Transforming doctoral education: Exploring industrial PhD collaboration in Sweden

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Doctoral education is transforming, along with societal changes, as it is no longer solely aimed at academic careers. A new landscape with various models for doctoral education is emerging with an increased alignment with industry. This study aims to deepen research by critically exploring industrial PhD education collaboration in Sweden. The perspectives of industrial PhD students, academia, and industry are integrated with work-integrated learning as a theoretical lens to identify benefits, challenges, and prerequisites for how to structure and manage such a collaboration. Qualitative methods are applied including a total of 38 respondents. Industrial PhD students embody PhD education, research, and university-industry collaboration, generating learning and understanding across sectors and industries. The current knowledge of PhD education is advanced by integrating multiple perspectives, to reveal prerequisites that are vital for how to structure and manage industrial PhD education collaboration, to promote work-integrated learning towards a way to build knowledge.

Keywords: Doctoral education, industrial PhD education, university-industry collaboration, work-integrated learning, Sweden

Doctoral education is increasingly important for knowledge creation, and is transforming along with societal changes to increase industry alignment as contemporary doctoral education is not solely aimed at academic careers (Haapakorpi, 2017; Jones, 2018; Valencia-Forrester, 2019). Thus, a new landscape for various models for doctoral education is emerging (Bernhard & Olsson, 2020; Borrell-Damian et al., 2015; Jones, 2018; Lee et al., 2009; Wildy et al., 2015) with an increased focus on training skills that are relevant for both academic and non-academic careers (O'Connor et al., 2023). University-industry collaboration is a widespread phenomenon for education and innovation in response to societal challenges (Rybnicek & Königsgruber, 2019) and is seen as critical to future economic and social prosperity by policymakers worldwide (Ripoll Feliu & Díaz Rodríguez, 2017). All sectors of society have to deal with competition and complex issues and hence need to include various perspectives and competences for knowledge creation and innovation (Bernhard & Olsson, 2020; DiBella, 2019; Trencher et al., 2013). It is of essential interest for governments, policymakers, academia, and industry that such collaboration is successfully accomplished (Rybnicek & Königsgruber, 2019). Collaboration across organizational borders and sectors, for example, university-industry collaboration, offers opportunities for co-production and innovation yet also affects students' transition from education to employment (working life) (Tuononen & Hyytinen, 2022). However, in the era of lifelong learning (James, 2020) there are essential transitions the other way around, that is, from employment (working life) to higher education, that is, doctoral education, a field that so far has received limited research attention.

This article explores industry employees' enrollment in doctoral education, that is, collaboration between education and work for working professionals (Berg & McKelvey, 2020; Bröchner & Sezer, 2020; Yang, 2022). The transformation of doctoral education is vital as research skills and competencies also aim for careers outside universities (Haapakorpi, 2017; Jones, 2018; Kyvik & Olsen, 2012; Valencia-Forrester, 2019). The title of Doctor of Philosophy (PhD) is the highest level of academic qualification,

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however, with structural variations from country to country. Thus, there is a world-wide increase of alternative forms of doctoral education based on collaboration between academia and work-life such as the professional doctorate (Fulton et al., 2022; Jones, 2018; Lee et al., 2009; Wildy et al., 2015), business doctorate for executives (Gill & Mullarkey, 2015), hybrid trajectories of doctoral students (Santos & Patricio, 2020) and industrial PhD education (Berg & McKelvey, 2020; Bernhard & Olsson, 2020). There are many commonalities between traditional PhDs and various forms of doctorates with a stronger alignment with industry. The main differences are often career focus, domain of research topic, that is, contribution to knowledge and practice, research focus, admission requirements and breadth of focus (Jones, 2018). Emergent academic adaptations of various models for doctoral education call for further research (Bernhard & Olsson, 2020; Borrell-Damian et al., 2015; Jones, 2018; Lee et al., 2009; Yang, 2022), especially research that captures the multiple perspectives of industrial doctoral students and collaborating partners in order to structure and manage a collaborative process generating creation of new knowledge and organizational learning.

One approach for university-industry collaboration is work-integrated learning (WIL) (Bernhard & Olsson, 2020, 2022; Olsson et al., 2021; Rampersad, 2015), here with focus on industrial PhD education. Industrial PhD students embody the collaborative interplay between education and work influencing organizational learning. Industrial PhD students are vital for collaboration and learning in and between university and industry, yet there is a lack of research within this field (Berg & McKelvey, 2020; Bernhard & Olsson, 2020).

