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# Industrial doctoral students as brokers between industry and academia

## Factors affecting their trajectories, learning at the boundaries and identity development

Lillemor Wallgren and Lars Owe Dahlgren

**Abstract:** *The authors look at the learning context for 23 industrial doctoral students and assess the prerequisites for the development of their identity as researchers. The students are located in three different industrial research schools – Management, Medical Bioinformatics and Building and Indoor Climate. The purpose of the study is to describe the students' total learning environment and to ascertain what factors influence, hinder or encourage their development within the doctoral education process. To achieve this, the authors use Lave and Wenger's situated learning theory, conceptual framework and, in particular, trajectory concept (Wenger 1998, 2000). By following the students' histories, participation and ways of belonging to different communities of practice, and their aspirations, huge variations in their learning trajectories can be documented. Six typical cases are elaborated in detail, with a specific focus on the students' participation in and belonging to the environments involved. The procedures for thesis project selection and supervision are two of the five factors scrutinized. However, the trajectory concept, while helpful in the investigation, had to be complemented. Other elements that needed scrutiny were the effects of differences in knowledge formation, unequal power relations and fluctuations in market requirements. Internal business reorganizations that change the company's focus, interests and personnel policies, and which in turn influence the students' progress and prospects, were also considered.*

**Keywords:** *doctoral education; industrial doctoral students; industrial research schools; knowledge transfer; situated learning; learning trajectory*

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## Background and purpose

Learning is now often considered as a means of developing individuals, organizations, society and even nations. One example of this is the establishment of industrial research schools at various Swedish universities: these schools are tasked with educating industrial doctoral students so that industry can be supplied with more PhD-level graduates, thus stimulating the development of competence and knowledge to increase national growth. The initiative to develop the schools was taken in 1996 by the Swedish Foundation for the Advancement of Knowledge and Competence Development (the KK Foundation), which offered universities partial funding on condition that they agreed to cooperate with companies in the education of industrial doctoral students. The initiative was well received and by 2000 there were thirteen industrial research schools with 140 industrial doctoral students.

Industrial research schools are therefore a relatively new venture, bringing academia and the business world together through the participation of the students in both sectors. This academia–industry–government project may be regarded as an example of Etzkowitz's (2002) concept of the Triple Helix. Thus, compared with a traditional doctoral student, an industrial doctoral student's education takes place in new contexts and the student has a role akin to that of an innovator and bridge builder.

In accordance with the KK Foundation, the primary support for the student is provided through an academic supervisor and a supervisor from the company (who also finds himself or herself in a new role and situation). Thus the student is a member of both a university department and a company unit and has a supervisor in each environment. The thesis project should focus on a research problem that is of interest to the company and, moreover, the student should work for the company to a certain extent.<sup>1</sup> In other words, the intention is to have the doctoral student involved in cooperative knowledge development through interactive research. As Nielsen and Svensson (2006, p 14) explain,

'Interactive research stresses the joint learning that goes on between the participants and the researcher throughout the entire research process.'

It can be assumed that these new conditions will have an impact on the doctoral education process and on the individual student and supervisors. Thus research on the topic is needed. In addition, existing research on doctoral education in connection with industry is limited.

With regard to research on doctoral students with financing from and obligations to industry, we refer to Harman's (2002, 2004) descriptions of Cooperative Research Centres in Australia, as these seem to correspond best with the concept of the industrial research school. Harman (2002, 2004), Gemme and Gingras (2004) and Behrens and Gray (2001) have undertaken surveys of industrial doctoral students, while studies by Wallgren (2003), Wallgren and Hägglund (2004), Wallgren and Dahlgren (2005) and Salminen-Karlsson and Wallgren (2005) are all based on interviews with students. The overall impression given by Wallgren and Hägglund (2004) is of the great diversity in situations and experiences described, which to a great extent is due to the wide spectrum of industrial environments involved. This means that measures to support the doctoral students must be very flexible and cover a variety of needs. From Wallgren and Dahlgren's (2005) study, it appears that the company environment has a profound impact on both the student's situation and the doctoral education process. The difficulties inherent in belonging to different communities of practice are also in evidence, as is the fact that not all the doctoral students in the study became 'brokers'.

Slaughter *et al* (2002) base their study on interviews with supervisors in the USA and describe industrial doctoral students as 'gifts' from academia to industry: the students are part of a gift exchange in which the university receives research resources, and which leads to a relationship of 'trust, solidarity and mutual aid' (Slaughter *et al*, 2002, p 284, citing Lévi-Strauss). The overall picture presented by Slaughter *et al* of industrial doctoral students as a workforce exploited by academia and industry does not, however, fit well with the data in the Salminen-Karlsson and Wallgren (2005) study. According to Salminen-Karlsson and Wallgren, in most cases at least one of the supervisors, and often both, showed genuine concern about the student's welfare and educational process. But there were, nevertheless, some supervisors who talked about the students and projects in very instrumental terms.

This article considers learning from a socio-cultural perspective, and the term 'social' has at least two meanings – one refers to the historical and cultural context and the other relates to personal relationships and interactions (Dysthe, 2003, pp 42–43). Learning is seen as something which is situated: the learner is a participant in a community of practice and knowledge is construed through cooperation in a specific context. The socio-cultural perspective has its roots in the pragmatic tradition of Dewey and Mead and the cultural-historical tradition is rooted in Vygotski, Luria and Leontjev and is used by anthropologists, sociologists and

educationists alike to study cultural and contextual conditions for learning (Dysthe, 2003, p 31). For Dewey (1999, pp 45–47), ‘environment’ comprises those conditions that promote or hinder, stimulate or hamper a living creature’s characteristic activities and thus what a person does or can do depends on the expectations, demands, approval and disapproval of others. Education, says Dewey, is a process through which one leads or brings up, and he claims that ‘environment’ means more than the totality of those things that surround an individual because it relates the specific context of the surroundings to his or her own active endeavour. According to Dysthe, Dewey uses the word ‘situation’ such that it corresponds to the socio-cultural understanding of the word ‘context’.

The purpose of this study, then, is to present a picture of the total learning environment of industrial doctoral students and to ascertain what factors influence, hinder or encourage their development within the doctoral education process. In order to arrive at such a description, the focus will be on significant features of their participation in the respective environments of university and company, and on how and how much they move between these environments. In other words, the aim is to describe as a learning trajectory the students’ process from their entrance into the course of study, through their participation, to their expectations for the future.

