PLANNING INDUSTRIAL PHD PROJECTS IN PRACTICE: SPEAKING BOTH 'ACADEMIA' AND 'PRACTITIONESE'

Ingrid Kihlander[1,2], Susanne Nilsson[1,3], Katarina Lund[1,4], Sofia Ritzén[1] and Margareta Norell Bergendahl[1]
(1) KTH Royal Institute of Technology, Sweden (2) Volvo Car Corporation, Sweden (3) St Jude Medical, Sweden, (4) Scania, Sweden

ABSTRACT
This paper discusses planning and organising of research conducted by Industrial PhD students, i.e. PhD students conducting PhD studies while employed in industrial companies. Industrial PhD projects within engineering design research in Sweden can be considered a phenomenon – existing but sparsely documented. This paper provides empirical illustrations by presenting three Industrial PhD projects conducted in three companies with product developing operations in Sweden. The specific research design of Industrial PhD projects yields benefits such as an effective bridging between academia and industry, but also faces challenges such as having a twofold aim of the projects: both academic and industrial. Based on experiences from the presented projects, implications for planning and organising of future Industrial PhD projects are discussed. Finally, we suggest that Industrial PhD projects are effective means, if used properly, for assimilation of research findings to industry, and for academia to understand the industrial practice.

Keywords: collaborative research, research design, industry

1 INTRODUCTION
The goal of design research, according to Blessing and Chakrabarti [1], is to make design more effective and efficient in order to enable design practice to develop more successful products. Design research thus not only aims to create knowledge, but is also assumed to cover implementation of tools and methods that improve design processes in industry [1]. Expected effects and implementation of design research results in design practice have, however, been poor [1][2]. This has been found related to lack of mutual understanding between academia and industry and the way design research studies are performed [1], as well as the issues they address, or rather do not address [2].
Improving research collaborations between industry and academia is considered critical and is actively encouraged by authorities, e.g. the European Union [3]. One means to enable and improve implementation and impact of research results in practice has in Sweden been Industrial PhD students. An Industrial PhD student is employed in a company, conducting PhD studies (part- or full-time) at the request of the employing company, and is affiliated to a research department at a university.
Within the engineering design research community in Sweden, Industrial PhD projects exist rather frequently, but their existence is sparsely documented. Based on this, the authors have made the assumption that limited documentation of this phenomenon restrains possibilities to learn from earlier experiences regarding the design of Industrial PhD projects. Therefore, the aim of this paper is to improve how to conduct research within engineering design by identifying what characterises the context for Industrial PhD students, discussing implications of these characteristics, and giving in conclusion a number of suggestions for planning and organising future Industrial PhD research projects.
The remainder of the paper is organised as follows. In Section 2 related literature is surveyed in order to establish the context of PhD students performing research in close collaboration with industry. Given the sparse documentation in research publications, other publications – such as governmental reports (in Swedish) – have been used as a complement. Section 3 presents the methodology used in the paper, and Section 4 provides empirical illustrations based on three Industrial PhD projects, currently conducted in Sweden. Challenges and lessons originating from the authors' experiences in practice are discussed in Section 5, and finally conclusions are given in Section 6.

2 THEORETICAL FRAMEWORK

Collaboration between universities and industry has existed for a long time. An example of such initiatives is the MIT Industry Liaison Program, which was established in 1948 in the US [4]. In Europe the CIFRE Programme (Convention Industrielle de Formation par la Recherche) in France and CASE (Cooperative Awards in Science and Engineering) in the United Kingdom have been initiated to enhance integration between industry and academia [5]. Further, the Industrial Research Programme in Denmark was established in the 1970s [5][6], and was turned into the Industrial PhD Programme in 1988, specifically directed towards doctoral education [7].

Within the engineering design research community in Sweden, there have been examples of graduate research schools with very articulated industrial connections, such as ENDREA (Swedish Engineering Design Research and Education Agenda) [8] and ProViking National Graduate Research School [9]. These graduate research schools have had the aim of working for better engineering methods and products, and also of educating PhDs for trade and industry [9]. Further, a current example of a Swedish graduate research school that encompasses Industrial PhD students within engineering design research, and where the projects presented in this paper are enrolled, is the Product Innovation Engineering program PIEp, which works for system changes for increased innovation capability [10]. These graduate research schools have included PhD students employed at universities as well as Industrial PhD students, for example from ABB, Scania and Volvo Aero in ENDREA [8].

