls for more empirical studies regarding collaborative arrangements for mutual learning (Bernhard and Olsson, 2020; Kihlander *et al.*, 2011; Santos and Patricio, 2020).

Work-integrated learning (WIL) is a transdisciplinary approach for collaboration between academia and work–life, an umbrella term for a range of university initiatives and forms to integrate theoretical knowledge with practice work bridging research, higher education and practice for mutual learning outcomes and preparing students for the transition into work–life (Bates, 2008; Bernhard *et al.*, 2018; Billett, 2004, 2009, 2014; Bowen and Drysdale, 2017; Gellerstedt *et al.*, 2018; Olsson *et al.*, 2021; Patrick *et al.*, 2008; Rampersad, 2015). Valencia-Forrester (2019) stresses that there is a need to apply WIL since integration of industry experience in PhD education may increase the employability of PhDs. WIL is here applied as theory and a model for university–industry collaboration aiming at knowledge exchange, learning and research. Thus, the aim of this study is to explore the benefits and barriers for learning in industrial PhD education through the perspectives of industrial PhD students. A WIL approach is applied to identify key issues that university and industry need to consider promoting mutual learning:

RQ1. What are the benefits for learning for industrial PhD students active in intersection of academia and work–life?

RQ2. What are the barriers for learning for industrial PhD students active in the intersection of academia and work–life?

Theoretical framework

A WIL perspective may embrace different approaches to learning, where theoretical and practical knowledge and experiences are integrated across educational as well as work–life and civil society contexts (Billett, 2009). Learning is a result of the social interactions in and around practices; people learn when they engage in everyday activities and interact with others (Billett, 2014) i.e. the social contexts are of importance for learning [Lave and Wenger, 2005 (1991); Hoel and Christensen, 2020].

WIL is often defined as an educational strategy in which students combine conventional academic learning with some periods of time at workplaces (industry) of relevance to a program of study and careers (Eames and Coll, 2010) . The WIL concept in higher education has developed over time and covers today education, collaboration and research (Bernhard and Olsson, 2020; Olsson *et al.*, 2019; Gellerstedt *et al.*, 2015; Harteis *et al.*, 2014). In higher education, WIL may be categorized as:

- co-op, the traditional cooperative education model (Barbeau, 1973; Franks and Blomqvist, 2004), often referred to as sandwich education (Ward and Jefferies, 2004) or internships (Sovilla and Varty, 2004);
- case, using practice as inspiration;
- imprint, bringing practice to class;
- tools, using professional tools;
- field, bringing class to practice (Gellerstedt *et al.*, 2015); and
- industrial PhD education (Bernhard and Olsson, 2020).

All categories of WIL are based on the fundamental idea of a tripartite collaboration between academia, students and industry integrating knowledge and skills from academia and work–life.

Research on WIL merges learning and working examining the relationships between them as joint collaborations and interactions for learning (Billett, 2014; Harteis *et al.*, 2014). Furthermore, research shows that theory and practice complement each other and enrich learning (Björck and Johansson, 2019). Adults continue to learn and develop through their occupational practice or workplace (i.e. life-long learning) hence, the industry settings need to be "legitimized, understood more fully and on their own terms as environments in which individuals come to participate and learn" (Billett, 2014, p. 690). Furthermore, as industrial PhD students often are mid-life professional students there is a need to proceed from the pedagogical discourse of adult learners (andragogy) when designing an industrial PhD education (Caley *et al*, 2021; Cohen *et al.*, 2016) to capture the full potential of WIL.