### Theoretical framework and research questions

To obtain a picture of the industrial doctoral students’ total learning environment, we have to follow their participation in and mode of belonging to different specific environments. It is important to understand if and to what extent they cross the borders between academia and industry. A further issue is the extent to which their thesis project is of mutual interest for the university and the company. Finally, the interaction between the doctoral student and other participants in the knowledge creation, as well as with the academic and industrial supervisors, will be scrutinized.

To illuminate these issues we find a socio-cultural perspective appropriate and adopt Lave and Wenger’s (1991) view of learning as a situated activity, which they call ‘legitimate peripheral participation’ – that is, the participant is a relative newcomer in a community of practice. Furthermore, Wenger (2000) believes that learning is realized through interplay between social competence and personal experience, which combines personal transformation with the evolution of social structures. Of central interest to this study are two

concepts: the *social learning system* and the *trajectory*. The former refers to the social system in its entirety, while the latter pertains to an individual’s movements into, within and eventually out of the system. These two concepts, and the elements that comprise them, are now discussed in detail.

#### *Social learning systems*

According to Wenger (2000), social learning systems consist of three structuring elements:

- *Communities of practice*, which define competence by combining three factors: (a) ‘joint enterprise’ – what the members collectively experience as their common activity; (b) ‘mutuality’ – the members build their community through a mutual commitment which binds them together and which creates relationships of trust between the members in their interactions.; and (c) ‘shared repertoire’ – communities of practice produce collective resources such as routines, artefacts, tools and notions (Wenger, 2000, p 229).
- *Boundaries* between communities, which offer learning opportunities in their own right. Wenger distinguishes between different types of bridges across boundaries: *people*, who act as ‘brokers’ between communities; *artefacts* (things, tools, terms, etc); *discourses* (common language); and *processes* (shared processes). All serve as different forms of ‘boundary objects’ and represent various *interactions* among people from different communities of practice. There are also *cross-disciplinary projects*, which combine the knowledge of multiple practices to get something done.
- *Identities*, which combine competence and experience into a way of knowing. Our ability to deal productively with boundaries depends on our ability to engage and suspend our identities. Wenger distinguishes between three different modes of belonging through which we participate in social learning systems: *engagement*, *imagination* and *alignment*.

#### *The concept of trajectory*

Since the doctoral students in our study are supposed to move between and participate in communities in both higher education and industry, and have a thesis project of interest to both sectors, a crucial issue is the extent to which the students develop an identity as an academic researcher or an applied industrial developer – or a mixed identity situated in both communities. For these reasons we use both the concept of *trajectory* and that of *boundary trajectory*. These concepts are defined as follows:

'Identity extends in time. It is a trajectory in progress that includes where you have been and where you are going, your history and your aspirations. It brings the past and the future into the experience of the present.' (Wenger, 2000, p 241.)

'Some trajectories find their value in spanning boundaries and linking communities of practice. Sustaining an identity across boundaries is one of the most delicate challenges of this kind of brokering work.' (Wenger, 1998, p 154.)

Learning at the boundaries is a source of new possibilities and of potential difficulties. At the boundaries, competence and experience tend to diverge: a boundary interaction usually involves exposure to a foreign competence and, according to Wenger (2000, p 236), it is important to pay attention to people who act, or could act, as brokers. Are they falling through the cracks? Are there people who are potential brokers but who for some reason do not provide cross-boundary connections?

To accomplish the aims of the study within the perspective of situated learning theory, the following research questions were formulated. What is the nature of the participation and belonging of the industrial doctoral students and how do they themselves experience their situation? Are there factors that influence their participation and the formation of their identity as a researcher?

## Methodology and sample

To obtain information as nuanced as possible, the methodology chosen comprised semi-structured interviews with the following themes: entering doctoral education; what it is like to be an industrial doctoral student; the time spent as an industrial doctoral student; and the student's vision of the future. We wanted to follow the students' knowledge trajectories by asking them to talk about themselves and how they became industrial doctoral students. Furthermore, what had been their expectations and incentives, how had their thesis project come about and what was it, and what were they going to use their doctorate for? We asked what they had done and where they had been, how they divided their time between research and work at the company, who they had worked with and what milestones they remembered, and we asked them to compare their experience of the reality with their expectations. Further, we asked them to tell us what they knew and what they thought about the general idea of industrial doctoral students. We wanted them also to tell us about their view of the role of bridge builder, what views of

knowledge they had encountered, how they had perceived gender issues at university and in industry. We asked them, finally, what was needed from company, university, supervisors and the students themselves to create what they considered an ideal education for industrial doctoral students.

We interviewed 23 industrial doctoral students (11 women, 12 men) and most of their supervisors in three industrial research schools supported by the KK Foundation. The research schools were, respectively, for Management, Medical Bioinformatics and Building and Indoor Climate. We have previously described differences that can be observed within a specific industrial research school (Wallgren and Hägglund, 2004). In this phase of the work, we wanted to know more about differences between the schools themselves – hence the choice of schools in distinct fields. Rather than basing the description of these different research schools on all the interviews carried out, we decided to concentrate in more detail on a limited number of informants. This was primarily because we wanted to get the most out of the interview data within a limited amount of space. Besides, we thought a combination of fewer cases and a summary of the characteristics of all three research schools would provide a good picture of the empirical data. With regard to the six cases selected, the original intention was to find two from each school, one of whom was expected to complete his or her doctoral studies while the other was either unsure about continuing or had decided to drop out. The selection went as planned in the Management and Building and Indoor Climate schools, but for the Medical Bioinformatics school it transpired that only two of the nine students were engaged in any kind of cooperation with a company, and thus the choice inevitably fell on these two.

Caesar and Lars are two of six doctoral students in the Management school; Kevin and Maria are two of nine in Medical Bioinformatics school; and Adrian and Nora are two of eight in the Building and Indoor Climate school. There is no gender perspective to the study and the names have been invented to guarantee the anonymity of the participants.

## Six cases

### *Adrian (Building and Indoor Climate school)*

Adrian's undergraduate thesis supervisor asked him if he would like to become an industrial doctoral student. He decided to accept so that he could attend conferences abroad and work with a company. The company is involved in product development and has many employees with licentiates and PhDs, and so Adrian is not regarded as out of the ordinary. He has had most

contact with the in-house doctoral students and students in his own field. When the company ran into problems and sales fell, he was employed as an expert at its headquarters, and people who had been made redundant wondered what he was doing there. Most of his thesis project was defined in advance, but he altered it because both the company and the industry more generally needed a standard. He became the company's representative. He has spent one or two days a week at the company and has participated in courses, carried out investigations, written a great many reports and given lectures whenever something new should be purchased. However, after two further reorganizations, Adrian himself was made redundant: he is now employed by the university and works on an hourly consultancy basis at the company.