2.1 Industrial PhD students in Sweden

Industrial PhD students have existed within Swedish industry for decades, mostly in large established product-developing companies, but can also be found in smaller companies and consulting firms. Official sources such as the Swedish National Agency for Higher Education [11], the Swedish Research Council [12], and Government Offices of Sweden [13] describe an Industrial PhD student as:

- employed by a company and receiving their salary from that company,
- conducting research within frames of an employment of a company (part- or full-time),
- admitted at a university and having the same demands of defending their dissertation as any other PhD student, and
- expected to work in industry after the PhD project is finished.

Despite the fact that Industrial PhD students have been present in Swedish industry for a long time, the phenomenon is sparsely documented and it was not until 2007 that the Swedish National Agency for Higher Education started to register the number of PhD students employed by companies. These statistics provide evidence that Industrial PhD students exist rather commonly in Sweden [11]. In Table 1, numbers of PhD students on three levels are presented: (1) Sweden in total, all research areas; (2) technical faculties, all Swedish universities; and (3) one example of a technical university, namely KTH Royal Institute of Technology in Stockholm where the authors are affiliated. At the time of this report, there were over 19,800 PhD students in Sweden, of whom approximately 5% were Industrial PhD students. In technical faculties the percentage of Industrial PhD students was considerably higher: 13% (at KTH 12%), which shows that Industrial PhD students are more common within technical faculties than in research in general. Additionally, Table 1 includes a column showing full-time equivalents (considering percentage of registered activity and financing) which confirms that many Industrial PhD students are performing other activities in parallel with conducting PhD studies.

Table 1. Number of active PhD student in Sweden 2009 [11]

	Number of PhD students (irrespective of financing)	Number of Industrial PhD students	Percentage Industrial PhD students	Full-time equivalents Industrial PhD students
1. Sweden	19857	938	4.7%	449
2. Technical faculties	5258	685	13.0%	321
3. KTH, Stockholm	1843	213	11.6%	99

2.2 Industrial PhD students – dealing with dual cultures

Being an Industrial PhD student means that the research is closely linked to the employing company. Industrial PhD Students have been found to provide benefits by bridging and integrating universities and external partners, stimulating knowledge transfer, contributing knowledge and network within their organisations, and thus providing a basis for strategic collaboration [13][14][15]. For example, an Industrial PhD student, updated on current research, can serve as a link to the academic world and new scientific knowledge, during the research project but also after graduation [12]. Being connected to universities is regarded as a potential source of innovative ideas [16][17], and good collaboration between academia and industry can become part of a company's competitive advantage and intellectual capital [18]. Perkmann and Walsh [19] state that both companies and academia benefit from close collaboration especially if: (a) the discipline of the researchers involved is associated with the sciences of the artificial objects produced in industry; (b) the researchers are highly research-driven; and (c) the researchers have a portfolio of different types of relationships with industry [19].

Besides transfer of knowledge from academia to industry, knowledge transfer from industry to academia is also important due to possibilities to generate know-what about technological problems, user requirements and market trends, and identification of new innovative research questions [19], as well as providing important input to academia regarding actual problems experienced in industry [14].

Being an Industrial PhD Student is an opportunity, but also means being in a constant conflict, having to handle both research and work in the employing company – i.e. long-term research alongside short-term project work with tight deadlines [20]. It has been found difficult to balance research studies with working in the company, although it varies a lot due to companies' different operations, varying context of the doctoral student, and how stationary the doctoral student is in the company [6]. For example, long-term collaboration, such as Industrial PhD projects, may not be suited to companies which are relying on quick feedback for making an incremental change to their product line, and these companies may experience a poor return on their investment in university projects [16].