WIL has the potential to provide direct benefits not only for work–life and academia, but also for a wider community as well as creating synergy between theory and practice (Gellerstedt *et al.*, 2015; Olsson *et al.*, 2021). WIL is mainly applied in undergraduate degrees and supported by industry and governments (Valencia-Forrester, 2019). Academic supervisors in PhD education stress that WIL brings forth students with greater maturity and improved research skills (Garza and Jones, 2017), while employers benefit by accessing work-ready students (Phillips, 2014). WIL students are often more psychologically prepared for work–life (Purdie *et al.*, 2013), with a stronger professional identity (Jackson, 2013) and have career benefits regarding early career job advancement and higher salary (Gellerstedt *et al.*, 2015). Apart from the pedagogical learning benefits, WIL also forms the basis for collaboration and interactions between higher education and industry (Olsson *et al.*, 2019). Thus, the WIL approach needs to adjust to the development of contemporary society and there are calls for more innovative applications of WIL as well as including broader, sector-wide research incorporating the perspectives of students, universities, industry and global perspectives on the future (Bowen and Drysdale, 2017; Bernhard and Olsson, 2020; Valencia-Forrester, 2019; Zegwaard and Rowe, 2019). The role of WIL in PhD education or third-cycle education is less explored compared to undergraduate education (Bernhard and Olsson, 2020; Valencia-Forrester, 2019). Thus, there is a need for more research on collaboration between university and industry with a focus on industrial PhD students as they are active in the university–industry intersection (Bernhard and Olsson, 2020). Furthermore, previous research stresses that there are dual knowledge gaps of career development options as industry employers have limited insight into the value of engaging a PhD graduate, while PhD graduates are often uninformed of employment opportunities outside of academia (McCarthy and Wienk, 2019), which further strengthens the need for future studies within this research field.

The WIL approach is in this study combined with the Informing flow framework, originating from Gill *et al.* (2016) to illustrate and analyze university–industry collaboration with the perspective of industrial PhD students. The framework has been practiced in previous university–society collaboration studies with focus on WIL and doctoral education (Bernhard *et al.*, 2018; Bernhard and Olsson, 2020). The informing flow framework is applied since it is closely related to the WIL approach stressing transdisciplinary work and exchange of knowledge among actors to break down boundaries that hinder interactions, flows of knowledge and learning and the relationship between individuals and organizations. The informing flow model is, thus, a strategic tool to identify and assess individual and organizational interactions related to informing channels and forms based on the premises of growing complexity of society and growing participant diversity of the

stakeholders. Key stakeholders are categorized as students' community, research community, community of practice (industry) and academia (Gill *et al.*, 2016).

As illustrated in Figure 1, industrial PhD students are placed in the center of the framework overlapping all key stakeholders, thus, embodying the informing flows between practice and university, and between practice and research. Furthermore, they are part of informing flows within practice, research and student communities (Bernhard and Olsson, 2020). Here, the collaboration is viewed as a cross-fertilization not only of disciplines but also of industry and academia, theory and practice related to industrial PhD education and workplace learning. Hence, this collaboration provides good opportunities for practical as well as conceptual development of workplace learning.

Methodology

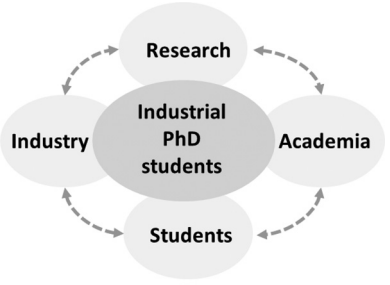
Based on the purpose of this study, this research is conducted as an explorative qualitative study focusing on industrial PhD students' perspectives across three disciplines at a Swedish university profiling in WIL. Qualitative method was chosen to understand people's [industrial PhD students'] experiences, beliefs, opinions, attitudes, behavior and interactions expressed in their own words. Using qualitative interviews include flexibility and, thus, semistructured interviews as format was applied (Bryman, 2008) to conduct the study in an explorative manner. In addition, documents such as national statistics on PhD education in Sweden, PhD education curricula and university policy documents were studied to fully understand the empirical settings before the data collection was undertaken.

An initial qualitative study of a small sample of five industrial PhD students and five employers from industry was conducted in 2019–2020 (Bernhard and Olsson, 2020). This study is a subsequent study to broaden and deepen the research problem by covering industrial PhD students in various educational phases, adding more disciplines as well as more industrial contexts.

Empirical setting

This study is contextually drawn from higher education in Sweden. Across all Swedish HEIs (universities) 17,371 PhD students (third-cycle students) were enrolled in 2021. Almost 6% of these were industrial PhD students, i.e. they were industry employed doctoral student, or other employment outside of higher education while conducting their third-cycle studies (Lundh, 2022; Swedish Higher Education Authority, 2021). Industry here refers to a wide variety of branches and workplaces in private and public sectors.