In retrospect, Adrian sees that he actually worked more than full-time: more precisely, 50% at the company and 80% on the thesis and that he was in effect a general resource for the company. The company wanted him to be involved and participate, and because he was new and young he did not want to tell his supervisors how much work he was doing. His main supervisor has a number of doctoral students, travels a lot and meets people to try to obtain funds for research. The industrial supervisor was interested in him and thought more about Adrian's development than about useful results. In industry, projects should be finished on time and should turn out as intended – otherwise they are regarded as a failure. At the university, things are more long-term and however things turn out something has always been learned. This difference meant that company work always came first, and Adrian felt bad about that. He has been an industrial doctoral student for five years but it was only one year ago, when his first article was published, that he felt he was actually achieving anything. The company has had access to the knowledge that both he and other people from the university have provided, and ought to think about what it wants from doctoral students in the future.

#### *Kevin (Medical Bioinformatics school)*

After taking his first degree, Kevin worked for two years as a production engineer. Then he contacted the company's research department and the main supervisor who proposed the research project. The industrial supervisor thought that the project was highly appropriate for the company and Kevin felt secure in the knowledge that the main supervisor did not initiate ill-conceived projects. Now that half of his time as a doctoral student is over, he finds that he has not cooperated with other people as he had expected. At the company, he has his own office, feels like a member of staff and presents his findings, but he has run his project

completely on his own and has worked only one day a week at the company. The methods he develops at the university he applies at the company, but the data he works with at the company are secret and, as he is there only once a week, it is hard to maintain continuity. It is the company project that suffers. For the industrial supervisor, Kevin's project is not the main priority as the supervisor has a business to run which must make money. Even though there are doctorate-holding engineers, people working on their undergraduate projects and people doing post-doctoral work at the company, Kevin misses contact with other doctoral students as they are all busy with their own projects. The research school, which has been good about organizing courses and providing financial support, has arranged doctoral student meetings, but few of the students who attend them have been in a company or worked on company projects.

Both the main supervisor and industrial supervisor are excellent with regard to their knowledge, but they have a lot to do. Kevin feels he is on his own with his project because the main supervisor has an answer for everything and no discussion is needed. Furthermore, Kevin himself is based at a research centre, while his main supervisor is at the university where he has a 'big lab group' for which Kevin does analyses. He thinks that it is both fun and an advantage to have a supervisor who has a theory group and a lab group. Kevin gets credit for the fact that the people in the lab group use his theoretical methods and he has written an article together with them. The centre has other research groups and they have formed a journal club. Another piece of interaction which resulted in an article involved a foreign researcher, with whom the main supervisor had contact. Kevin has also presented his research at a workshop for doctoral and post-doctoral students. Knowing that after the PhD there is the chance to get a well-paid job has been a big incentive, and he would like to get a good job in the company where he has been placed.

#### *Lars (Management school)*

Lars had worked for 17 years when his company, which is geared towards technology and employs a number of PhDs, advertised the industrial research school on its home page. Lars had to work while he trained as a researcher. He was not prepared for graduate studies and remembers that in his first course he did not understand what people were talking about – as both language and discourse were strange to him. In the business world things have to move quickly, while the university approach is to think and analyse. The doctorate holds no importance either for the company or for his career, but it is a personal confirmation that he

has accomplished something. For four to five years Lars worked a 60-hour week. He did company work for 50% of the time and research for the other 50%. Students were expected to define the thesis project themselves and Lars looked into this in the context of his work. The company managers knew him, he had a good name in the organization, he was firmly anchored there, he had a good contact network and he had good supervision. However, just when Lars and his manager had agreed that he should be free for a few months to write his thesis, there was a significant change. New managers arrived who did not know who he was, so it was not a good idea to stay at home and write. He was offered a senior position, which he was obliged to accept as he needed a job. Although the only thing left in the research project is the writing, and although some of the managers agree that he should finish his thesis, it is not possible to work part time when you are in a senior position – and, as a practical person, it is much easier for Lars to take care of the short-term tasks at work than to tackle the long-term writing. He wants to finish the thesis, but feels he has already succeeded as his motivation was to apply the knowledge he acquired in the process of research, which is exactly what he has done.

The research school has been very important, especially for the first batch of doctoral students. It brought about mutuality and structure through a course programme and meetings with all the doctoral students and the supervisors. It is now almost a year since Lars was last at the research school. The company's reorganization has meant that it has had difficulties in getting involved with Lars's project. He has had seven or eight managers, and has changed industrial supervisor many times. As an industrial doctoral student, you cannot be alone in the bridge-building role. Little attention has been paid to identifying industrial supervisors, and now he does not have one at all. The role of industrial supervisor should be a function that is firmly embedded in the company so that demands are made and goals are set. In this way, the doctoral student's work and research will not just be his or her own business – it will also be the company's. It is not enough for the company simply to provide money.

*Maria (Medical Bioinformatics school)*

Maria did her Master's thesis examination work at the company. She became a doctoral student as she wanted to continue in the same subject area. A year later she applied to the school of research to get financing. The school has offered excellent courses and the opportunity to get to know doctoral students. Maria had the naïve idea that doctoral students spent most of their time in the laboratory experimenting and then wrote a report. In

fact, she spends 30% of her time in the laboratory, 30% writing and doing other research-related work, and the rest is given over to administrative matters – such as meetings, contact with the company and looking after the apparatus. Maria thinks it would be good to have a post-doctoral student and a technician to look after all the equipment. She receives a lot of apparatus which is necessary for her research from the company rather earlier than other people. In return, the company gets feedback about how well its near-market products work and what will interest the customers. When she does lab work and discovers faults and shortcomings in the apparatus, Maria telephones the company – but when the company has an acute problem it wants analysed, this becomes a project on demand. Maria accepts that this is to be expected, because you have to look after the hand that feeds you.