In order to increase the probability that both academia and industry will perceive the collaboration as rewarding, there is a need to understand and deal with expectations and requirements on the PhD student by the various parties. The success of collaborative research between industry and academia is governed by a complex interaction of critical factors. Choice of partner, environmental factors, and project management have been found to be such success factors according to Barnes and Pashby [21]. They found that project management was of specific importance, as was identification of clearly defined, and mutually agreed, project objectives and roles. Further, their findings placed significant emphasis on a need to manage the inevitable cultural differences between academia and industry, where the main issues were related to a need to agree on priorities and timing [21]. This was most significant in research projects involving PhD students, as they have clearly defined requirements with regard to their research work, which constrained their role within industrially oriented projects [21][22][23]. A general lack of understanding on the part of many industrial participants regarding what constitutes doctorate-level research was seen as a main cause of these issues. Further, a need to manage issues regarding academic right to publish was seen as critical, along with proper management of intellectual property and dealing with project scope extensions [18][21].

To further increase chances of success, Valkenburg and Kleinsmann [24] claim that a research project carried out in industry needs to have two deliverables: results that answer research questions, and pragmatic suggestions for how research results can be implemented. Guide and Van Wassenhove [23] point out that to establish long-term industry contacts takes time and energy, so students should prefer universities which value practitioner research and already have established collaboration with industry.

Facilitating tacit knowledge transfer (e.g. experiences, skills and mental models) has been found to be crucial in knowledge transfer from engineering research centres to companies [25]. This type of knowledge cannot be transferred to others unless there is a "deep" relationship between individuals, and therefore management of successful tacit knowledge transfer should focus on individuals involved in the process to ensure they develop intimate relationships [24]. Hence, trust between partners, which takes considerable time to develop, has been identified as a key issue influencing the effectiveness and success of collaborations between industry and academia [25], where Industrial PhD students can provide a continuity of personal relations and a stable link between companies and the research world while the PhD studies are conducted.

Another concern related to industry-academia research is academic freedom. When investigating how a number of Swedish Industrial PhD students experienced their situation regarding freedom to choose

research questions and methods, Wallgren found that the companies left these decisions to the researchers as they did not want to risk interfering with academic freedom – or in fact that they, in some cases, did not show much interest [6]. Regarding effects on the way PhD students conducted or communicated their research, Behrens and Gray [18] found that industry funding did not infringe on this; instead they found it even more likely that this research resulted in academic publications.

Industrial PhD students may be labelled 'insider researchers', using the definition by Adler and Adler [26]. Insider researchers are defined as individuals undertaking research in and on their own organisations as complete members, which in this context means having both pre-understanding and access to the organisation, but also wanting the choice to remain members on a desired career path when the research is completed [27]. Working as an insider researcher has been shown to increase usability and trustworthiness of the research findings in product development processes due to continuous data access, enabling insider researchers to grasp what really happens on a daily basis [28].

It is argued by some authors that insider researchers are native to the setting and prone to charges of being too connected, thereby not maintaining the distance and objectivity necessary for valid research [29]. Other researchers challenge this viewpoint and show that insider research is not only valid and useful, but also provides important knowledge about what organisations are really like [27]. Therefore, a key for researchers when considering insider-research projects is to become aware – through a process of reflexivity – of strengths and limits of their pre-understanding, using their knowledge and experience to reframe their understanding of situations to which they are close [27].

3 METHODOLOGY

In order to generate a more in-depth knowledge regarding opportunities and challenges in planning of Industrial PhD projects in practice, three Industrial PhD research projects involving the authors (as PhD students and supervisors) will be used as empirical illustrations. Data in the three cases, regarding the different employing companies and the specific research projects, were compiled and an overview can be found in Table 2. Further, by reflecting on the data, complemented by first-hand experiences from these research projects, the authors subsequently compared the cases, identified common themes, and compared with reviewed literature using a cross-case analysis [30]. These illustrations will expose both differences and similarities between different Industrial PhD projects' arrangements, and will thus contribute to elucidating how Industrial PhD projects can be organised.

4 EMPIRICAL ILLUSTRATIONS: THREE INDUSTRIAL PHD PROJECTS

The three Industrial PhD projects used as empirical illustrations are all research projects conducted at the academic department of Integrated Product Development (IPD), School of Industrial Engineering and Management, KTH Royal Institute of Technology, in Stockholm, Sweden. The research at IPD covers organisational and technical processes for efficient and effective development of innovative technology-oriented products, services and systems. The illustrated research projects share the research theme of early innovation phases, and they are a part of the Product Innovation Engineering program (PIEp) [10]. The Industrial PhD students are employed in established companies in mature industries (automotive and medical), and presentations of these research projects is found in Table 2.