Drawing on the above identified gaps, the aim of this study is to deepen research by critically exploring various perspectives in industrial PhD education collaboration, based on the transitional role of industrial PhD students. The perspectives of industrial PhD students, academia, and industry are integrated and conceptualized into a suggested framework with WIL as a theoretical lens to identify prerequisites for how to structure and manage such a collaboration. Given this tripartite collaboration the following research questions are addressed:

1. What are the benefits and challenges of industrial PhD education collaboration for industrial PhD students, academia, and industry partners?
2. How may the structure and management of industrial PhD education collaboration be conceptualized based on identified challenges to achieve the full potential of the collaboration and support the industrial PhD students throughout the education?

THEORETICAL FRAMEWORK

Earlier research on university-industry collaboration stresses the importance of building relationships that encourage knowledge sharing and learning by identifying vital collaboration elements of continuity and commitment, coordination, communication and relationships, trust, courage and creativity, and co-creation opportunities (Olsson et al., 2021). Inter-organizational trust is a prerequisite for collaboration and learning requiring long-term investments, overlapping personal and professional relationships and close interactions (Kunttu & Neuvo, 2019). Learning in and between organizations is a collaborative process evolving over time via interactions combined with the building of trust, transparency, mutual respect and understanding (Battistella et al., 2021; Bernhard & Wihlborg, 2022; DiBella, 2019). Rybnicek and Königsgruber (2019) categorize generic collaboration factors as institutional (resources, structure, willingness to change), relationships (communication, commitment, trust, culture), outputs (objectives, knowledge, technology transfers), and framework (environment, contracts, intellectual property rights, geographical distance). These authors also argue that there are

moderators affecting the collaboration such as different phases of collaboration over time, different organizational levels, different disciplines and collaboration partners of different size (scale). University-industry collaboration is further affected by context such as collaboration partners' different strategic orientations, motives for collaboration and organizational cultures (Rupčić, 2021). However, as pointed out by Strengers (2014), interdisciplinarity and industry collaboration may create tension and pressure on the PhD student, counteracting the good intentions of collaboration, knowledge creation and organizational learning between and within collaborating organizations.

In order to explore industrial PhD education collaboration, WIL is applied as a theoretical lens as it has the potential to provide a deeper understanding, not only for the transition between work-life and academia, but also for a wider community creating synergy between theory and practice (Gellerstedt et al., 2015; Jackson & Rowe, 2022; Olsson et al., 2019). The concept of WIL has developed over time and is today an umbrella term covering education, collaboration, and research (Bernhard & Olsson, 2020, 2022; Billett, 2014; Olsson et al., 2021). In recent decades there has been an increased growth of various WIL offerings within higher education encompassing needs for new perspectives of education design and collaboration (Ferns et al., 2021; Zegwaard et al., 2019). WIL is often defined as an educational strategy in higher education in which students combine conventional academic learning with some periods of time at workplaces (industry) of relevance to a program of study and careers (Bates, 2008). In higher education WIL may be categorized as: (i) co-op, the traditional cooperative education model (Barbeau, 1973; Drysdale & McBeath, 2012); (ii) case, using practice as inspiration; (iii) imprint, bringing practice to class; (iv) tools, using professional tools; (v) field, bringing class to practice (Gellerstedt et al., 2015) and (vi) industrial PhD education (Bernhard & Olsson, 2020). All categories of WIL are based on the fundamental idea of a tripartite collaboration between academia, students, and industry (Jackson & Rowe, 2022), integrating knowledge and skills from academia and work life. However, 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 PhD students with greater maturity and improved research skills (Garza & Jones, 2017), yet WIL at the PhD level remains an under-researched area.