Swedish PhD programs correspond to four years of full-time studies comprising 240 European Credit Transfer System (ECTS) credits (Swedish Higher Education Authority,



Source: Authors' own work

Figure 1.
A WIL-based model for informing flows of industrial PhD education (Bernhard and Olsson, 2020)

2021). Industrial PhD students in Sweden have the same academic demands as traditionally enrolled academic PhD students. The empirical research context of this study is University West in Sweden that at present has two large research environments with doctoral degrees: production technology and WIL. University West has a WIL profile as the only Swedish university. In 2001, the university was commissioned by the Swedish Government to further develop WIL as a pedagogical strategy. Doctoral degrees in WIL in informatics and pedagogy have been offered since 2011, whereas production technology has a long tradition of engaging PhD students in applied research together with industry. In 2020, an additional doctoral degree in WIL was launched.

Data collection and analysis

This study explores the benefits and barriers for learning of an industrial PhD education through the lens of the industrial PhD students who are acting in the intersection of academia and work–life.

During this period, University West had 21 industrial PhD students enrolled in the three disciplines of informatics, specializing in WIL, production technology and WIL. Qualitative methods were applied including interviews. All 21 industrial PhD students were invited, i.e. a total survey, and 19 of them participated in this study.

The industrial PhD students were in various stages of their PhD education: 14 in the beginning, three in the middle phase and two at the end as illustrated in Table 1. Four industrial PhD students were undergoing their PhD education corresponding to half-time studies while the others were enrolled in 80–100% studies. The distribution among disciplines were five from informatics with a specialization in WIL, six from production technology and eight from WIL. The respondents included nine women and 10 men ranging in age from 27 to 55.

Respondents	Data collected	Sector	Phase of PhD education
R1	Nov 2019	Private	Beginning
R2	Nov 2019	Public	Beginning
R3	Nov 2019	Public	Middle
R4	Dec 2019	Private	Beginning
R5	Nov 2019	Public	End
R6	June 2021	Private	End
R7	June 2021	Private	Beginning
R8	Oct 2021	Private	Beginning
R9	Oct 2021	Private	Middle
R10	Jan 2021	Private	Beginning
R11	Oct 2021	Private	Beginning
R12	Oct 2021	Public	Beginning
R13	Oct 2021	Public	Beginning
R14	Nov 2021	Public	Beginning
R15	Nov 2021	Public	Beginning
R16	Nov 2021	Public	Beginning
R17	Nov 2021	Public	Beginning
R18	Nov 2021	Public	Middle
R19	Nov 2021	Public	Beginning

Table 1. Overview of respondents

Source: Authors' own work

Various kinds of workplaces (i.e. employers) in society were represented as 11 of the industrial students were employed in the public sector and eight in the private sector. Thus, the industry in this study represents workplaces of the following lines of businesses: manufacturing and automotive industry, IT consultants, interior design, regional health and care, local authorities, HEIs and Science Park.

The semistructured interview guide for the industrial PhD students covered the following five themes: benefits and challenges being an industrial PhD student, how learning is generated at the university and industry, dissemination of research at the workplace and how collaboration between academia and industry is experienced. Furthermore, the interviews in 2021 also included questions regarding if and how the COVID-19 pandemic had an impact on the PhD-education since earlier research state challenges causing obstacles and disruptions in PhD education and dissertation progress related to industry-crisis and societal lock downs (Andal and Wu, 2021; Donohue *et al.*, 2021; Fulton *et al.*, 2022; Wang and DeLaquil, 2020).

The data collection was conducted from October 2019 until January 202 and included in total 19 respondents. Due to the respondents studying and or working in different contexts and the ongoing COVID-19 pandemic, the data collection was performed as a mix of face-to-face semistructured interviews and digital (telephone, Zoom) interviews to give voice to the respondents. All interviews were individual except for one interview that included two industrial PhD students together. Seventeen interviews were conducted by the two authors together, ranging from 20 to 40 min. Two respondents chose to contribute by writing e-mail responses following the questions in the interview guide. All interviews were recorded with informed consent and transcribed.