The PhD students differ in their experience in working in their company, from newly hired to more than 15 years of employment, which means that a focus for the PhD student in project C has been to establish relations within the company while it has been essential for the students in project A and B to re-define relations to suit their new role as Industrial PhD students.

In all three cases the PhD students have been a part of the initiation process of their own PhD project, defining goals and objectives in discussions with scientific supervisors and managers at the companies. All three students are given large responsibility by their companies in managing themselves and their research projects. Further, it is expected that they will continue working in their companies after the PhD project is finished (through loyalty, or as in case B, also with a contract).

There is only one PhD student involved in each Industrial PhD research project. To a different extent in each project, the scientific supervisor participates in the research not only in the supervisor role but also as a co-researcher. Time spent on research in parallel with other work performed at the company differs between the three Industrial PhD students. In projects A and C, the PhD students have as their main task to conduct PhD studies (time spent on research should be minimum 80%), while the PhD student in project B works 50% directly with activities for improving innovation in the company in parallel with pursuing a PhD. However, the goal for student B is that the industry-related activities and

the research will gradually converge and the doctorate time plan will thus be similar to the other two students' plans. Another difference is the organisational placement of the PhD student (B as staff, A and C at engineering departments). In all cases it was explicitly discussed during the initiation of each respective project, and the decisions were mainly guided by where the placement was considered most beneficial for the PhD student and the research project.

Table 2. Overview of three Industrial PhD projects

	A	B	C
Industrial settings			
Business	Automotive	Medical Device	Automotive
Company	Volvo Car Corporation	St Jude Medical, CRM Sweden	Scania
Headquarters	Göteborg, Sweden	St Paul, US	Södertälje, Sweden
Main owner	Zhejiang Geely Holding Group	St Jude Medical	Volkswagen AG
Market	International	International	International
No of employees (global)	20000	14000	35000
R&D sites in Sweden	Göteborg	Järfälla	Södertälje
R&D employees (Sweden)	3500	200	2500
Organisational placement of PhD Student	R&D, Body and Exterior Engineering	Continuous Improvement and Innovation	R&D, Truck Chassis Development
Year of employment at company	2000	1995	2009
Research settings			
Research topic	Decision making in early product development phases	Organization and management of front end of innovation	Tools and work procedures for increased innovation capability
Time frame of project	2007-2011	2009-2013	2010-2014
Time for research	Minimum 80%	50-100%	Minimum 80%
Steering committee at company: and steering committee meetings per year)	Yes (Functional manager, Industrial supervisor and Academic supervisor): 3-4	No specific steering group for PhD project but for Front end of innovation (Industrial supervisor and Functional managers): 0(10)	Yes (Functional managers and Academic supervisor): 2-3
PhD student network at company	Yes	No	Yes
Academic affiliation	Integrated Product Development, School of Industrial Engineering and Management, KTH Royal Institute of Technology, Sweden	Integrated Product Development, School of Industrial Engineering and Management, KTH Royal Institute of Technology, Sweden	Integrated Product Development, School of Industrial Engineering and Management, KTH Royal Institute of Technology, Sweden
Research School(s)	PIEp	PIEp	PIEp, ProViking

The three companies have various experience of initiating and hosting Industrial PhD projects. In the cases of A and C, there are established networks of Industrial PhD students within each company. For example, there are currently more than 25 Industrial PhD students in company A, and about 25 former Industrial PhD students who have finished their PhD (e.g. [31]). Internal company material within companies A and C state that having Industrial PhD students incorporates both internal and external purposes. Internally, Industrial PhD students contribute through generating and implementing

important results, as well as developing expertise and competence within strategic areas. Further, the individual Industrial PhD student is considered as a future specialist and leader. External purposes defined are that Industrial PhD students contribute in building strong networks between the companies and universities, and also to strengthen the company's profile as high-tech and research-oriented.
As can be seen in Table 2, all three research projects have some sort of arrangement for anchoring, assimilation and dissemination of research project and results. In projects A and C there are specific steering groups for the project, which consists of representatives from both industry and academia. In the case of project B, a specific steering group for the project is not appointed, but a steering group composed of functional managers for the front-end innovation work, i.e. the research topic itself, is appointed. Further, for project A, a reference group is appointed, consisting of specifically chosen individuals from the company who are very well connected within the company, and are considered to have great influence, both formal and informal. The members in steering and reference groups serve as ambassadors internally for the research conducted, but also provide valuable input to the research.
All publications produced by the three Industrial PhD students have to be reviewed and accepted as publishable by the respective company according to a defined (company-specific) process, which should also be applied in cases of intellectual property issues.

