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UNIVERSITY-INDUSTRY COLLABORATION IN HIGHER EDUCATION: EXPLORING THE INFORMING FLOWS FRAMEWORK IN INDUSTRIAL PHD EDUCATION

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ABSTRACT

Aim/Purpose	The aim is to explore the informing flows framework as interactions within a PhD education practicing a work-integrated learning approach in order to reveal both the perspectives of industrial PhD students and of industry.
Background	An under-researched field of university-industry collaboration is explored revealing both the perspectives of industrial PhD students and of industry.
Methodology	Qualitative methods were applied including interviews and document studies. In total ten semi-structured interviews in two steps were conducted. The empirical context is a Swedish PhD program in informatics with a specialization in work-integrated learning.
Contribution	By broadening the concept of work-integrated learning, this paper contributes empirical results on benefits and challenges in university-industry collaboration focusing on industrial PhD students and industry by applying the informing flows framework.
Findings	Findings expose novel insights for industry as well as academia. The industrial PhD students are key stakeholders and embody the informing flows between practice and university and between practice and research. They are spanning boundaries between university and industry generating continuous opportunities for validation and testing of empirical results and models in industry. This may enable increased research quality and short-lag dissemination of research results as well as strengthened organizational legitimacy.

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Recommendations for Practitioners	This explorative study show that it is vital for practice to recognize that challenges do exist and need to be considered to strengthen industrial PhD programs as well as university-industry collaborations. Additionally, it is of importance to formalize a continuously dissemination of research in the industries.
Recommendations for Researchers	Academia is recommended to recognize the value of the industrial PhD students' pre-understanding of the industry context in the spirit of work-integrated learning approach. The conditions for informing flows between research and practice need to continuously be maintained to enable short-term societal impact of research for both academia and industry.
Impact on Society	This study contributes ways to reach short-term societal research impact through industrial PhD education that bridges and consolidates industry-university collaboration generating mutual learning and understanding.
Future Research	Future international and/or transdisciplinary research within this field is encouraged to include larger samples covering other universities and a mix of industrial contexts or comparing industrial PhD students in different phases of their PhD education.
Keywords	university-industry collaboration, industrial PhD education, work-integrated learning, third-cycle education, informing flows framework

INTRODUCTION AND BACKGROUND

Issues of digitalization and the pace of technological progress are vital societal challenges, especially the use of information technology throughout all sectors of society, and this needs to be recognized in university-society collaboration. In recent decades higher education in developed countries has experienced a rather demanding transformation towards increased interaction with industry, community, and governments (Altbach et al., 2019). Complex local and global societal challenges often need the inclusion of many perspectives and many problems are transdisciplinary in nature (Cohen, 2009). New forms of university collaboration with contemporary society are required. All levels of university programs and research need to meet societal challenges through education and research as well as various outreach approaches (De Jong et al., 2014; Galan, 2018; Larsson & Holmberg, 2018; Lind et al., 2013) or industry-university course partnerships (Kock et al., 2000). Universities should also act as a provider of trained researchers, and there is increased interest in collaborative PhD education, i.e., third-cycle education (Borrell-Damian et al., 2010; Gill & Mullarkey, 2015; Grimm, 2018; Gustavsson et al., 2016; Roolaht, 2015). Furthermore, there are calls for higher education to embrace an entrepreneurial approach (Giones, 2019, Klofsten et al., 2019) in order to inform society and act as knowledge hubs embedded in society (Bölling & Eriksson, 2016; Gellerstedt et al., 2018; Gill et al., 2016; Lind et al., 2013; Olsson et al., 2020). Research impact and innovations are highly valued by governments, thus of crucial importance for universities (Altbach et al., 2019; Gellerstedt et al., 2018; Rampersad, 2015; Selsky & Parker, 2005). Hence there is a demand for increased exchange of information in university-society collaborations in order to generate and disseminate new knowledge, research findings and innovations (Bölling & Eriksson, 2016; Olsson et al., 2020) as well as for academia to understand industrial practices (Gill et al., 2016; Kihlander et al., 2011). However, translation of research findings into societal benefits and practice is lengthy and may take up to 10–17 years from research funding to publication (De Jong et al., 2014; Houghton et al., 2010; Morris et al., 2011). University research is expected to produce returns on investments, value, and applicable results for society and collaborations aiming for short-lag research impact are vital (Olsson et al., 2020).