This qualitative, explorative study, aimed for research rigor by conducting semistructured and coded interviews and further with awareness of how to reduce research bias as recommended by Gill and Gill (2020). Furthermore, detailed documentation of all steps in the research process was conducted to enhance transparency and replicability. Following research ethics and striving for research rigor, the authors have not had any supervisory relationships with the industrial PhD students and their organizations and have not served on their thesis committees although the authors of this article are employed at the same university. Anonymity has been applied to make the industrial PhD students feel independent and openly describe the benefits and challenges. This entails not presenting details about the PhD project topics nor the industrial PhD students' disciplinary affiliations, gender and age. All collected data was analyzed by the two authors in several steps to identify patterns and themes (Alvesson and Kärreman, 2007). Identified themes related to benefits and barriers for learning were analyzed as interactions between academia and industry according to Figure 1. An initial coding of all the data was done individually by each author using color markings and analytic memos to capture the researcher's ongoing reflections, inspired by Linneberg and Korsgaard (2019), followed by iterative steps of analysis conducted together by the two authors. To illustrate this analytical process, the identified themes are used as subheadings in the Findings section below.

Findings

This section presents the benefits and barriers for learning in industrial PhD education through the lens of industrial PhD students who are acting in the intersection of academia and work–life.

The benefits for learning for industrial PhD students

According to the respondents, there were several benefits for learning being active in the intersection of academia and work–life, being part of a research context as well as an

industrial context spanning boundaries between university and industry with mutual benefits as illustrated with analytical themes and selected quotes below.

Proximity and access for learning. The main benefits of being an industrial PhD student are recognized as inclusion in academia and in industry bringing access to data, projects and networks. Further being an employee [insider] also gives opportunities to more easily get access to confidential information. This may be summarized as proximity and access for learning being close and well anchored to the research area:

> It is very good to have one foot in the organization [industry] as you keep your friends and workmates and continue to work in your work context [. . .] I also try to look at myself as an "inspirer" [for the workplace] being part of the research and the scientific way of thinking bringing it into work-life. (R2)

> As I have established contacts at my company [. . .]. it has allowed me to choose where to collect data. It is also an advantage to being forced to take two perspectives, both the workplace perspective and the academic one. (R4)

> The major advantage is the proximity to empirical data, the accessibility to exciting projects and interesting people. (R5)

Contextual understanding and tacit knowledge. Another learning benefit is the experiences and work practices from work–life that the industrial PhD students view as advantages, i.e. having contextual understanding and tacit knowledge based on their professional experiences. This prior knowledge is enhancing their possibilities to accommodate the contents of the industrial PhD education combing theory and practice:

> I have years in the industry, and there is a lot of silence in organizations that is not that easy to discover. If you come into a company and conduct a study, interviewing and observing then you do not notice the tacit processes, what is not so explicit but what just happens in some way, the contacts between people, synergies that are only there. (R6)

> I am not starting from scratch; I am *not* newly graduated from university and have a little clue of how the world around works in a way. Nobody really needs to explain to me the industrial context. (R8)

Generating learning and new knowledge. Furthermore, the respondents are highlighting the WIL perspective when generating learning and new knowledge in industry during the PhD education. Mutual learning opportunities for both university and industry are emphasized as the industrial PhD student is closely connected to the workplace. The fact that PhD education also offers opportunities and tools to critically reflect and review their own workplaces is a benefit:

> People will benefit from this knowledge, and I have access to channels to disseminate the results of my research. I also see an advantage in that I am involved in developing my workplace. (R16)

> The greatest advantage I experience is that I get the opportunity to see my organization in a completely different way. I have rediscovered my own organization [. . .] I had to critically review myself as much as I critically examined my own workplace. (R18).

> It is the masterpiece of WIL in both directions [. . .]. really a win-win if you provide the conditions [at the workplace] for it. (R17)

An adaptable industrial PhD education. Furthermore, the possibility of PhD education to be adaptable to societal changes and novel approaches for learning is emphasized. Here, the opportunities to continue the industrial PhD education despite the ongoing the COVID-19 pandemic is viewed as a benefit. The COVID-19 pandemic enforced on-line PhD education, allowing taking all courses regardless of geographical location and, hence, keeping up the completion rate of the PhD education:

> The greatest advantage on a personal level is that it has been possible for me to complete a PhD program [at a distance]. (R14)

The barriers for learning for industrial PhD students

Despite recognized benefits there are several challenges such as the perceived limited understanding of employers, balancing and switching between separate roles, belonging and identity, collaboration agreements and ethical dilemmas thematically categorized and illustrated in selected quotes below.