In response to this there are calls for more empirical studies regarding collaborative arrangements over time between university and industry (Bernhard & Olsson, 2020; Patricio & Santos, 2020). Hence, there is a research gap regarding benefits and challenges of industrial PhD education collaboration that needs to be further explored (Assbring & Nuur, 2017; Bernhard & Olsson, 2020; Patricio & Santos, 2020; Roolaht, 2015). Existing studies have mainly focused on industrial PhD students´ learning outcomes and educational experiences (Berg & McKelvey, 2020). Published research encompasses European industrial PhD programs in informatics and engineering in Sweden (Berg & McKelvey, 2020; Bernhard & Olsson, 2020; Bröchner & Sezer, 2020), business science, engineering, and health science in Portugal (Sousa et al., 2020; Tavares et al., 2020), hybrid trajectories within engineering and technology sciences and social sciences in Portugal (Patricio & Santos, 2020), engineering and automotive manufacturing in Germany (Grimm, 2018), programs as policy tools for university-industry collaboration in Estonia and Denmark (Roolaht, 2015) and in the United States, the interdisciplinary business doctorate program for executives (Gill & Mullarkey, 2015).

Apart from the pedagogical learning benefits, WIL also forms the basis for collaboration and interactions between higher education and practice (Olsson, Arvemo & Bernhard, 2019; Olsson, Bernhard, Arvemo & Lundh Snis, 2021). 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 for broader, sector-wide research incorporating the perspectives of students, universities, and industry in

the future (Bernhard & Olsson, 2020; Bowen & Drysdale, 2017; Valencia-Forrester, 2019; Zegwaard & Rowe, 2019). Valencia-Forrester (2019) states that there is a need to include WIL as industry experience in PhD education in Australia. McCarthy and Wienk (2019) also point out that the PhD degree covers skills and tools that are essential to all sectors of contemporary society. The role of WIL in PhD education is less explored compared to undergraduate education (Bernhard & Olsson, 2020, 2022; Valencia-Forrester, 2019). Thus, there is a need for deeper research on collaboration between university and industry focusing on industrial PhD students as they are active in the intersection of university and industry (Bernhard & Olsson, 2020, 2022). Furthermore, previous research stresses that there is a dual knowledge gap as industry employers have limited insight into the value of engaging a PhD graduate, while PhD graduates are often uninformed about employment opportunities in industry (McCarthy & Wienk, 2019).

In order to illustrate and analyze university-industry collaboration based on the premises of growing complexity of society and growing participant diversity of collaboration partners, a WIL-based model of industrial PhD student collaboration is applied (Bernhard & Olsson, 2020). This model originates from the informing flow framework that stresses transdisciplinary work and exchange of knowledge among actors to break down boundaries that hinder flows of knowledge (i.e., interactions) (Gill et al., 2016, p. 7). Key stakeholders are categorized as communities of students, research, practice (industry) and university (academia). Industrial PhD students are at 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 & Olsson, 2020). Here, the collaboration is viewed as a cross-fertilization not only of disciplines but also of academia and industry, theory and practice related to industrial PhD education.

METHODOLOGY

This explorative qualitative research on industrial PhD student collaboration was conducted over a three year period (2019-2022) to capture several disciplines and perspectives (Bernhard & Olsson, 2020, 2022). A case study approach is applied providing a flexible, multiple perspective research approach in WIL contexts (see Lucas et al., 2018). This study contributes to research on cross-boundary organizational collaboration for learning by focusing on the overlapping role of industrial PhD students. The perspectives of industrial PhD students, academia, and industry are applied with WIL as a theoretical lens to identify issues for improved collaboration.

Research Context

This study is contextually drawn from Swedish higher education with focus on industrial PhD education. A Swedish PhD program corresponds to four years of full-time study comprising 240 ECTS credits (Swedish Higher Education Authority, 2021). Swedish industrial PhD students are acting in the intersection between higher education and work, with the same academic quality demands for admission (i.e., master's level), and national learning outcomes required for the PhD thesis and third cycle graduation as traditionally enrolled academic PhD students, combined with demands and expectations from their industrial employers. Across all Swedish universities 17,100 PhD students were enrolled in 2020 of which approximately 6% were industrial PhD students (Swedish Higher Education Authority, 2021). The empirical research context is University West in Sweden, which is the only Swedish university with a WIL profile embracing education, collaboration, and research (University West, 2021).

Data Collection and Analysis

Data collection was conducted from November 2019 to March 2022 by applying qualitative methods. The sample includes three categories of respondents (n=38): 19 industrial PhD students within the three disciplines of Work-integrated Learning, Informatics with a specialization in WIL, and Production Technology; nine representatives from academia and 10 respondents from industry. All 21 industrial PhD students at University West were invited, that is, a total survey, and 19 of them participated in this study. The academy perspective was represented by the main supervisors and head of PhD education. The industry perspective was represented by industrial supervisors/mentors covering both the private and public sectors.