One transdisciplinary approach to increase university-society collaboration is work-integrated learning (WIL). WIL is an umbrella term for various approaches and forms that integrate theoretical

knowledge with practice work and bridge research, education and practice (Bates, 2008; Bernhard et al., 2018; Billett, 2009; Bowen & Drysdale, 2017; Gellerstedt et al., 2015; Olsson et al., 2020; Patrick et al., 2008; Rampersad, 2015; Selsky & Parker, 2005). In this paper WIL is viewed as research together with practitioners (Bernhard et al., 2018; Patrick et al., 2008; Rampersad, 2015). WIL is a model of collaboration that particularly focuses on knowledge exchange between university and society and the dual societal learning outcomes for the involved actors (Lundin et al., 2008). WIL has the potential to provide direct benefits not only for workplaces and universities, but also for a wider community as well as creating synergy between theory and practice (Arvemo et al., 2018; Gellerstedt et al., 2015). The WIL concept in higher education may be categorized as follows: (i) co-op, the traditional cooperative education model (Barbeau, 1973; Betts et al., 2009); (ii) case, using practice as inspiration; (iii) imprint, bringing practice to class; (iv) tools, using professional tools; and (v) field, bringing class to practice (Gellerstedt et al., 2015). Apart from the pedagogical benefits with experiential learning, WIL also maintains the transfer between higher education and practice (Olsson et al., 2019, 2020), and WIL students have career benefits regarding early career job advancement and higher salary (Gellerstedt et al., 2015). Although WIL is an umbrella term, the concept needs to adjust to the development in contemporary society and be broadened to include global perspectives on the future (Bowen & Drysdale, 2017; Olsson & Bernhard, 2020). An under-researched aspect of WIL is related to third-cycle education and the collaboration between university and industry through industrial PhD students as they are active in the university-industry interface (Bernhard & Olsson, 2020; Olsson & Bernhard, 2020). The concept of industrial PhD students here refers to students that originated from the industry and are fully employed in industry during their PhD education, i.e., the industry is investing in an employee to become a PhD doctorate. Accordingly, the industrial PhD students are at the same time involved in both the university and the industry, with the same academic demands as traditionally enrolled academic PhD students. They act as a channel or broker of knowledge spanning the boundaries between university and industry (Assbring & Nuur, 2017; Berg & McKelvey, 2020; Bernhard & Olsson, 2020; Galan, 2018; Gustavsson et al., 2016; Kuntuu et al., 2018; Olsson & Bernhard, 2020; Thune, 2009), hence also struggling with dual cultures and expectations (Bernhard & Olsson, 2020; Kihlander et al., 2011).

In order to achieve deeper insights and analyze this kind of university-society collaboration from different perspectives, an informing flow framework, originating from Gill et al. (2016) is applied. This informing science framework is closely related to the WIL approach as it stresses transdisciplinary work and exchange of knowledge from one field to another in order to break down boundaries between collaborating actors that hinder the flow of knowledge by using information technology (see Cohen, 2009). The informing flow model for looking at business school informing channels has its overall aim to function as a strategic tool to identify and assess interactions related to informing channels and forms. This model is based on the premises of growing complexity of society and growing participant diversity of the stakeholders/clients being informed. In their framework the stakeholders/clients were categorized as the students, the research community, and the community of practicing managers that employ the students as the three most important stakeholders (Gill et al., 2016). In this paper the collaboration is viewed as a cross-fertilizing not only of disciplines but also of university and industry/theory and practice related to industrial PhD third-cycle education in informatics with the specialization in WIL. Focus is on informing flows as interactions between university and industry in PhD education identifying challenges and benefits that may affect these interactions. According to a previous case study (Bernhard et al., 2018), research on PhD program collaboration and work integrated learning through the lens of the informing flow framework, the interactions between university, students, research, and practice needs to be further developed.

There is however limited research on the benefits of university-industry collaboration regarding PhD education (Assbring & Nuur, 2017; Bernhard et al., 2018; Bernhard & Olsson, 2020; Olsson & Bernhard, 2020; Roolaht, 2015), and it is mainly focused on the students' learning outcomes and educational experiences (Berg & McKelvey, 2020; Thune, 2009). Emerging research covers, e.g., European

industrial PhD programs in informatics and engineering in Sweden (Berg & McKelvey, 2020; Kihlander et al., 2011), engineering and health science in Portugal (Tavares et al., 2020), engineering and automotive manufacturing in Germany (Grimm, 2018), programs as policy tools for university-society collaboration in Estonia and Denmark (Roolaht, 2015), and, in the USA, the interdisciplinary business doctorate program for executives (Gill & Mullarkey, 2015). Furthermore, research on collaboration and strategic collaborative arrangements over time between industrial PhD students and industry is scarce (Kihlander et al., 2011).

As a response to calls for further research (e.g., Bernhard et al., 2018) the aim of this explorative study is to apply the informing flows framework on interactions within a PhD education program practicing a work-integrated learning approach. The benefits and challenges that may affect these interactions from both the perspectives of industrial PhD students and of industry are explored. The empirical context is a Swedish industrial PhD program in informatics with a specialization in work-integrated learning. The following research questions are thus addressed:

RQ 1: What are industrial PhD students' views on the PhD education collaboration?
RQ 2: What are industry views on the PhD education collaboration?

Qualitative methodology was applied and ten semi-structured interviews with five industrial PhD students and five representatives from organizations (industry) were conducted.