Employers' limited understanding affecting learning. By far the most articulated barrier for learning is the perceived limited understanding of employers of the industrial PhD students' entire work situation, work practices and implicit expectations to prioritize work tasks and duties at the workplace before PhD studies. Industrial PhD students emphasize their struggle to make time for their PhD studies at the workplace:

> My employer has a hard time understanding that it is so labor-intensive taking courses and submission of assignments. (R1)

> It was not easy; it was difficult to make time and *get away* from work to follow out my PhD courses. My department did not understand at all the time and concentration required [. . .] I was not given the conditions to carry out my PhD studies. (R17)

The dilemma of balancing and switching between different roles. The definition of an industrial PhD student *per se* encompasses dual roles, still this is challenging according to the respondents. Part-time studies are tough and tend to expand the time frames becoming more than full-time especially if the PhD education is designed for full time studies. This is a dilemma that is a barrier for learning:

> It is all about balancing and switching between different roles and often opposite perspectives and goals such as what is in the interest of research or company management. (R5)

> I had many different roles [. . .] Now and then I had to replace my boss and be department manager when my boss was not in place [. . .] there was an attitude that: 'please stop that [PhD studies] and come here and work for real instead. You are needed on the floor!' (R17)

> If you are employed by a company, you must work much more, you have many more things to do than just your research and PhD. It is much more difficult to finish the PhD on time due to other responsibilities. Usually, the company does not prioritize the research that much since things change extremely fast in industry. (R9)

Lack of belonging and identity. Most industrial PhD students accentuate feeling alone during PhD education. Some of the respondents of this study also view themselves as outsiders not really belonging anywhere. This is especially prominent among those industrial PhD students who are in the beginning phase. Hence, the benefit of learning by belonging to both university and industry mentioned above, is also experienced as a barrier,

which has been further intensified during COVID-19 with restricted travel and only virtual connections:

> You are alone – that is the main challenge! It is incredibly lonely to be an industrial PhD student. (R18)

> My relationship with the university is a challenge and I am mainly thinking of the COVID-19. Now I am halfway through my PhD education, but I have still not visited the university. My feeling of belonging suffers, and the university feels extremely far away. (R13)

Deficient collaboration agreements. Furthermore, the respondents highlight the barriers for learning related to collaboration agreements of their PhD education that sometimes include multiple actors (e.g. due to financing within research projects) as these constellations often generate conflicts of interest, administrative bureaucracy and lack of mutual understanding of the perspectives of industry and academia:

> You are in the middle – in my case, I am in the middle of three organizations: all the old contact networks that you had are still there, but the relationships become completely different as you step away. (R18)

> In my case it was very confusing initially due to conflicts of interest among the collaborating partners. (R12)

> There was repeatedly a lot of trouble with the arrangement of my financing [salary-payments]. (R17)

> As an industrial PhD student, you end up a little outside the digital infrastructure. Every year my profile page is deleted on the university website and every year I have to argue with the IT department about it [. . .]. and I do not get access to the Wi-Fi for employees. (R4)

Ethical dilemmas affecting learning. In addition, respondents experience ethical dilemmas being an "insider" related to data access, publication, anonymity e.g. being employed at a unique organization and safety. This may affect the industrial PhD students' learning:

> There are barriers for me as internal data is not accessed freely anyway although I have had more opportunity to negotiate more data for myself. There is a greater trust in me, but at the same time it is a greater responsibility for me to make sure not to publish what is sensitive. I have a responsibility to my company, and I am probably scrutinized more harshly than an external person. (R6)

> I would have liked my supervisor to participate during field observations. In my world the [academic] supervisor is a novice, and I am the more senior one with special knowledge and requirements for safety – who is then responsible? [. . .]. when the research ethics course meets reality, the whole course collapses like a house of cards. (R18).