5 DISCUSSION

Since we investigated Industrial PhD Students in a Swedish context, we acknowledge that there are particular aspects due to national politics and regulations which we have chosen not to explore further in this discussion. Instead we focus on a number of themes that were identified in the cross-case analysis, including implications for planning and organising such research projects in practice.

5.1 What is the size of your piece of the puzzle?

Since an Industrial PhD student faces the same academic demands as a regular PhD student, we agree that it is important to have the dialogue about project scope at an early stage, to ensure that requirements and expectations from industry and academia are aligned [18][21][22][23]. From the planning phase of the illustrated research projects, we have experienced that the companies have a good understanding of e.g. the need to take PhD courses, spend time at the university, or to attend conferences. Limitation in scope, however, seems harder to handle. We experience a cultural difference regarding this matter, expressed mainly in that companies would rather see a complete picture, whereas academia would rather deliver an exact description in a very narrow field. Therefore we want to emphasise that company people involved in the projects should be made aware of academic requirements for pursuing a PhD. The PhD student will undergo an education where the goal is to learn how to do research, where research in itself is explorative, and hence hard to scope initially. The research will most likely be carried out at the company, which gives the company an excellent opportunity to learn about itself in a specific aspect, but also requires the scope to be narrow enough to enable the student to reach the depth needed for a PhD dissertation.
Further, we have experienced a need to remind the industrial partner occasionally that a PhD project is a long-term commitment, creating knowledge, where the possible gain is large but might take longer to obtain than in a regular change project in the company. It is important to keep in mind that results from an Industrial PhD project are twofold; firstly the research results, secondly (and perhaps even more importantly for the company) an employee is being educated into an expert in a field of strategic value to the company. In the planning phase it is thus highly important to make sure that all people closely involved in the project – such as functional managers, supervisors and steering committee – fully understand the scope of the research project. In the illustrated cases, each PhD student was involved in planning their project, which we know is not always the case in Industrial PhD projects. However, we experience this as very positive creating deep commitment to the research task.

5.2 Do you speak 'academia'? Do you speak 'practitionese'?

As stated earlier, the field of design research suffers from problems with assimilation of knowledge from research to industry [1][2], and we assert that Industrial PhD students can serve as a bridging function addressing this issue. Observing that knowledge flows must occur and channels for transmission are needed [17], we found that an Industrial PhD student not only brings knowledge gained in research into the employing company, but also knows how to “translate” that knowledge into a language that the company is familiar with, i.e. speaking both 'academia' and 'practitionese'. Besides

learning how to write scientific papers, which is a tough struggle on its own, Industrial PhD students also need to become skilled in transferring academic knowledge into company-adapted PowerPoint presentations. We also acknowledge the possibility to be involved in non-research activities, since this provides experience of the internal culture and supports developing a better sense of needs and changes in the organisation that might influence research findings. For example, participating in regular departmental meetings both at the company and in academia provides valuable insights into the two cultures that the Industrial PhD student should be able to deal with.
Furthermore, in the illustrated examples the Industrial PhD student is committed (by contract or loyalty) to stay with the company after PhD graduation, not unlikely working with implementation and knowledge transfer related to the research topic. To enable transfer of research results into practice, two of the companies have from the start chosen to position the PhD student in the functional engineering organisation – the place where future change implementations related to their research have to happen – instead of in a staff position. Steering committee members (in projects A and C) are recruited for their present and future probable strategic role in the company and their knowledge of the organisation, rather than their expertise in the fields of research. In the third company, the PhD student is placed in a support organisation. Her long experience from working in the functional engineering organisation of the company, together with the appointed steering group (including people responsible within the areas subject to changes), is considered to enable effective knowledge transfer. Based on the three described cases, we cannot identify the best organisational placement for an Industrial PhD student, but we assert the importance of properly discussing the issue. Therefore we believe that organisational placement as well as selection of stakeholders for the project, for instance individuals in the steering group, are factors that need careful consideration in the planning of an Industrial PhD project. The impact of organisational placement on the implementation of research results is poorly explored in the literature we have reviewed, and may be considered a subject for future studies.