The industrial PhD students were in different stages of their PhD education: 14 in the beginning stage, three in a middle phase, and two students in the final stages of their studies as illustrated in Table 1. The distribution among disciplines was: five from Informatics with a specialization in WIL, six from Production Technology, and eight from WIL. Different kinds of organizations (i.e., employers) in society were represented as 11 of the industrial PhD students were employed in the public sector and eight in the private sector. The industrial PhD students were enrolled in industrial PhD education varying from part-time studies to full-time studies, ranging from 50% to 100%.

TABLE 1: Overview of industrial PhD students.

Industrial PhD Students (IPS)	**Sector**	**Phase of PhD Education**
IPS1	Private	Beginning
IPS2	Public	Beginning
IPS3	Public	Middle
IPS4	Private	Beginning
IPS5	Public	End
IPS6	Private	End
IPS7	Private	Beginning
IPS8	Private	Beginning
IPS9	Private	Middle
IPS10	Private	Beginning
IPS11	Private	Beginning
IPS12	Public	Beginning
IPS13	Public	Beginning
IPS14	Public	Beginning
IPS15	Public	Beginning
IPS16	Public	Beginning
IPS17	Public	Beginning
IPS18	Public	Middle
IPS19	Public	Beginning

All academic supervisors for industrial PhD students were invited to participate. The academy perspective was represented by nine respondents as main academic supervisors from three disciplines, some of whom supervised more than one industrial PhD student, and representatives from management of PhD education at the university (referred to as A1-A9).

The practice perspective was represented by 10 respondents (all the industry supervisors/mentors for the 19 industry PhD students were contacted). The respondents represented organizations from the

public sector (7) and private sector (3). They had various experiences of employing and managing industrial PhD students and the number of employed industrial PhD students ranged from 1 to 55. The respondents had the following professional roles: research and development managers, operational manager, and senior advisor, almost all of whom had a doctoral degree (referred to as P1-P10).

A semi-structured interview guide was constructed to give voice to respondents from different perspectives (Linneberg & Korsgaard, 2019). The interview guide included issues on benefits, challenges, research collaboration and learning through the perspectives of industrial PhD students, academia, and industry. As the study progressed additional questions on the impact of the COVID-19 pandemic were added. As the respondents were geographically dispersed and due to the ongoing COVID-19 pandemic, data collection was performed via a mix of face-to-face interviews, telephone interviews, digital interviews and/or e-mail survey. All interviews were conducted by the two authors together, ranged from 20–40 minutes, and were recorded with informed consent, transcribed, and coded. All transcripts of the face-to-face or telephone/digital interviews with industrial PhD students have been validated by the respondents. Additionally, several email surveys with respondents from industry have been followed up by telephone/digital interviews to validate their responses. Following national ethics legislation, international research ethics and striving for research rigor (Gill & Gill, 2020) all data was collected with informed consent and the authors have not had any supervisory relationships with the industrial PhD students or their organizations. They have not served on their thesis committees, although the authors of this paper are employed at the same university. Anonymity was guaranteed for all respondents to ensure they felt independent and safe to openly describe their respective perspective.

All collected data was analyzed to identify patterns and themes following an analytical method in iterative phases: familiarization with the data, generating initial codes, searching for themes, reviewing potential themes, and defining and naming themes (Braun & Clarke, 2012). An abductive cyclical analysis process was applied (Saetre & Van de Ven, 2021) throughout the three-year study as the perspectives of industrial PhD students, academia and industry were explored along the progression of the theoretical framework and collected data. An initial coding of all the data was done individually by each author using color markings and analytic memos to capture the researchers' ongoing reflections, inspired by Linneberg and Korsgaard (2019). Iterative steps of analysis conducted together by the two authors followed to identify and analyze themes related to benefits, challenges, collaboration and learning as interactions between academia and practice.

FINDINGS

To identify prerequisites for industrial PhD education collaboration, all three perspectives, industrial PhD students (IPS), academia (A), and practice (P)are integrated in this section to illustrate benefits and challenges of industrial PhD education collaboration and to conceptualize structure and management essential for such a collaboration.