Discussion

This article contributes to the under-researched field of industrial PhD education by demonstrating the importance of university–industry collaboration in doctoral education. The learning benefits and barriers are highlighted through the lens of the industrial PhD students who are acting in the intersection of academia and work–life. By applying a WIL approach, key issues that university and industry need to consider promoting mutual learning are identified. In contrast to earlier research on industrial PhD education that mainly focused on learning

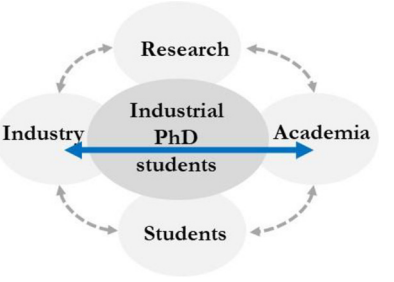
outcomes and educational experiences, this explorative study gives voice to industrial PhD students' perspectives. As pointed out above, existing research agrees on that industrial PhD students act as brokers of knowledge and span the boundaries between academia and work–life (Assbring and Nuur, 2017; Berg and McKelvey, 2020; Bernhard and Olsson, 2020; Gustavsson *et al.*, 2016; Kunttu *et al.*, 2018; Thune, 2009). Undoubtedly there are several benefits due to industrial PhD students having one foot in academia and one in work–life. The main benefit for learning is *proximity and access for learning*. Inclusion in academia as well as in industry enables the industrial PhD students' embodying and integrating the university–industry collaboration in accordance with the idea of WIL. Most of the interactions between industry and academia pass through the industrial PhD students (Figure 1). Furthermore, as the industrial PhD students are experienced practitioners from industry, they possess *contextual understanding and tacit knowledge* that give opportunities to integrate theory and practice during their entire PhD education that may support industry and academia (Figure 1). Industrial PhD students are highlighting the WIL perspective when *generating learning and new knowledge* during the PhD education as interactions and flows of information between all key stakeholders [students' community, research community, community of practice (industry) and academia (Figure 1)]. This kind of interactions, hence, offer multiple learning opportunities, innovations (Berg and McKelvey, 2020) and may also advance societal impact of PhD student research (Gustavsson *et al.*, 2016; Olsson *et al.*, 2021). Besides inclusion in the research community, students' community and academia support the industrial PhD students' ability to critically reflect and review their own workplaces by integrating theory and practice. A university–industry collaboration should be prepared to deal with unexpected societal circumstances to keep and sustain the relation and its benefits. Seen from international studies it is beneficial with *an adaptable PhD education*, i.e. resilient, and adaptive to societal changes transforming along with societal needs (Giones, 2019; Gomes *et al.*, 2005; Fulton *et al.*, 2022; Malfroy, 2011; Santos and Patricio, 2020; Valencia-Forrester, 2019). Hence, industrial PhD education may fulfill this based on close interactions between academia and industry capturing contemporary phenomena and or challenges to explore. In this study, the COVID-19 pandemic exemplifies an adaptable PhD education. User-friendly virtual platforms are, thus, important for complex interactions such as university–industry ones to build and sustain relations around industrial PhD-education. To sum up, the respondents state that the benefits are closely related to communication, proximity and inclusion. Furthermore, there are important lessons learned regarding communication from the pandemic that may strengthen future academia and industry interactions.

Despite identified benefits, there are also barriers for learning for industrial PhD students. By far the most articulated barrier is the *perceived limited understanding of employers* of the industrial PhD students' entire work situation. This may result in conflicts of interest regarding e.g. work schedule and workload. The interactions between academia and industry (Figure 1) hence, need to be strengthened throughout the *entire* PhD education and to support the industrial PhD student and not counteract the identified benefits. The benefit of having one foot in academia and one in industry is also a challenge *balancing and switching between different roles* which means working part-time and dealing with opposite goals, expectations and dual cultures (Kihlander *et al*, 2011). This may be even further challenging if the employer has limited understanding of PhD education. Most industrial PhD students accentuate feeling alone during PhD education, thus, *lack of belonging and identity* is a challenge. Hence, the benefit of belonging to both university and industry mentioned above, is also experienced as a disadvantage, which has been further intensified during COVID-19 with restricted travel and only virtual connections (Andal and Wu, 2021; Donohue *et al.*,