5.3 Loaded or overloaded?

The access to an abundance of empirical data is an obvious advantage for Industrial PhD students, and a condition we highly appreciate and value. Being overwhelmed by a constant flow of data, described as “drowning in a sea of milk and honey” by Jönsson [32] when observing industry projects closely over time, is a feeling fully recognised by the authors.
Selection and delimitation of the research focus (identified as a success factor for good research collaboration [14]) becomes once again important in the research planning when there is so much to choose from. However, Valkenburg and Kleinsmann [24] give comfort in such moments of data overload, "…since it cannot be the case that practice is not interesting enough to investigate!"
Not only data are immensely available for an Industrial PhD student; the opportunity to get feedback on research findings, planning and priorities is another example that is advantageous. Even though attention from individuals within the company is limited due to the high pace characterising today’s working environment, the Industrial PhD student is to a large extent able to spontaneously arrange meetings when the opportunity arises, since they are present in the company.

5.4 May I bite the hand that feeds me?

The way an Industrial PhD project is designed, the Industrial PhD student is getting a monthly salary from (one of) the research subjects. Thus a strong relationship of dependence between the PhD student and the company exists, which could suffer from an unclear research design. It would be naive to ignore potential conflicts of interest that can arise since the company, even if genuinely interested in learning about its own organisation, also has an interest in being described in positive terms in any kind of public document. The authors, however, experience that the companies are showing respect for academic quality and freedom, and that they understand a PhD student’s role is to critically study the own organisation in order to provide learning opportunities. But what would happen if research results are not in favour of the company? In the illustrated cases, there are routines for how to handle research publications, meaning that the Industrial PhD student is obliged to get any intended publications approved before submitting them for publication. Such a right should not be misused, and therefore it is important to make the purpose of the reviewing process clear: i.e. to avoid sensitive data about the company being spread (ensure confidentiality) and not to influence how research data are presented. However, our observation is that having a review process for publications within the company has

positive effects. Senior managers in the company need to read, and consider what the PhD student is about to publish, which can be regarded as a small but significant knowledge-assimilation activity.
Besides the subject of confidentiality, which all researchers are obliged to deal with, the Industrial PhD student may also face issues of more political nature, even more prominent in engineering design research aiming to improve ways of working in a company. Being organisational members themselves, these students need to balance the organisation's formal justification of what it wants with their own personal justification for what needs to be changed, where Brannick and Coghlan [27] have pointed out that the researcher's credibility is an effective driver of change. Additionally, on the individual level, one should not neglect any potential influences regarding consequences, good or bad, that the reporting of the research results has on the future career within the company. A key to this is assessing the power and interests of relevant stakeholders [27], which is in line with our experiences. One should constantly manage the expectations, explicit as well as tacit, of different stakeholders in the organisation in order to facilitate the transfer of knowledge generated in the research project.

5.5 Is it possible to study your own business?

Some argue that being deeply grounded in a company culture, as an Industrial PhD student is or will be, hinders carrying out unbiased research [29]. Others argue that this is more or less a necessity in order to understand what is really going on and to develop truly new insights [27], not least in the research area of complex and dynamic processes like product development [28]. Being thorough when choosing a research methodology can help to avoid such pitfalls [24]. Carrying out studies at other companies in parallel provides useful perspectives regarding phenomena found in one's own organisation. Belonging to a research school or academic faculty hosting other Industrial PhD students is beneficial as it provides possibilities to carry out studies together in each other's organisations.
We believe that a key to success in performing research in your own organisation is to become aware, already in the research planning phase, of the importance of organising for and starting to develop personal skills – in being both connected with and distanced from the company and the organisational phenomenon under investigation. A major aid in developing the kind of reflexivity needed in keeping a distance and obtaining new perspectives is the collaboration between PhD students and academic supervisors. By constantly challenging views and findings found inside the company of the PhD student, perhaps influenced by a strong unconscious loyalty to the company, the supervisors ensure more objective and unbiased results.
The PhD students in the given examples have two offices (company and university). Having access to an office at the university has been found particularly valuable when there is a need to take a step back and look at the data gathered without interference from the subject of analysis. This office can also serve as a "refuge" when the fast-moving pace of the company is too far out of tune with the reflexive nature of the research projects: the university office provides much-needed respite. Additionally, we acknowledge the benefit of being a number of Industrial PhD students affiliated with the same academic department that encourages research close to industry, due to the opportunity it creates in sharing issues, reflections and ideas.