Benefits of Industrial PhD Education Collaboration

The mutual benefits of industrial PhD education collaboration are strongly emphasized by respondents as illustrated by selected quotes in Table 2. The benefits are categorized in the following sub-themes: (i) access to practice – inclusion in networks, projects, and empirical data; (ii) understanding of practice – contextual understanding, inclusion, and tacit knowledge; and (iii) integration of theory and practice – multiple perspectives and knowledge creation.

TABLE 2: Benefits of industrial PhD education collaboration: Quotes from respondents.

Access to practice – inclusion in networks, projects, and empirical data
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 look at myself as an 'inspirer' being part of the research and the scientific way of thinking bringing it into work life (IPS2).
The major advantage is the proximity to the empirical data, the accessibility to exciting projects and interesting people (IPS5).
The industrial PhD student is close to the practice or empirical experience and the research is often very important also for the employer (A2).
An opportunity to ensure that the research topics and questions are relevant to society, i.e., societal impact. To be able to make an imprint on society, that is not as evident when it comes to traditional PhD students. It is also a way to get new partners (A7).
There are many phenomena that cannot be studied unless subjectivity is allowed. Some people have more prerequisites to study certain phenomena because they are accepted as insiders hence acting in a context where they understand what is happening. The insider perspective is as important as the outsider perspective, and you must integrate these two in research (P3).
Understanding of practice - contextual understanding, inclusion, and tacit knowledge
I have a number of years in the industry, and there is a lot of 'silence' [tacit knowledge] 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 just there (IPS6).
The industrial PhD students are a little more down-to-earth and have a little more grasp of what works in practice (A4).
An industrial PhD student has cultural skills and is an 'insider' who may find the current issues to study (P3)
The industrial PhD students come from my world. We have a shared understanding founded on a common base [in practice] (P10).
Integration of theory and practice – multiple perspectives and knowledge creation
This is the ultimate way to build knowledge within a field! The PhD student builds contact paths between the organization and academia. Learning is generated through proximity, continuity, knowledge making, and bridge-building principles…. you get many validation opportunities [tests] … It creates great added value and what is of interest for society (P3).
The greatest advantage 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 organization (IPS18).
To develop knowledge, methodology and company strategies our company needs researchers. The PhD student and I work closely together with product development. It is affecting our competence development positively. (P1)
The industrial PhD student is a link to the university for knowledge exchange, is building new knowledge, is contributing to competence development of co-workers, and is acting as an ambassador for research that may generate internal spin-offs (P6).
That the theoretical perspectives are mixed with practical perspectives, which forms the foundation for research with both theoretical and practical impact (A9).

Respondents from all three perspectives emphasized several benefits of an industrial PhD education collaboration. A major benefit is that the industrial PhD students are active in the intersection of academia and industry with access to practice, networks and empirical data combined with the industrial PhD students' understanding of practice, contextual understanding, and tacit knowledge.

Challenges of Industrial PhD Education Collaboration

Despite all the recognized benefits of industrial PhD education collaboration there are tensions and challenges that all collaboration partners need to consider, as illustrated by selected quotes in Table 3. The identified challenges are categorized in the following sub-themes: (i) understanding and expectations of the collaboration; (ii) formal agreements for collaboration – administrative bureaucracy,

financing, and conflicts of interest; (iii) inclusion and access; and (iv) integration of research in practice – societal impact.

TABLE 3: Challenges of industrial PhD education collaboration: Quotes from respondents.