THEORETICAL FRAMEWORK

As stated above, earlier research mainly focuses on the students' learning outcomes and educational experiences (Thune, 2009), although some benefits of this kind of collaboration are recognized (Assbring & Nuur, 2017). Andersen et al. (2017) stress the importance of skills, planning, and communication to design and run a successful university-industry collaboration. Furthermore, trust, continuity, and long-term relationships between university and industry are vital for successful collaboration and societal impact (Olsson et al., 2020). The industrial benefits of a university-society collaboration may include collaboration for product or process development, access to academic networks, competence development/supply, and business opportunities (Berg & McKelvey, 2020; Broström, 2012).

Recent research on impacts of industrial PhD education in Sweden show short-term impacts such as competence development, new or strengthened collaboration with universities and companies, legitimacy, technology transfer, and networks. The long-term impacts for industry are new business opportunities, industrial renewal/development, increased competitiveness, networks, and competence development and innovation capacity (Berg & McKelvey, 2020; Gustavsson et al., 2016). Impacts for universities are, e.g., increased number of PhD students enrolled, strengthened collaboration with companies, boosting faculty competence development, new research collaboration and strengthened position within a research area nationally and internationally, development of doctoral education, and external research funding (Gustavsson et al., 2016). Kihlander et al. (2011) point out that to increase the probability that both academia and industry will view the collaboration as mutually rewarding, the various collaborative parties need to understand and cope with expectations and requirements placed on the industrial PhD student. Additionally, prerequisites identified as success factors for collaboration around industrial PhD education are, according to earlier research (Grimm, 2018; Gustavsson et al., 2016; Kihlander et al., 2011; Kolmos et al., 2008; Tavares et al., 2020), joint design and support of the program, aligned dual requirements, long-term organizational commitment from university and industry, and a supportive organizational structure. The collaboration and aims should be strategically anchored in both university and industry with transparent regular communication following the student's progress and joint supervision, design, and scope of PhD projects. Furthermore, careful recruitment of motivated students who may work in the interface between university and industry is vital. Organizational flexibility is important to provide the PhD student with flexibility and time to

collaborate with colleagues in university and industry and to avoid isolation or high workload. However, the divergence between university and industry may cause dilemmas such as the different time horizons regarding research results, industry's need to keep data confidential, and the university's need to disseminate knowledge as article publications (Tavares et al., 2020).

A framework model for looking at business school informing channels developed by Gill et al. (2016) has its overall aim to function as a strategic tool to identify and assess resources spent on activities related to informing channels and forms. This model is based on the premises of growing complexity of the environment and growing participant diversity of the stakeholders/clients being informed. With this background, Gill et al. (2016) argue for a change in informing channels from not only relying on traditional lectures and traditional knowledge-based collaboration, but instead towards more interactive informing channels with increased emphasis on discussion and simulation, and on the construction of interactive exchange of information. In their framework the stakeholder/client category was reduced to the students, the research community, and the community of practicing managers that employ the students as the three most important stakeholders (Gill et al., 2016). Using this framework, slightly modified, findings from a study evaluating a PhD program (third cycle) and research environment from a WIL perspective (Bernhard et al. 2018) indicate that communication and interaction initiated from PhD students and research environment towards industry were generally strong, while in the opposite direction originating in practice was weaker. Collaboration activities were identified and visualized within and between the research education/environment and university key stakeholders as illustrated in Figure 1.

In order to embrace deeper insights into these results, a recent case study was performed identifying several informing flows between and within institution, research, practice, and student communities. All flows tended to go through the industrial PhD students (Bernhard & Olsson, 2020).

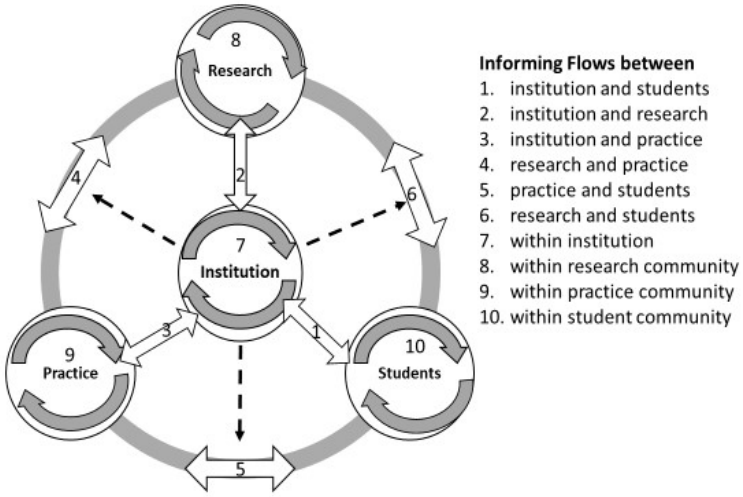

Figure 1. The stakeholders and the ten informing flows in the Informing Flows Framework.
(Source: authors adapted from Gill et al., 2016, p. 7)

Thus, research on interaction and informing flows between university, students, research and practice needs to be further developed (Bernhard et al., 2018; Bernhard & Olsson, 2020; Olsson & Bernhard, 2020), especially the two-way exchange and mutual benefits of collaboration on PhD education (Gustavsson et al., 2016).