At first she worked in the company but was later moved to the university – perhaps so that she would be located closer to academic research. With the move, she demonstrated different apparatus to invited members of the university. Many of the university people ask for things to be analysed and so Maria puts in a lot of time without financial compensation. When she questioned this, her main supervisor said that it was right that she should do this work for free as many people were envious of the expensive equipment that she was able to use. Introducing new doctoral students also takes time from the project, but Maria understands that this is appropriate as she has been involved in the process for some time. The main supervisor, who travels a lot, runs a PhD group at the university, but he also spends a lot of time out at the company, where Maria thinks he is employed. The industrial supervisor is high up in the company hierarchy. His degree of engagement varies and so communication is often with people who report to him. The main supervisor thinks it is important that Maria makes new contacts, so she frequently attends academic and commercial conferences to study the competition – the company gets value for the money invested in this way too. When things seem really bad, Maria wonders whether she should just drop the whole thing and get a normal job. The whole culture of doing and returning favours is one of her reasons for wanting to get out into industry when she has finished. In a company, she thinks, you are in the real world.

*Nora (Building and Indoor Climate school)*

After taking her undergraduate degree, Nora started to work in the company that still employs her. When she saw the internal advertisement for the doctoral project she applied, even though she knew nothing about doctoral education. She wanted to return to the department where she had undertaken her undergraduate

examination work and do things that she could not do at the company. The doctoral research project was fully described in the advertisement, but it was subsequently changed radically. It became much more technical, as the academic supervisor was very keen on measurement and, in Nora's opinion, it is easier to measure and thus obtain data than to think deeply. Now the project is only indirectly concerned with the company's business concerns, but its customers and some other firms are nevertheless interested. Her academic supervisor, who was previously employed by the company, has many industrial contacts, but he does not regard student supervision as a priority. The industrial supervisor works in the company's R&D department and takes charge of all its doctoral projects. He has not been interested in Nora's research, probably because the focus of the project is no longer relevant to the company. She had meetings with him in the first year but then it all fizzled out, although he has a lot of contact with her academic supervisor about starting new projects.

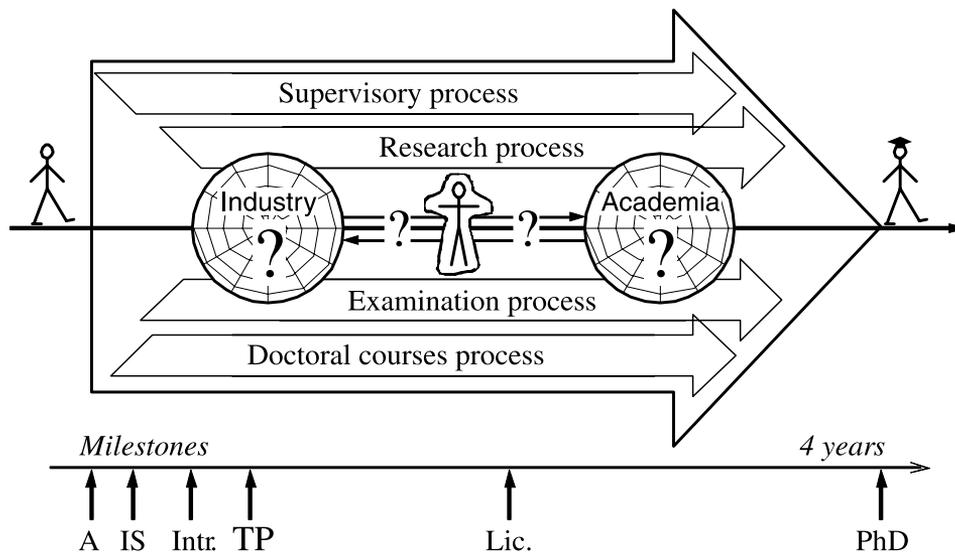
During the first three years, Nora was located at the university and 20% of her time was dedicated to the company's R&D department within the framework of her thesis project. Then, however, a crisis arose in the sales division. She was 'lent out', even though the head of R&D thought that she should continue working on her doctorate. The head of sales, on the other hand, thought that the research could wait. Nora herself wanted to do her best for the company, because she feels it is a good company. Now she is on 50% sick-leave and has come to the decision to finish half-way through. She is writing her licentiate thesis, but her work lacks coherence as she was always busy carrying out small investigations for the company. As a doctoral student she has felt very alone. The name 'research school' sounded good, but the doctoral students have met only once a year to present their work to their supervisors. The university is obliged to ensure that there are both a study plan and regular follow-ups. She has produced results, but feels uncertain about them as she has not had any confirmation of success. To do a PhD has never been a matter of prestige for her, but she would like to be a bridge-builder and has networks both at the university and at the company. What she now wants is to keep working in the R&D department, but she does not know whether she will be permitted to do so.

#### *Caesar (Management school)*

Caesar was working as head of production when the company advertised in its internal newspaper for industrial doctoral students to be its leaders of the future. He saw this as an opportunity to work 50% of

his time with business problems and spend the remaining 50% at the research school. He knew nothing about doctoral education, so he found the knowledge resources at the school incredible. The company was grappling with enormous problems, but it had not even scratched the surface of available knowledge. The school meant a great deal to him during the first two to three years. Together with other doctoral students he took courses there, wrote papers, went to conferences and attended seminars and courses abroad. This provided a firm basis, but it would have been better to work with common questions and share the empirical data. Caesar has been a doctoral student for six years now and has reached the final stages of his thesis work. For him, being a doctoral student means 'navigating': participating in the work group, attending every meeting and the research load make for 12-hour days. The company wants results that it can put immediately into use and he has delivered these. Overall, the division between work and research has been 50/50, but it has varied. The research process has been cumulative. Caesar wrote an article on the question that began the process. Then a concrete problem came up in the company which required further, external knowledge. Caesar was given this assignment, which led to extensive discussions with the academic supervisors about the research question. The questions increased with time as the roots of the real-life problem were identified and he raised these issues in his articles. The arrangement has worked out because Caesar's supervisors, company and colleagues have been accommodating when, at times, things have run out of sync.

Six years is a long time. Caesar has worked with different people, his managers have come and gone, and there have been many organizational changes. A key factor was that his earlier managers, who were enthusiastic when the research school started, felt that he should continue. The main supervisor's contact with the company did not turn out as planned, as the company could not manage the required continuity. Now Caesar has no industrial supervisor. With the departure of the person who had been involved in the original negotiations (and who was a member of the company's senior management), interest in and understanding about what an industrial doctoral student could bring to the company also disappeared. For bridge-building to work, there must be people on both sides – academia and industry – and time must be set aside. For Caesar, the driving force has been the company's internal need, but dealing with that requires several years of experience in the company and an ability to act politically to 'navigate'. According to Caesar, you have to build up a virtual network. Through such a network, he can see that he is in the best unit,



**Figure 1.** The trajectory concept symbolically applied to the industrial doctoral students' participation in the doctoral education process.