Understanding and expectations of the collaboration
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 (IPS9).
It is a challenge to see a completely different timeline than we are used to and to give enough time to the PhD project and to the industrial PhD student (P4).
It is all about balancing and switching between different roles and often opposite perspectives and goals. (IPS5)
As a supervisor I do not have the same level of control of what requirements the employer places on the industrial PhD student (A7).
The expectations from industry and from university may sometimes clash ... It is difficult to integrate the need for societal knowledge with knowledge gaps/research interest from academia (P7).
Formal agreements for collaboration
There was repeatedly a lot of trouble with the arrangement of my financing [salary payments] (IPS17).
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 I do not get access to the Wi-Fi for employees (IPS4).
The bureaucratic ways of the university do not always match the approaches and processes of external partners. We are much, much, much slower, which is a challenge (A5).
The university has to develop more formal structures, processes and procedures around industrial PhD students (A3).
A well-functioning reference group is needed around the industrial PhD student with representatives from academia and industry throughout the entire PhD education to continuously discuss expectations and their fulfillment or not (A9).
The questions that arise [in agreements] are almost always linked to confidentiality, publication rights and ownership of results (A8).
In my case it has been very confusing initially due to conflicts of interest among the collaborating partners (IPS12).
Inclusion and access
It is incredibly lonely to be an industrial PhD student. In my case, I am in the middle of three organizations (IPS18).
I strongly argue that my industrial PhD student should be made visible [included] on the university website. Especially now when she is doing interviews with respondents that may want to check her up at our website, yet she is not mentioned and not visible at all! (A3).
A challenge is to make the industrial PhD students visible within the organization [industry], especially if they are doing research that is outside the daily work of the employees within the company (P6).
There are challenges 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 scrutinized more harshly than an external person (IPS6).
We always end up in a dependent position vis-à-vis the industry organization in which you have to 'conduct' yourself a little more and act a bit more carefully, perhaps more than what you do with a traditional PhD student (A4).
Integration of research in practice - societal impact
One challenge, but also an opportunity, is to be able to retain the strengths of both work-integrated learning and of professional knowledge and technology at the workplace (P1).
To use competence in an adequate way when the industrial PhD student has graduated. We would like to see staff with a dissertation having 20 percent research in their position after graduation (P9).
Not all employers think about or prepare for the [career] development that takes place for the industrial PhD student. After graduation you do not take care of the individual who is then trained as a researcher, they assume that he/she will go back into business just as before (A2).
Continuity is vital since it takes time to develop lasting relationships. It is important to have endurance. You also must have contact and trust at the strategic level of the organization, i.e., structural continuity (P3).
At the other side of the scale lies the fact that it is not always positive if society [industry] completely sets the agenda for what we study. We need to listen very carefully to the challenges and problems of society; still there must be academic research freedom and we must be able to conduct research that may criticize society (A7).

Conceptualizing the Structure and Management of Industrial PhD Education Collaboration

Based on the identified multi-perspective challenges, a suggested framework for how to structure and manage an industrial PhD education collaboration to achieve the full potential of the collaboration and support the industrial PhD students throughout the education is presented. Novel findings of the challenges of an industrial PhD education collaboration are presented from all three perspectives, integrated, and conceptualized in the suggested framework. An essential challenge is the limited understanding of each other's contexts, perspectives, and expectations. Furthermore, the importance of detailed formal agreements and structures for continuous interaction and dialogue among collaborating partners, education, and work is clearly recognized.

As illustrated in the WIL-based framework of industrial PhD education collaboration (see Figure 1) novel findings emphasize that industrial PhD education collaboration generates organizational learning and understanding across sectors and industries, that is, interaction between practice and academia. Practical and transferable skills are developed that are requested by academia as well as employers outside academia, hence generating cross-sector learning and societal impact based on the fundamental ideas of work-integrated learning.

Industrial PhD students clearly recognize benefits from being active in the intersection of academia and practice having contextual understanding and tacit knowledge, thus strengthening the interactions between practice and academia, and between practice and research. There are flows of research results through formal and informal interactions, for example, academic seminars, publications, workplace meetings, and operative work together with colleagues, that improve dissemination of new knowledge. The industrial PhD students partly embody this collaboration being active in research and student communities as well as academia and industry.