METHODOLOGY

This research is conducted as an explorative case study, focusing on industrial PhD students and university-society collaborations within a Swedish doctoral program (third-cycle education) in the discipline of informatics with a specialization in work-integrated learning.

RESEARCH CONTEXT

This study is contextually drawn from higher education in Sweden. Across all Swedish universities 16,861 PhD students were enrolled in 2018 and of these 979 (almost 6 percent) as industrial students (Swedish Higher Education Authority, 2019). Doctoral education has been transformed along with societal needs and labor markets for PhDs, and PhD education does not merely aim for academic careers (Malfroy, 2011; Metcalfe, 2006). The design and funding of a PhD education show national variations; thus, the majority of PhD students are by tradition funded by universities and external funding. However, industry funding of PhD students is increasing and often also includes industry experts taking part in supervisory committees (Borrell-Damain et al., 2010).

The empirical research context is University West in Sweden, which is one of 31 public Swedish higher education institutions (Swedish Higher Education Authority, 2019) and has an overarching profile and basic principle applied to learning, research, the exchange of ideas, and educational development. University West took one of the first initiatives for supporting WIL in 1990 as the only university in Sweden to adopt cooperative education (co-op) in bachelor's programs. In 2002 University West was commissioned by the Swedish government to develop WIL as a pedagogical strategy. During 2011–2019 University West offered two doctoral degrees with specialization in WIL in the fields of informatics and pedagogy, which means that the PhD program is based on WIL not only as an aim for the research projects, but also as a pedagogical approach. There are both PhD students employed by the university as well as PhD students employed by industry, i.e., industrial PhD students who follow these doctoral degree programs. A Swedish PhD program corresponds to four years of full-time study comprising 240 ECTS credits (Swedish Higher Education Authority, 2019). In the Swedish context, the PhD students are enrolled in PhD education programs and required to take credit courses and write an independent thesis. This study concerns industrial PhD students enrolled in the informatics program with a specialization in WIL at University West that focuses on the use and development of information technology (IT) in the workplace. It deals with studies of the way IT affects learning, knowledge, and cooperation in the workplace. Informatics with a specialization in WIL is an interdisciplinary subject area with links to work organizational science, computer science, educational science, sociology, media and communication science, and cognitive science. For the doctoral degree, the courses comprise 90 ECTS credits (60 of which are in compulsory courses) and a thesis project comprising 150 ECTS credits.

DATA COLLECTION AND ANALYSIS

This study explores the informing flows framework on university-industry collaboration in higher education with focus on industrial PhD education in order to capture the perspectives of industrial PhD students and of industry. A qualitative methodology was applied, and individual semi-structured interviews were conducted in two steps to reveal (i) industrial PhD students' views on the PhD program and collaboration between research, university, and industry in autumn 2019, and (ii) industry's' views on investing in industrial PhD education and interaction between research, university, and industry in spring 2020. Furthermore, document studies were conducted as data was collected via the university administration from the industrial PhD-students' official annual individual study plans for the PhD study programs in order to validate information about the PhD students, their employment, their study progress, their thesis project and scientific work, and contact persons at their organizations. Hence, in this qualitative, interpretive study, we aimed at striving for research rigor by selection of respondents, semi-structured and coded interviews, use of respondent validation and triangulation

to confirm findings, and awareness of how to reduce researched bias (Gill & Gill, 2020). Furthermore, a detailed documentation of all steps in the research process was conducted in order to enhance transparency replicability.

During 2020 the School of Business, Economics and IT, University West had five enrolled industrial PhD students and nine traditional academic PhD students within the field of informatics with a specialization in WIL. All five industrial PhD students participated; as mentioned above, they originate from and are fully employed in industry during their PhD education still following the same academic demands. They were however in different stages of their PhD education and represented different sectors of society. The respondents included three women and two men ranging in age from 37 to 50. Three of them are from the public sector and two from the private sector, representing industries such as health, education, IT consulting, and the furniture/design industry. Three of the respondents were in the beginning of the program, one respondent was in the middle, and one at the end as illustrated in Table 1. The percent of their PhD enrollment varied from 50 percent to 100 percent. Following research ethics and striving for research rigor (Gill & Gill, 2020), we have not had any supervisory relationships with the industrial PhD students and their organizations, nor been serving on their thesis committees yet the authors of this article are employed at the same university. In order to make the industrial PhD students feel independence not affecting students' responses about their organizations we have offered and applied anonymity. The representatives from the organizations where the PhD-students are employed have not had access to the industrial PhD-students' interview transcripts.