*Note:* The process is supported by sub-processes in which the student develops from newly admitted (A) to the holder of a PhD. After presentation of an individual study plan (IS) the introduction phase (Intr) is followed by a search phase designed to result in a thesis proposal (TP). About halfway through the PhD process, a 'licentiate' degree (Lic) is one possible milestone in Swedish doctoral education.

and is aware of other peoples' roles and positions in the company. He has discussed what he is going to do with his doctorate with his current boss and has been given an issue to investigate. He would also very much like to keep one foot in the academic world and to maintain contact with his colleagues from the school of research.

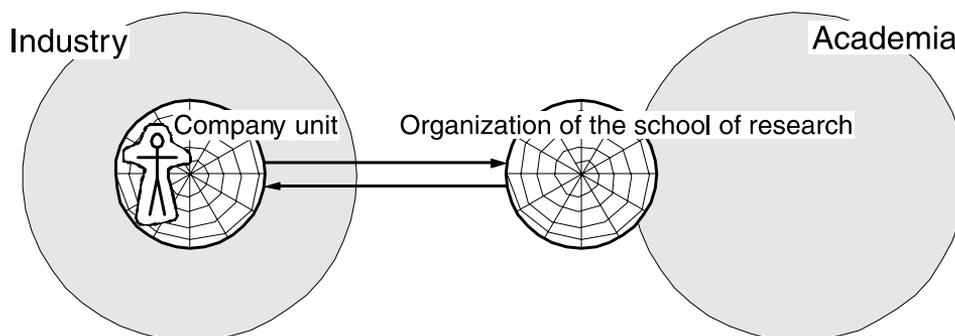
**Analysis**

It is evident from the above summaries that there is great variation in the participation and mode of belonging among the doctoral students, as well as in their experience of the process. However, there are also common factors. For instance, when they joined the programme, not one of the 23 doctoral students interviewed knew anything about doctoral education or what it really meant to be an industrial doctoral student.

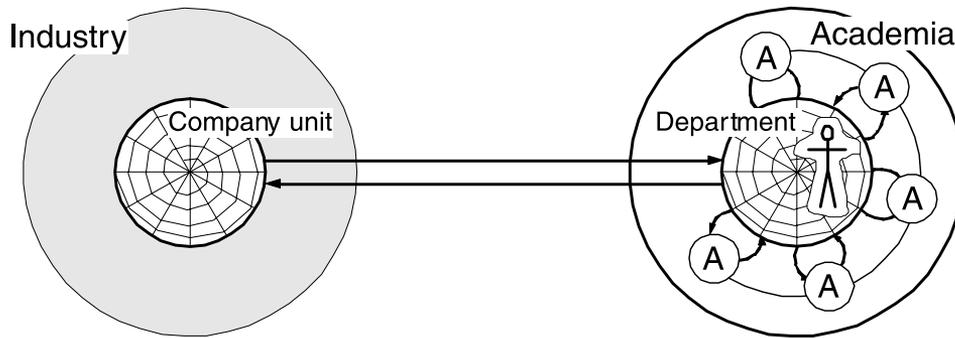
Furthermore, even if their aspirations vary, almost all want to stay in industry after they have completed their education, but none knows how his or her competence will be used.

In this section, we apply the theoretical concepts described earlier. By symbolically applying the trajectory concept, we can illustrate the four-year doctoral education process as one that is supported by four sub-processes in which the industrial doctoral students develop through their participation from newly admitted student to receiving a PhD (see Figure 1).

By following the students' accounts of their participation in the different communities of practice to which they belong, and their acting as brokers between these, the nature and extent of their participation and belonging can be discerned. Thus Figures 2–4 can be regarded as partial descriptions of Figure 1,



**Figure 2.** Industrial doctoral students' participation/reification in the Management research school.



**Figure 3.** Industrial doctoral students' participation/reification and role as brokers in the Medical Bioinformatics research school.

Note: 'A' denotes interaction with other departments and universities.

emphasizing aspects of the students' participation and subsequent contributions to reification as a consequence of their different positions and roles in the interplay between academia and industry (and sometimes in the lack of such interplay). In short, the figures illustrate what kind of identity the students develop during the whole doctoral education process.

Most of the six doctoral students in the Management research school participate in only two communities of practice: the company unit and the school. They are core members of both, although their participation in the school decreases after a couple of years. During the first two or three years the research school was very important to them, with several saying that at that stage it was the director of doctoral studies administration who played the most significant role in their education.

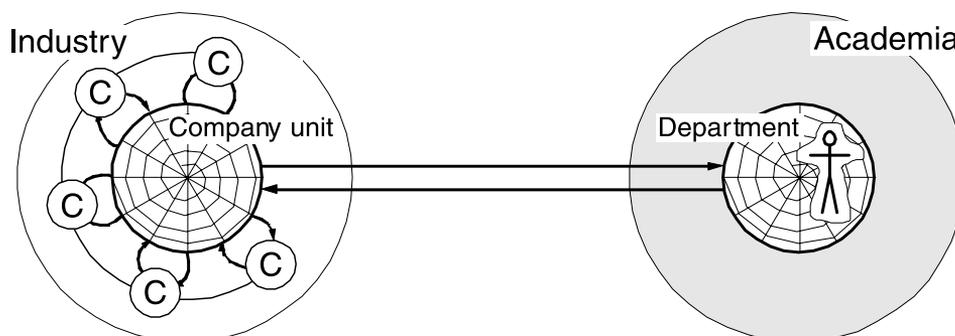
The 17 doctoral students in the research schools for Medical Bioinformatics and Building and Indoor Climate all reported peripheral participation in the school while at the same time, unlike the management students, almost all belonged to and participated in highly expansive social learning systems consisting of at least three and often many more communities of practice. Membership of these communities extends the

students' identities across boundaries. But the learning systems also differ from school to school with regard to practice. The doctoral students in the Medical Bioinformatics research school participate in the work of the company but, above all, they participate in boundary processes between several university departments and academic research groups. The doctoral students in the Building and Indoor Climate research school do participate in the work of the academic department, although they are mainly active in boundary processes with and between different company activities.

Deeper analysis shows that all three structuring elements in the doctoral students' social learning systems and their boundary trajectories vary due to five factors:

- entrance conditions;
- doctoral thesis projects;
- the organization of the schools of research;
- supervision; and
- their aspirations.