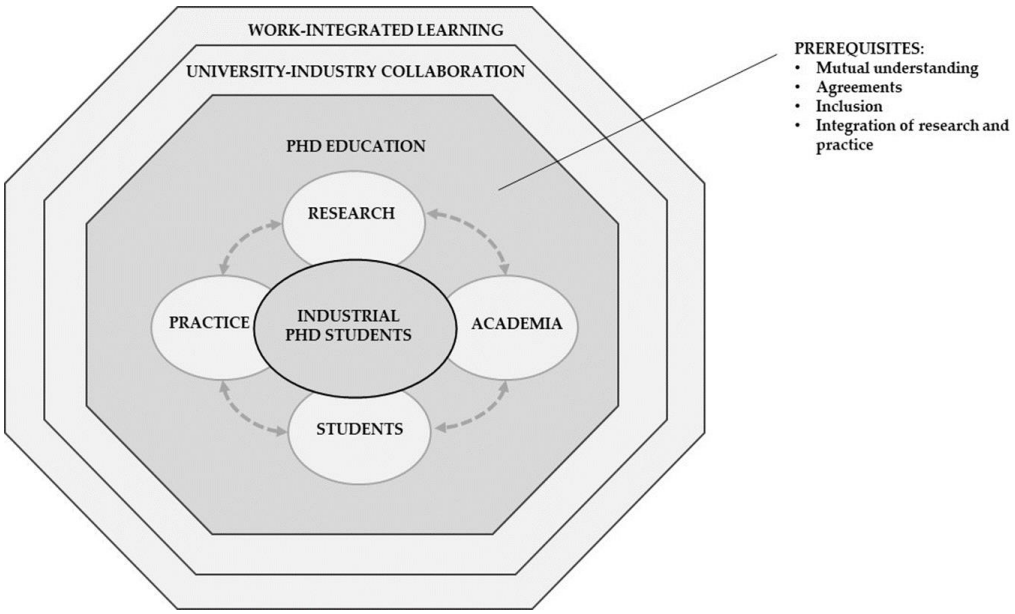
This study has highlighted tension between academia and industry. There are thus issues that academia and industry need to consider and resolve to improve involvement and collaboration such as reaching a deeper understanding of PhD education and industrial PhD students' workload, minimizing conflicts of interest and administrative bureaucracy, structuring financing and formal agreements, securing inclusion and belonging, and structures and routines for work promotion opportunities. This multi-perspective study clearly states that there is a need for increased formalized interactions between practice and academia to support the industrial PhD students spanning organizational boundaries. Notably, findings reveal that financial agreements including more than two organizations, for example, research projects with multiple partners, have negative impacts especially on the industrial PhD students' sense of belonging and identity, which may counteract identified benefits of collaboration.

Like the industrial PhD students, the respondents from academia stress benefits such as access to practice and empirical data offering opportunities for validation and testing of results and models in practice. However, challenges emerging that may counteract cross-sector learning are the fragmented life of the industrial PhD students with dual roles, deliveries and expectations, and academic supervisors' limited understanding and control of the requirements the employers place on the industrial PhD student.

Respondents from industry (practice) emphasize organizational learning such as knowledge sharing, knowledge creation, link to research, competence development, creating an environment for discussions and collegial support, and internal spin-offs. Yet, challenges recognized are difficulties in

reaching an understanding of the different contexts of academia and industry; different expectations and timelines; that academia recognizes and exploits industrial PhD students' pre-understanding of the industry context in the spirit of work-integrated learning; continuity in the relationship between academia and industry; finding financial solutions; and retaining competence after industrial PhD students' graduation.

FIGURE 1: A WIL-based framework of industrial PhD education collaboration.



DISCUSSION AND CONCLUSION

Drawing on the identified research gaps on industrial PhD education collaboration, this study aims to deepen research by critically exploring various perspectives in industrial PhD education collaboration based on the transitional role of industrial PhD students. The perspectives of industrial PhD students, academia, and industry are integrated and conceptualized into a WIL-based framework for industrial PhD education collaboration to identify prerequisites for how to structure and manage such a collaboration.

Industrial PhD education collaboration is argued to generate learning and understanding across sectors and industries. Based on the present multi-perspective findings, it is essential for involvement of *all* collaborating partners to recognize that challenges and tensions between academia and industry do exist and need to be considered to strengthen industrial PhD education as well as sustainable university-industry collaborations. Maintaining WIL in doctoral education is a shared responsibility among collaborating partners as there are mutual benefits. This process of collaboration is strongly dependent on individual industrial PhD student's opportunities to be included in the generation and dissemination of knowledge through close interactions, dialogues, and collective interpretations. Industrial PhD students as working professionals are bridging university-industry collaboration which corresponds to emerging research (Assbring & Nuur, 2017; Berg & McKelvey, 2020; Bernhard & Olsson, 2020, 2022; Patricio & Santos, 2020) as well as research on critical issues in university-industry collaboration such as need of trust, strategic orientation, continuity, and organizational culture (Olsson

et al., 2021; Rupčić, 2021; Rybnicek & Königsgruber, 2019; Strengers, 2014). By integrating and conceptualizing novel findings from three different perspectives this study reveals the following critical issues acknowledged as prerequisites to reach the full potential of industrial PhD education collaboration based on work-integrated learning:

- Understanding and expectations of the industrial PhD education collaboration. The interactions between academia and practice need to be increased to reach a deeper understanding of each other's perspectives and organizational contexts as well as the dual expectations of the contributions of an industrial PhD student during the entire PhD education. Continuous dialogue and close interaction are needed to build long-term relations, involvement, and trust for mutual knowledge creation by structuring and operationalizing the collaboration in actions, practices, and routines over time.
- Formal agreements for industrial PhD education collaboration. The collaboration needs detailed formal agreements to ensure all partners avoid conflicts of interest and maintain the relationship, thus not having negative impact on the industrial PhD students' work conditions. Both academia and industry need to be aware that financial agreements with multiple partners may endanger the benefits of collaboration.
- Inclusion and access. There are ethical dilemmas to consider regarding inclusion and access for industrial PhD students acting in different contexts and organizational cultures such as belonging, visibility and legitimacy, dual responsibilities, and dealing with confidential data. Industrial PhD students need structure and guidance from both academic and industry supervisors/mentors. The risk of jeopardizing academic research freedom is also identified as a dilemma.
- Integration of research and practice. The scope of the industrial PhD students' theses need to be carefully anchored in industry and research to achieve an integration of theory and practice based on a mutual understanding of the work-integrated learning approach. Since findings show that industrial PhD students already during their ongoing PhD education generate societal impact as flows of learning and new knowledge, collaboration partners are encouraged to formalize recurring interactions to disseminate new knowledge. Furthermore, industry demands to have a long-term perspective on the work promotion opportunities of the industrial PhD student to keep and engage the graduate industrial PhD student in relevant work tasks to retain knowledge and skills. On the other hand, it is also favorable for academia to keep the relation with the industrial PhD student after graduation by involving them part-time in education and/or research projects, that is, extending work-integrated learning for academia and industry beyond graduation.

This explorative study advances research on WIL in PhD education by integrating multiple perspectives from academia, industry, and industrial PhD students on the working professionals' transitions between employment (working life) and doctoral education. Prerequisites that are vital for structuring and managing industrial PhD education collaboration promoting WIL towards the "ultimate way to build knowledge'" (P3) are revealed. Identified challenges need to be considered by all collaborating partners to reach the full potential for industrial PhD education collaboration.

Limitations and Future Studies

This explorative study is a first multi-perspective step that may pave the way for future studies as it contributes novel insights for industry as well as academia. Although there are international variations on how PhD education is structured and collaboration with practice, the findings of this study may be

translated to and applied in other contexts. There are limitations as this study originates from a single university. The study was conducted during the COVID-19 pandemic which may have affected the results. Further research is of importance to deepen and broaden the field of PhD education to meet the demands and development of contemporary society.

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The International Journal of Work-Integrated Learning (IJWIL) publishes double-blind peer-reviewed original research and topical issues related to Work-Integrated Learning (WIL). IJWIL first published in 2000 under the name of Asia-Pacific Journal of Cooperative Education (APJCE).

In this Journal, WIL is defined as " *An educational approach involving three parties – the student, educational institution, and an external stakeholder – consisting of authentic work-focused experiences as an intentional component of the curriculum. Students learn through active engagement in purposeful work tasks, which enable the integration of theory with meaningful practice that is relevant to the students' discipline of study and/or professional development"* (Zegwaard et al., 2023, p. 38*). Examples of practice include off-campus workplace immersion activities such as work placements, internships, practicum, service learning, and cooperative education (co-op), and on-campus activities such as work-related projects/competitions, entrepreneurships, student-led enterprise, student consultancies, etc. WIL is related to, and overlaps with, the fields of experiential learning, work-based learning, and vocational education and training.

The Journal's aim is to enable specialists working in WIL to disseminate research findings and share knowledge to the benefit of institutions, students, WIL practitioners, curricular designers, and researchers. The Journal encourages quality research and explorative critical discussion that leads to the advancement of quality practices, development of further understanding of WIL, and promote further research.

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Types of manuscripts sought by IJWIL is of two forms: 1) *research publications* describing research into aspects of work-integrated learning and, 2) *topical discussion* articles that review relevant literature and provide critical explorative discussion around a topical issue. The journal will, on occasions, consider good practice submissions.

Research publications should contain; an introduction that describes relevant literature and sets the context of the inquiry. A detailed description and justification for the methodology employed. A description of the research findings - tabulated as appropriate, a discussion of the importance of the findings including their significance to current established literature, implications for practitioners and researchers, whilst remaining mindful of the limitations of the data, and a conclusion preferably including suggestions for further research.

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