Table 1. Overview of respondents

Respondents	Sector	Phase of PhD Education
Industrial PhD students		
R1	Private	Beginning
R2	Public	Beginning
R3	Public	Middle
R4	Private	Beginning
R5	Public	End
Organizations		
O1	Private	
O2	Public	
O3	Public	
O4	Private	
O5	Public	

Two contact persons at each of the industrial PhD students' organizations (industries) were invited to participate in the second step of the data collection. In total five contact persons participated representing the public sector and the private sector. They had various experiences of employing and managing industrial PhD students. The selected organizations had from 1 to 55 employed industrial PhD students. The respondents had the following professional roles: research and development managers, operational managers, and senior advisor, almost all of them with an academic degree.

The interview guide for the industrial PhD-students covered four themes: (i) the benefits and the challenges being an industrial PhD-student; (ii) if and how they perceived that their thesis project within the PhD education generated learning and new knowledge at the university and/or at the specific workplace (industry); (iii) the process and routines for knowledge exchange and knowledge transfer related to the PhD education at the workplace (industry), and (iv) their views of the overall collabora-

tion between university and workplace (industry). The interview guide for the respondents at the organizations covered the following themes: their profession; their working role in the organization related to the industrial PhD-student; the organizational benefits and challenges having an employee following the industrial PhD-program; if and how they perceived that the thesis project of the industrial PhD-student generated learning and new knowledge at their specific workplace (industry); the process and routines for knowledge exchange and knowledge transfer related to the PhD education at the workplace (industry), and their views of the overall collaboration between university and workplace (industry); if needed, what may be improved in the collaboration between the university and the organization; the approx. number of industrial PhD-students employed within the organization.

Due to the respondents studying and or working in different contexts and due to the ongoing COVID-19 pandemic, the data collection was performed as a mix of face-to-face interviews, focus groups, telephone/Zoom semi-structured interviews in order to give voice to the respondents (see Linneberg & Korsgaard, 2019), and as an email survey with open-ended questions with follow-up telephone interviews. The interviews were performed by the two researchers together and ranged from 20–40 minutes, were recorded with informed consent, transcribed, and coded. All transcripts of the face-to-face or telephone/Zoom interviews with PhD-students have been validated by the respondents. The email surveys with respondents from the organizations have been followed up by telephone/Zoom interviews in order to validate their responses.

All collected data was analyzed in several rounds to identify patterns and recurring themes as well as contradictions, fulfilling the aim of this study (Alvesson & Kärreman, 2007). As the data was collected in two steps, coding was also conducted in two cycles. Furthermore, an initial coding of all the data was done individually by each author using color markings and analytic memos to capture the ongoing researchers' reflections (Linneberg & Korsgaard, 2019). Then the data was analyzed according to the pre-defined codes, i.e., the different flows in the informing flow framework (Gill et al., 2016) by the two authors together. The informing flow stakeholder categories applied in this study were all PhD students, the research community, the university, and the community of practicing managers (industry) who employ the industrial PhD students.

FINDINGS AND DISCUSSION

This section presents and analyzes findings of this study based on the two research questions.

INDUSTRIAL PHD STUDENTS' VIEWS ON THE PHD EDUCATION COLLABORATION

The respondents state several benefits they experience being industrial PhD students such as inclusion in academia as well as industry, being part of a research context and an industrial context with access to networks, and synergy effects related to empirical data and new knowledge as illustrated by the following quotes.

> I think it is very good to have one foot in the organization [industry]. Partly because you keep your friends and workmates. You may continue to work in your work context and not lose that part. In my case, the health center is part of the research, which means that it gives me a lot of input for my research to work at the health center based on the fact that I am part of the research process when developing a test bed. I also try to look at myself as an "inspirer" being part of the research and the scientific way of thinking bringing it into work life and I know that it is not easy to have that focus in the daily work, but since I work 50-50 I can bring it to my workmates. (R2)

> The advantage is that this can probably enrich both my dissertation and the results that I bring into the business. I have no difficulty whatsoever in gaining access to empirical data because there is a lot of it at my organization. (R1)

> The big advantage is the proximity to the empirical data, the accessibility to exciting projects and interesting people. There are synergy effects, working with development projects that generate data, which can and may be used for research purposes. (R5).

> … to get to know a whole new research field and a research environment that I would not have known if I had not been accepted as a doctoral student. That has been a big advantage! After all, I have gained insight into knowledge that I would not otherwise have received, and this has opened up a new world in terms of what research already exists ... but also as a door opener to be part of a research environment. Not only do I need to read about other people's research, but I can actually take part in a research environment where *I* get to share my experiences, which means that I also get more benefit from what I get back. I see that as a very, very big advantage and it has expanded my networks a lot. (R3)

The mutual benefits are strongly emphasized by the respondents who are acting as channels or spanning boundaries between university and industry, corresponding to earlier research (see Assbring & Nuur, 2017; Galan, 2018; Gustavsson et al., 2016; Kunttu et al., 2018; Thune, 2009). However, there are also challenges for industrial PhD students, expressed below as difficulty in focusing, changing roles, shortage of time, heavy workload, having to prioritize among tasks, and organizational lack of understanding of the design of the PhD program.