In the following discussion, we first set out what is common to all schools in terms of regulations (UFB 3,



**Figure 4.** Industrial doctoral students' participation/reification and role as brokers in the Building and Indoor Climate research school.

Note: 'C' denotes interaction with other companies.

2005) and agreements and the specific conditions and procedures for the different schools. Two case studies are provided for each school.

#### *Entrance conditions*

*General.* The recruitment process is not defined either in agreements or regulations, and among the schools investigated in this study it varies both between and within the different schools. This is one reason why the students' personal experiences differ, as do the conditions for learning and developing for both individuals and communities of practice. Similarly, the students' incentives vary: only a few of the 23 see the doctoral degree as the main driving force. Even the allocation of time between education and company work is not consistent: there are ratios of 80/20 and 50/50, and these affect the participation, belonging and identity development of the industrial doctoral student within the different sectors, as does the length the working week. There are no specific demands on a company to sign a collaboration agreement with the university.

*Management school.* Recruitment takes place in groups via internal company advertising. On admission, all six doctoral students interviewed had worked for many years in business and industry after their first degree and were now core members of their companies with leading positions. The most common incentive, as in the case of Caesar and Lars, was to learn in order to develop the company's business. Thus it is important that the field of research is the same as the field of work. In order to combine these activities, Caesar and Lars stress the importance of being competent and understanding the company's practice. They also stress the need to be seen as competent people so that relationships can be created and networks built with others in the company with the same areas of interest and competence. To be a manager and a doctoral student simultaneously is a problem.

*Medical Bioinformatics school.* Like Maria, the nine doctoral students were recruited primarily in connection with their first degree or examination work. Maria's incentive was to continue working in the field that interested her. She was moved from the company where she did her examination work to the academic department, which she considers her home base, with other doctoral students. At the company it was difficult to identify with the work because her participation was seen as something different, while at the same time she herself considers that the company's practice, which is research, differs from academic research. Maria's doctoral project is to use the company's equipment in her research and to test, assess and evaluate its function

and provide feedback to the company. The prescribed ratio for the students at this school is 20% work and 80% doctoral education, and all adhere to this except Maria, who works 40–50% of her time at the company. Everyone has a 40-hour week. Kevin had been working at the company where he is still employed for a couple of years when he found an academic supervisor and contacted the company's research department so that he could embark on the doctoral project. He uses the methods he develops at both the university and the company, but as the company research is secret, there has to be a separate company project. He feels that the time he spends at the company is too short for him to participate adequately to create his own identity there. In general, he feels alone and even at the university he feels he has problems in creating rewarding relationships.

*Building and Indoor Climate school.* Half of the eight doctoral students interviewed were recruited in connection with their examination work or first degree. Adrian was asked by his examination work supervisor and agreed mainly because of the cooperation with the company involved and the opportunity to attend conferences. At first he was employed by the company, which works with product development, but felt it was better to move and be employed at the university where there is time for reflection and where there are other people with whom he can identify and have discussions. At the company, rapid results were expected and as a newcomer Adrian wanted to show that he was competent and understood the company practice. Consequently he became very involved in achieving high targets in his thesis project, and the agreed 20% of time at the company became 50%. Nora applied through an internal company advertisement to get into the research environment where she is now based. Within the framework of the project, 20% of her time is lent out to the company's R&D department, where she acts as a knowledge resource for customers. She feels competent in this role. She understands the needs of the company and academic environments and has working networks and relationships in both. During her first three years, she has followed the 80/20 norm, working a 40-hour week – as have six of the other doctoral students at this school.

#### *Doctoral thesis projects*

*General.* Regarding the doctoral thesis project it is rarely mentioned by the KK Foundation, with regard to industrial schools of research, that it should be of interest for the particular company involved. The current study shows that in practice the relevance of the project varies from school to school depending on

whether or not (a) it has been predefined in the course of recruiting the doctoral student, (b) it is primarily academic or is generally related to company activities, and (c) it works as a bridge between activities and directly influences the bridge-building role of the student.

*Management school.* It is the task of the students themselves to find suitable thesis projects that will enable them to play a role in the company and develop relevant knowledge and competence. The student's role in the company is similar to that of an agent for change and development, while the research school provides a frame of reference and academic contacts while the student acquires an academic attitude and a methodology for analysis and problem solving. It is therefore difficult to see the thesis project as a bridge in the form of a boundary object, around which cross-boundary connections arise. This difficulty is exacerbated by the fact that all the students in the school, just like Caesar and Lars, lack an industrial supervisor with whom they can interact – indeed, even their academic supervisors do not have the opportunity to interact with an industrial counterpart. Caesar and Lars are potential brokers, but both mention problems with 'bridging' and with the role of bridge builder.

*Medical Bioinformatics school.* Most of the nine thesis projects are subject-related, as for the case of traditional doctoral students, and were defined either by the supervisor or by the supervisor together with the student. The project is central in the case of this school, while continuous contact with the company is weak. Maria and Kevin are two exceptions: both interact with a company, have industrial supervisors and function as brokers. Their projects function as boundary objects in the form of artefacts and as tools which they apply and develop by participating in university work. The thesis project is also used in the interaction between university and company. In the academic environment, Maria gives demonstrations for several groups, takes care of newcomers and goes to academic and commercial conferences, where she participates both academically and commercially as she is considered competent in both contexts. The company receives feedback on the apparatus it puts at her disposal and which is necessary for her research work. Maria's thesis project has become a cross-disciplinary project in which knowledge from both environments is needed for her research and apparatus development. At the same time, many boundary interactions occur around about this project. Due to the company's secrecy policy, Kevin's thesis project works only as a boundary object in the form of a tool between the academic and business environments.

*Building and Indoor Climate school.* In this school, all eight thesis projects were largely predefined. The students study critical problems for the participating companies, which are usually active participants thanks to the efforts of the industrial supervisors. Both Nora and Adrian are happy to function as brokers. They bring knowledge from different disciplines to different communities and thus they are engaged in cross-disciplinary projects. Their projects function as boundary objects and bridges between industrial companies and the academic institution. Both Nora and Adrian, however, are critical of the fact that they were not involved in formulating the thesis project from the start. Both have changed their projects and this has had a considerable impact on them and their studies.

#### *Organization of the research schools*

*General.* Since there are no prescriptions for how an industrial school of research should be organized, they vary considerably. The organization of the Management school differs substantially from that of the other two, as does its importance for its doctoral students and their participation.