6 CONCLUSIONS

Industrial PhD students have great possibilities to closely study their own organisations and reveal new insights about organisational life, which may be transferred to other organisations or the research community. Further, they become experts in fields important to the companies where they are employed, and they become effective means for implementing improved ways of working. Therefore, we argue that having Industrial PhD projects is an effective means, if used properly, for assimilation of research findings to industry, and for academia to understand industrial practice.
Since over 10% of the PhD students at technical faculties within the Swedish university system are Industrial PhD students, it should be of interest to both academia and industry that these research resources are utilised properly. Based on literature examined and the authors' experiences and lessons from the three cases used as empirical illustration, we have identified a number of challenges that arise when planning Industrial PhD projects. These challenges are related to the difference in requirements and expectations in academia and industry. The identification of scope and a thorough selection of the individuals to be involved in the project, specifically considering the appropriateness of the PhD student him/herself, is particularly prominent in the project planning in order to increase the probability of a successful outcome for both academic and industrial partners. Planning how to

communicate findings both to industrial partners and within academia is another key factor, along with creating time and room for reflexivity. In many ways it is a balancing act where clarity in expectations and roles is of utmost importance. The following suggestions are given:

- Make sure that the company fully understands what it means to have an Industrial PhD student pursuing a doctoral degree, including aspects of academic freedom and quality, prerequisites for defending a dissertation, rules for publication, and limitations in research scope.
- Thoroughly discuss the balancing of time between operative industry projects on one hand and the research project on the other hand, creating room and routines for reflexivity.
- Find ways to anchor research results in the organisation during the PhD project, in order to verify research findings but also to facilitate later implementation of results, e.g. appointing a steering or reference group in the company, and defining an internal reviewing procedure for publications.
- Select an academic faculty with experience from working closely with industry, which values industrial relevance as well as academic rigour, and which has an understanding of the interests of the different stakeholders that an Industrial PhD student has to balance.
- Plan for exchange of information between academia and industry. The role of interpreter should be taken seriously in order to ensure that both parties can get the most out of the exchange.

We believe that our findings (even though based on a limited number of investigated Industrial PhD projects) will contribute to better planning and organising for future engineering design research, and thereby increase the possibilities for successful academia-industry research collaborations. Further cases could be added in order to provide a richer empirical base in future work.

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Contact: Ingrid Kihlander
KTH Royal Institute of Technology
School of Industrial Engineering and Management
100 44 Stockholm, Sweden
Tel: Int +46 8 790 7887
Email: ingridk@kth.se

Ingrid is an Industrial PhD student at Volvo Car Corporation, and affiliated with Integrated Product Development at KTH, Royal Institute of Technology in Stockholm, Sweden. Her research interest is decision-making on early product development phases.
Susanne is an Industrial PhD student at St Jude Medical and Integrated Product Development at KTH Royal Institute of Technology, focusing organisation and management of the front end of innovation.
Katarina is an Industrial PhD student employed at Scania and advised at Integrated Product Development, KTH Royal Institute of Technology, in Stockholm. Her research field is within work methods for creativity in efficient R&D organisations.
Sofia is Associate Professor in Integrated Product Development at KTH, Royal Institute of Technology in Stockholm. She is also the director of the national research and change program Product Innovation Engineering program (PIEp).
Margareta is Professor since 1997 in Integrated Product Development at the School of Industrial Engineering and Management at KTH in Stockholm. She is also vice president of KTH responsible for the development of the KTH Faculty for Innovation Engineering in close cooperation with KTH's major partner organisations.