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

> While it is a challenge to stay focused on the dissertation project when there are so many sidetracks - perhaps this is particularly challenging for research in informatics/Information Science that is close to practice and where conferences and publications are ranked high. It is about balancing and switching between different roles and sometimes contradictory perspectives and goals, e.g., what is in the interest of research, management, or patients. (R5)

> As an industrial PhD student, there are many people you are responsible to and work towards [employers], I have R&D [at the industry] that pays my doctoral position, and the university of course and it can be a bit fragmented since everyone wants you to be involved, partly to get involved and partly to have things there, but I have to try to stay focused even if I would like to be part of more. Because you need time for your research. There I can feel some guilty conscience towards the university and R&D. Maybe you should have been there and met other PhD students both at the university and other industrial PhD students at my organization as well as the other staff who work there. (R2)

Another challenge that is stressed among the respondents is feeling alone and the fact that the benefit of belonging to both university and industry mentioned above is also experienced as a disadvantage.

Furthermore, the respondents highlight the work-integrated learning perspective when generating learning and new knowledge in industry although they state different experiences mainly due to their different stages in their PhD education.

> The test bed itself is like an arena for learning and exchange of knowledge between both the academy, the companies, and the health center. The idea of the digital test bed is service design as method and that we should work with service design, which means that the staff is involved in the development of the products, i.e., one takes the staff's knowledge for help, and also, when it is relevant, one takes to some extent the patients' knowledge, which means that it will involve the staff to the greatest extent in the development, which makes it a knowledge-sharing activity. (R2)

> The company has organized about ten internal and external lectures to inform about the project and to disseminate knowledge about the project's way of digitally addressing the

> problem we are investigating. A new business area has been started where the involved parties take part in the research and develop it further towards concrete products. It has been quite bad on the part of the university to catch up and do something about the project. (R4)

In addition, the respondent (R5) stresses that there has been a great deal of informal discussions and exchange in the daily work around the coffee table. Furthermore, there has been interest in the research by the respondent among colleagues at work as well as similar interest for the "job" among research colleagues at the university.

> It has been an important signal value that my occupation exists. It is also important for the development of the health care that they chose to invest in funding a PhD education in Informatics/WIL which is not a traditional research PhD education within medical/health care research. (R5)

According to the respondents, some of the organizations have routines for knowledge exchange and follow-up of the PhD program. There are different organizational processes and routines for knowledge exchange of the industrial PhD students' education such as regular meetings, through different types of documentation and by taking part in the Individual Student Plan (ISP) prepared by the university.

Hence, findings show several informing flows (see Figure 1) that are supported related to the quotes above mainly as mutual flows between practice and students (flow no. 5), between research and students (no. 6), between research and practice (no. 8) as well as flows within the students' community (no. 10) and the practice community (no. 9). Since the industrial PhD students represent both student community and practice community these flows overlap accordingly.

Industry Views on the PhD Education Collaboration

All respondents from industry were interested in increasing their collaboration with the university. They mentioned several benefits with the industrial PhD education collaboration, such as connecting university and industry, knowledge creation and dissemination, course partnerships, competence development, product development, and innovation as illustrated by the quotes below.

> This is the ultimate way to build knowledge within a field! The PhD student builds contact paths between the organization and academia. An industrial PhD student has the cultural skills and is an "insider" who may find the current issues to study. (O3)

> All businesses benefit from direct contact with academia and research. (O2)

> In order to develop knowledge, methodology and company strategies our company needs researchers. This collaboration is very important to us and I hope that we will have more course partnership and more employees who will choose to become an industrial PhD student. (O1)

> Within the R&D unit [at the health care organization] we aim to create interest in and encourage activities for research and scientific work also within non-medical professions. (O5)

> Continuity is vital since it takes time to develop really lasting relationships. It is important to have endurance. You also have to have contact and trust high up in the organization. It is important to access the strategic level because if the individual contacts you have at lower levels disappear, then everything can die. It is important to find places at different levels in the organizations where you have good contacts. One should not understand continuity only as personal continuity, but it is equally a structural continuity. (O3)

These organizational benefits are also recognized in earlier research (see Berg & McKelvey, 2020; Broström, 2012; Gustavsson et al., 2016). Another benefit emphasized by one respondent was that the collaboration created legitimacy for the organization and products towards their customers. This is illustrated in the following quotation:

> The collaboration gives us a different perspective on our business development and new insights. It may also generate brand new products in the longer term and a way to market ourselves as a competence partner to our customers. (O4)

Some challenges were identified by the organizations. One of these was to find ways to integrate new knowledge in practice and to anchor the scope of the research project in practice and institution. Another one was the fear that the academic value in the PhD students' pre-understanding of the industry context is limited. Challenges regarding time limits for project results and workload were strongly emphasized and these correspond to earlier studies (Grimm, 2018; Gustavsson et al., 2016; Kihlander et al., 2011; Kolmos et al., 2008; Tavares et al., 2020).