*Management school.* As has been noted, the organization of this school is very significant for the six doctoral students. The account of the organization provided by Caesar and Lars is consistent with a community of practice in which integrated elements have been extensively developed. There are *events*, such as courses, meetings, paper writing and conference travel, which impart a high level of learning energy and a *rhythm* that creates a sense of structure for the students. Through recruiting groups of students and scheduling meetings of the whole group or selected members, the school encourages *connectivity*. The theses are the *learning projects* and the first director of studies was, for the first two to three years, an active *leader*.

*Medical Bioinformatics and Building and Indoor Climate schools.* Judging from the students' descriptions, the institutional organization of these schools is very different, and all the students participate only very peripherally in that organization. Of the 17 doctoral students who are, generally speaking, located primarily in the academic environment, about half think that the school organization lacks meaning, others that it has some relevance through the courses available and arranged meetings with other doctoral students, while yet others emphasize the financial aspects of belonging to an industrial research school. Unlike those in the Management school, these doctoral students are participants in expansive social learning systems,

consisting of at least three (and often many more) communities of practice. (See Figures 2–4.)

### *Supervision*

*General.* Supervision in Swedish doctoral education is governed by regulations. In the case of industrial research schools there is an additional agreement that supervision should be shared between university and company. However, the nature, role and competence of the industrial supervisor varies, as does the location and working of the academic supervision. Together, these factors affect the doctoral student's participation and identity development.

*Management school.* Supervision is almost always within the research school organization, either with the whole group of industrial doctoral students or with sub-groups. None of the six students has an industrial supervisor: in this research school the industrial supervisor role is associated with the role of manager.

*Medical Bioinformatics school.* In contrast to the other doctoral students in this school, Kevin and Maria do have an industrial supervisor. Kevin's industrial supervisor presented his thesis at the same institute as his academic supervisor, and both are very busy people. The main supervisor has several PhD groups at different locations in the university and is involved in external academic collaboration. Kevin functions as a broker between these locations and the industrial supervisor's company. He also participates in boundary encounters in which research from a variety of different subject areas is discussed. Maria's main supervisor is affiliated to both university and company, where the industrial supervisor holds a senior position. The industrial supervisor is very busy and has little time for Maria who has to rely on contacts with other company employees. The main supervisor travels frequently and has many contacts. He wants Maria to participate in both research and commercial conferences. He also thinks she should look after the research apparatus and demonstrate how to use and apply it both within his own academic research group and also to other people, and Maria does this.

*Building and Indoor Climate school.* All eight doctoral students have both an academic and industrial supervisor. Adrian's supervisors presented their theses at the same time. The main supervisor travels frequently and has a large network of contacts, and Adrian decided himself to redefine his thesis so that it resulted in a standard he thought was necessary for the company and the industry more generally. Nora also has industrial and academic supervisors. The latter is very busy with an extended network of contacts in both academia and

industry. Together with her academic supervisor, who was previously employed at the company, she changed the thesis project with the result that the company's customers became interested in it while the industrial supervisor and the company lost interest in her research and her contact with them thus decreased. On the other hand, the industrial supervisor is in close contact with the academic supervisor and together they start up new projects.

### *Aspirations*

*General.* As we have seen, the doctoral students do not know what will happen after they have completed their studies, but most want to stay in industry whether or not they take their PhD. However, there is some difference between the schools, depending on whether or not the students assume that they can stay on at the company.

*Management school.* Five of the six students want to stay with the company. When they began the programme for future leaders, they all had leading company positions and seemed to be working on the assumption that they could stay on. Caesar is soon to present his thesis and has already ensured that he has a new job lined up in the company. He has indicated that he would like to continue to spend 20% of his time in the academic world. Whether or not Lars will complete the programme is uncertain, but he feels he has achieved his goal of applying knowledge gained during his doctoral education within the company.

*Medical Bioinformatics school.* Five of the nine students want to go into industry, two want to go into academia and two do not know. Kevin has leave of absence from his company and, after taking his PhD, wants above all to have a well-paid job in it. For Maria, what is most important is that after completion of her PhD she can carry on working in her field, but she wants to leave the academic world with all its favours and returns of favour and is afraid of getting stuck in education.

*Building and Indoor Climate school.* Six of the eight students see industry as their future choice and three want to stay at their present company. None of them is definite about staying on in academia. Adrian does not know and is concentrating on finishing his thesis, but he thinks he and his supervisors should have discussed in advance what would happen afterwards. Nora is just on leave of absence from the company while she is studying, and wants to stop after she has taken her licentiate and carry on working in the R&D department to which she is affiliated as a doctoral student. However, she does not know if she will be allowed to do this.

## Discussion

According to Wenger (2000, p 236) brokering knowledge is delicate, but developing the boundary infrastructure of social learning systems involves paying attention to people who act as brokers. Considering the findings of this study, there is all the more reason to agree with this. In this section the five factors identified – entrance conditions, doctoral thesis project, organization of the research schools, supervision and students' aspirations – will be discussed as well as the conditions that were common to all the industrial doctoral students, irrespective of their research school. In addition, other factors will be discussed that were not identified by applying the chosen theory and concepts, but which nevertheless had a considerable influence on the students' participation and identity development.

It is noteworthy that, despite all their differences, the majority of the 23 doctoral students *felt alone*: attention needs to be paid to the causes of this. One reason is the lack of supervision: in some cases, there are no industrial supervisors and in other cases the supervisors, both academic and industrial, are very busy. Some doctoral students in the schools for Medical Bioinformatics and Building and Indoor Climate were moved from company to university because of differences in knowledge building or scarcity of work – and this was much appreciated by the students. Another reason for feeling alone is that sometimes the company has little interest in the thesis project – as, for example, when the project is radically changed.

A common characteristic of all 23 doctoral students was their *ignorance of doctoral education* and *what it means* to be an industrial doctoral student when they began the programme. According to the regulations, the university must inform students about the educational programme. Also common to all, and very apparent, is a lack of knowledge about what will happen when they have finished their studies – nor do the students know what will happen if they give up their research, either in relation to themselves as individuals or to the knowledge base and networks they have helped to create and have used within the company and/or at the university.