2021; Wang and DeLaquil, 2020). Again, the interactions between academia and industry need to be strengthened to support the belonging and identity of the industrial PhD students, especially in the early phases of the PhD education (Figure 1). *Deficient collaboration agreements* generate barriers for learning for industrial PhD students related to financing, administrative bureaucracy and conflicts of interests between academia and industry. Based on these results, it can strongly be argued that financial agreements including more than two organizations e.g. research projects, have a negative impact on the industrial PhD students who are struggling with the feeling as outsiders and not belonging anywhere. In addition, unlike traditionally enrolled academic PhD students who are often struggling to find employment in academia or industry after graduation, industrial PhD students are employed. Yet, industry needs to have a long-term perspective with agreements including work promotion opportunities to keep and engage the graduated industrial PhD student in relevant work position to use and retain knowledge and skills. Seen from the academia perspective, it is beneficial to keep the relation with the industrial PhD student after graduation by part time involving them in education and or research projects, i.e. extending WIL for academia and industry beyond graduation. Furthermore, *ethical dilemmas affecting learning* such as data access, ethical research principles (Roos *et al.*, 2021), dissemination of research results and safety during data collection, need to be recognized and dealt with in accordance with the research community by both academia and industry (Figure 1). Accordingly, academia and industry must invest time and energy in relationships to reach an understanding of each other's expectations and limitations regarding e.g. funding, research topics, data access, dissemination of research findings and societal impacts. Thus, there is a need for increased communication and continuous interactions (informing flows) between academia and industry to promote mutual learning during the entire industrial PhD education.

To achieve identified learning benefits and deal with barriers in industrial PhD education collaboration, there are issues that academia and industry need to consider since the industrial PhD student should not alone be responsible of bridging academia and work–life. Thus, the interactions between these academia and industry need to be strengthened throughout the entire PhD education which is illustrated with the bold arrow in Figure 2. Both academia and industry must have detailed insights into industrial PhD education to recognize and fully exploit these learning benefits while building mutual relationships, sustaining and resilient collaboration over time promoting a future workforce of researchers with skills, practices and learning capabilities applicable in contemporary society.

Based on the present study, the following key issues are recommended to reach a sustainable industrial PhD education collaboration:



Source: Authors' own work

Figure 2.
Strengthened interactions between academia and industry in industrial PhD education collaboration

- Academia needs to establish a shared point of departure to sort out and identify mutual expectations and limitations of the collaboration and mutual learning related to the design of industrial PhD education.
- Academia and industry should plan and carry out continuous activities, meetings and dialogues to support industrial PhD students' learning throughout the entire education.
- Academia and industry should develop detailed collaboration agreements when industrial PhD students are enrolled to avoid financial and ethical dilemmas.
- Academia and industry have a shared responsibility to plan and continuously conduct activities to follow up industrial PhD students' progress, entire workload, completion and dissemination of research results promoting mutual learning.
- Academia and industry have a shared responsibility to strengthen, legitimize and communicate the industrial PhD students' belonging and identity in both academia and industry.
- Industry needs to develop strategies for work promotion or career opportunities and life-long learning after PhD graduation to reach the full potential of the investments in the industrial PhD student.

Conclusion

This explorative study contributes advancing the current knowledge of contemporary academy adaptations of different hybridized models for doctoral education following the emerging new landscape of doctorate educations with focus on Swedish industrial PhD students with one foot in academia and one in work–life. A WIL approach is applied to highlight key issues that academia and industry need to consider promoting mutual learning. Implications for sustainable industrial PhD education collaboration are highlighted as recommendations for academia and industry. Both academia and industry must invest time and energy in relationships to understand each other's expectations and limitations for supporting industrial PhD students' learning. Furthermore, this study contributes a WIL approach to PhD education to illustrate collaborative interactions and mutual learning opportunities for academia and industry. Industrial PhD students are generating new knowledge and transferable skills during their PhD education for academia and work–life embracing two different worlds. Continuous support from academia and industry is needed throughout the entire PhD education promoting a future workforce of researchers with skills, work practices and learning capabilities applicable in contemporary society. The results of the present study argue for the need to transform PhD educations along with society to promote a future workforce of researchers with skills and new work practices applicable in work–life.

The limitations of this explorative study are acknowledged as the study covers industrial PhD students' perceptions, one single university and three disciplines of PhD education. Thus, future research is encouraged to cover the perspectives of industry (workplace) and academia, additional disciplines/universities to further enrich the studied phenomenon and identify and learn from good practices. Comparative studies of traditionally enrolled PhD students and industrial PhD students are also of interest for future research as a new landscape of PhD education is emerging. Quantitative methods and large national or international samples to reveal industrial PhD students' progress, finishing rates and gender compared to traditional PhD students may also be of interest for future research.

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