> The challenge lies mainly in the fact that the work tasks within the framework of the employment must have a close connection with the scope of the PhD thesis, and that the research results then will be able to be implemented in the current organization. (O5)

> 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. (O1)

> One challenge that I have been pondering for many years is that as an industrial PhD student you are almost taught to deny that you have a very solid pre-understanding. It is in the traditional view of what it means to be a researcher to be able to be very distant and as objective as possible and all this. I agree with that on the one hand but on the other hand there are very many phenomena that cannot be studied unless subjectivity is allowed. You have to realize that some people have more prerequisites to be able to study certain phenomena because they are accepted as insiders in the organization and hence acting in a context where they understand what is happening. I think the insider perspective is as important as the outsider perspective ant that you need to integrate these two in research. (O3)

> As it relates to research, it is a completely different setting for us since we are a sales organization. This means that we must remind ourselves that this really is research. It is a challenge to see a completely different timeline than we are used to. Another challenge may be being able to give enough time to the project and to the PhD student. (O4)

> Then there is also an immaturity in the organization as today we have few managers who have a doctoral degree. Most managers do not understand the importance of writing a thesis and what will happen when you finish your PhD studies. (O3)

> After all, we have many small, decentralized organizations that are too small to be able to carry the costs of an industrial PhD student as someone who is not completely "in production." What I am trying to work for, is to get this into some kind of organizational career development offered at a regional level, where one can work as a researcher and also be able to do other things in the organization … it is slowly but surely moving forward … and it is based on finding the right managers who want to address these issues and who are prepared to adapt career options to the individual employee. (O3)

Furthermore, keeping the employed industrial PhD student after graduation in the organization was highlighted as a future challenge:

> One challenge is to be able keep the PhD student in the organization after graduation … but most people still remain in the organization in some way – almost everyone changes role compared to the one they had before and that is probably not that strange. (O3)

Hence, findings show several benefits but also challenges that need to be considered in this kind of university-industry collaboration. Furthermore, one vital result from the study is that the organizations stress that already during their ongoing PhD education the industrial PhD students generate learning and new knowledge such as innovations, new products and new work processes in the organizations based on studies and empirical data as illustrated in the following quotes:

> The industrial PhD project gives us new knowledge. It also gives us knowledge in product development based on research data. (O4)
>
> To a very high degree in a number of beneficial effects for the organization such as the work environment and the desire to find innovative ways of performing operative work. (O2)
>
> Learning is generated through proximity, continuity, knowledge making, and bridge-building principles. (O3)

Findings also show that the dissemination of research results is performed at the workplace during everyday operative work as well as regular workplace meetings and seminars for colleagues, and as international and national publications.

> The PhD student and I work closely together with product development in our organization and it is obvious that what our student learns in the third-cycle education affects our competence products positively. We also have formal reconciliation once a year with top management at our organization when the Individual Study Plan within the PhD program is discussed, informed and followed-up. (O1)
>
> Dissemination of results is mainly done at workplace meetings. (O2)
>
> We have regular seminars where we share what we are doing. It is a way to do that and then we always encourage the PhD students to involve their immediate surroundings in a very clear way and regularly present and discuss what they are working with. Because we know that if you do not have your closest manager with you and colleagues on your side, then you will get a lot more work. (O3)
>
> I think that collaboration is strongly related to the concept of work-integrated learning. When you collaborate a lot and have a common goal formulation or research question, then you get many validation opportunities that one does not have otherwise. This collaboration enables one to really test and see if one is on the right path ... there can be completely different cycles when you perform research in strong collaboration. There are, of course, risks and weaknesses but I believe above all that it creates great added value since it provides benefits and what is of interest for society. (O3)
>
> Direct research results are reported through studies, publications and national/international presentations. (O5)

Notably, findings show both short-term and long-term dissemination of research results and learning at the workplace/practice, partly in contrast to earlier research (Malfroy, 2011; Metcalfe, 2006). There are formal and informal organizational ways and informal flows to spread and discuss new knowledge and to involve colleagues in the PhD project. Furthermore, the continuous dissemination of research results at the organizations offers important opportunities for validation and testing of results for the industrial PhD students.

To sum up, applying an informing flows framework on a PhD education collaboration with focus on industrial PhD students generates several strong informing flows which were identified between and within university, research, practice, and student communities. Unlike earlier research (Bernhard et al., 2018) informing flows originating in practice were strong due to the industrial PhD students and their unique position both in industry and academia.

Additionally, in further development of the Informing Flows Framework (Gill et al., 2016), the industrial PhD students may here be viewed as key stakeholders in the model since they are both overlapping and bridging the boundaries between communities of research, practice, students, and university, as illustrated in Figure 2. Most informing flows to and from stakeholders go through the industrial PhD students having a central role in university-industry collaboration. The industrial PhD students thus embody the informing flows between practice and institution (university) see flow no. 3 in Figure 1; and between practice and research, see flow no. 4 in Figure 1. Furthermore, they are part

of informing flows within practice, research, and student community, see flows no. 8, 9, 10 in Figure 1.

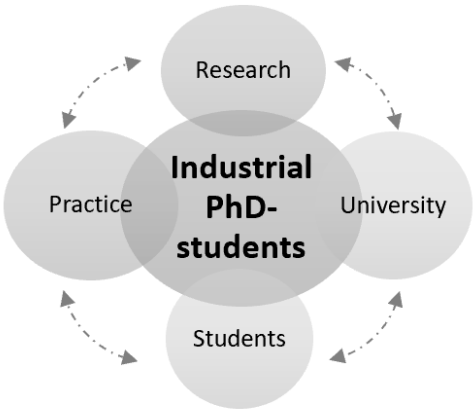

Figure 2. A WIL-based model for Informing Flows of industrial PhD education

CONCLUSION

This explorative study has sought to advance the current knowledge of university-industry collaboration in third-cycle education by applying the informing flows framework on interactions within a PhD education collaboration in order to answer the two research questions by revealing both the perspectives of industrial PhD students as well as of the industry.

By doing this, a work-integrated learning approach is applied on university-industry collaboration in higher education. Hence, this study contributes to broaden the WIL concept to also include the category of industrial PhD education. Accordingly, by applying the lens of work-integrated learning on industrial PhD programs, we state that the WIL concept in higher education should include all the following categories: (i) co-op, (ii) case, (iii) imprint, (iv) tools, (v) field, *and* (vi) industrial PhD education.

IMPLICATIONS

From our findings, the following implications on interactions between university and industry have been identified, here merely viewed as tendencies due to the explorative nature of the study.

- Several informing flows were identified between and within university, research, practice, and student communities, all viewed as aspects of work-integrated learning as stated above.
- Unlike earlier research, flows originating in practice were strengthened due to the industrial PhD students and their unique position both in industry and academia. Most informing flows to and from communities of research, practice, and university go through the industrial PhD students, and they hence have a central role in university-industry collaboration, see Figure 2.
- There are several benefits for industrial PhD students such as inclusion in academia as well as industry, being part of a research context *and* an industrial context with access to networks, and synergy effects related to empirical data and new knowledge.
- There are challenges for industrial PhD-students that demonstrate the need of further increased communication and continuous flows as interactions between university and practice during the entire PhD education.
- The industrial PhD-students are acting as channels or spanning boundaries between university and industry generating continuous opportunities for validation and testing of empirical

results and models in industry. This may enable increased research quality and short-lag dissemination of research results as well as strengthened organizational legitimacy.

- There are flows of research results through formal and informal organizational processes that improve disseminations of new knowledge. Industrial colleagues have the opportunity to be involved in the PhD projects, e.g., during operative work, workplace meetings, seminars, and in publications.
- The continuous flows between and within university, research, practice, and student communities, hence, enable short-term societal impact of research, e.g., ripple effects as flows of research knowledge and methods from institution and research to practice.
- Findings show that the industrial PhD students already during their ongoing PhD education generate flows of learning and new knowledge, such as competence development, new products, new work processes and innovations in the organizations.

RECOMMENDATIONS

This explorative study is a first step that may pave the way for future studies as it contributes novel insights for industry as well as for academia. The focus on the informing flows between university and industry may generate short-term societal research impact through industrial PhD education especially in informatics with PhD students from various industries and sectors. The industrial PhD students are bridging and consolidating industry-university collaboration. Consequently, this kind of university-industry collaboration is generating transdisciplinary and mutual learning and understanding across sectors and across industries. Long-term effects of this kind of work-integrated learning collaboration may result in stronger relationships, building on trust as well as breaking down organizational boundaries between industry and academia.

Based on the present findings of this explorative study, it is vital for practice to recognize that challenges do exist and need to be considered to strengthen industrial PhD programs as well as university-industry collaborations; to integrate new knowledge in practice; to anchor the scope of the industrial PhD students' thesis in practice *and* in research; to understand industrial PhD students' workload and time-limits; and to keep the graduated PhD students as employees within the organization. Additionally, we argue that is of importance to formalize a continuous dissemination of research at the workplace.

As in practice, we recommend that academia needs to recognize the value of the industrial PhD students' pre-understanding of the industry context in the spirit of the work-integrated learning approach. The conditions for informing flows between research and practice need to continuously be maintained to enable short-term societal impact of research for both academia and industry.

LIMITATIONS AND FUTURE STUDIES

There are limitations of this explorative study due to the single case and the number of respondents. Future international and/or transdisciplinary research within this field is encouraged to include larger samples covering other universities and a mix of industrial contexts or comparing industrial PhD students in different phases of their PhD education.

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