With regard to those factors that, according to the analysis, underlie the great variation in students' participation and identity development, these influence the students' situation to such an extent that they must receive attention. The different *recruiting processes* mean that the students' experience varies greatly from the outset of their studies. In this study, the range is from people who have just graduated with their first degree to graduates who have worked in industry for 10–20 years. Taking Wallgren and Hägglund (2004) as

a point of departure, changes in the doctoral education for industrial doctoral students can be considered. For example, an independent preparatory programme might be introduced for doctoral courses. Two-phase doctoral studies might also be looked at, with distinct periods at the university and in industry – this approach might be better adapted to the different phases of the educational process, such as writing the dissertation, which requires a great degree of concentration.

At the same time, any rethinking has to take into account what is required and what is possible in relation to the student's company.

With regard to the *doctoral thesis project*, a key question arises: should the student be recruited to an already formulated project or should the project be devised jointly by the student, company and supervisor so that it corresponds to the student's specific interest and background? From the perspective of Ellström (2004), the student's interaction with his or her environment (learning as a process) and the result of this interaction (learning as a product) are both central aspects of learning. But which is the most important in the case of doctoral studies? The choice of a thesis project must take into account not only scale, relevance to the company's activities and the student's education, but also the type and degree of involvement it demands on the part of the student.

How should a research school be *organized* and what role should it play? There is no clear definition of the concept of a school of research, apart from what is prescribed by the regulations for doctoral education. The Management research school is very much appreciated by its doctoral students, but it is organized as a community of practice that has developed its own processes for crossing the boundaries between academia and business effectively. It creates its own boundaries and prevents the doctoral students from functioning as brokers. According to Wenger (2000, p 243),

'For communities of practice, it requires a balance between core and boundary processes, so that the practice is both a strong node in the web of interconnections – an enabler of deep learning in a specific area – and at the same time, highly linked with other parts of the system – a player in system wide processes of knowledge production, exchange, and transformation.'

This study raises many questions about *supervision* which, as Lindén (1998) stresses, is a key tool in the doctorate-level learning process. All supervision has to be carefully tailored to take account of the specific situation (Lauvås and Handal, 2001). In an industrial research school, where there should be more than one

supervisor, this process becomes even more delicate. Moreover, the role of an industrial supervisor is relatively new and as yet is not clearly defined. As Salminen-Karlsson and Wallgren (2005) point out, it cannot be taken for granted that the academic and industrial supervisors will work as a team. The place where supervision occurs is of great importance, as the supervision is to an extent defined and bound by its context (Lindén, 1998). This study shows that the physical location of the industrial supervisor, academic supervisor and doctoral student influences the student's participation. The Management research school organizes supervision as a team activity, and so it is located at the school.

*What about the future?* As has been mentioned, almost all the students interviewed had no clear idea about this – despite the fact that, apart from their self-development, they had also made a considerable contribution to both institute and company. The issue here is what will happen to the person and the knowledge developed as they emerge from the doctoral education programme?

According to Hessle (1987, p 35), a new step in the 'legitimacy ladder' should be introduced so that the doctoral students can:

- inform relevant groups in society about their research results;
- develop theories/methods against the background of the new competence they have acquired;
- start/launch new research projects; and
- supervise future researchers.

With the help of the theory set out earlier in this paper, the factors summarized in this section were identified as the dominant influences on students' participation and identity development. However, there are other underlying factors, such as differences in knowledge acquisition and market forces and the significance of power relationships within supervision and employment. Wenger *et al* (2002, p 139) note that,

'... it is important not to romanticize communities of practice or expect them to solve all the problems without creating any.'

They go on to describe some common problems. We cannot rely entirely on Wenger's concepts in identifying the factors that influence industrial doctoral students' participation and identity development. Below, we discuss other issues that can create problems and are specific to the kind of community of practice formed by industrial research schools.

*Conflicting ideas about knowledge acquisition.*

According to Svensson (2001, p 243), based on Gibbons *et al*, there are differences between traditional (academic) knowledge building and alternative knowledge building. These differences became apparent in our study, not least with regard to questions of time and planning. In addition, differences in the work environments were found to influence the effectiveness of the doctoral education. In Ellström's view (2001, p 30) there is a different emphasis in businesses with 'development logic' as opposed to those with 'production logic'.

*Market forces.* Reorganization was common in the research schools and precipitated what the students saw as the most critical events in their education. Companies typically face tough competition and have to adjust rapidly to changing market conditions. As a result, some of the thesis projects evaporated, as did the connection between work and research. Doctoral students were moved, made redundant or given a new role which proved difficult to combine with study. Industrial supervisors came and went, as sometimes did the head of department who was originally involved in initiating the project.

*Power relations.* It is obvious that supervision is strengthened when the academic supervisor cooperates with the industrial supervisor, or is involved in both university and company activities. With regard to the employment status of the doctoral students, we agree with Rainbird *et al* (2004) who note that certain rules pertain when education is connected to employment. Our study enforces the criticism by Fuller and Unwin (2004) who discuss the shortcomings of situated learning theory with regard to structural restrictions and lack of equality. Rainbird *et al* (2004) agree with their findings and further point out that learning in the workplace cannot be taken for granted but that all forms of paid employment are structured by a set of rules. In their view, existing theory is not sufficient for developing an understanding of this mode of learning, precisely because notions of power relationships and structural constraints remain vague and unclear.

### **Credibility and generalizability**

In research comprising quantitative data and applying statistical or mathematical methods of analysis, there is a long tradition of calculating the validity and reliability of the results. The credibility of qualitative studies may not easily be determined by such scrutiny. Glaser and Strauss (1967) proposed the concept of credibility as an alternative for qualitative research methods. The core of credibility is the trustworthiness of the researcher's

categorization, interpretation and labelling of the primary data. One way of exhibiting this is to describe how units of analysis have been delimited – for example, whether entire interviews, sentences or fragments of interviews have been analysed. Another way is to support conclusions and interpretations with excerpts from the interview material. In this paper, we have also used the six case studies to provide ‘thick slices’ of data, letting individual students illustrate the idiosyncratic features of research schools or groups of students. Our analysis, furthermore, is an example of what has been denoted ‘negotiated consensus’ (Dahlgren *et al.*, 1992); that is, the procedure in which researchers prepare their own suggestions for categorizing and interpreting the data and thereafter come together to negotiate a common view of how the data may be understood.

The study was carried out in three research schools. One of our main conclusions is that doctoral students face different situations during their education depending on the particular discipline and industry sector. Caution is therefore needed in generalizing the results to other situations. It is, however, our conviction that some significant results will be applicable to other research schools in the same sectors and with similar structures as those described here.

## Conclusions

The conceptual framework of situated learning theory, according to Lave and Wenger (1991), works well as an analytical tool for discerning different patterns in doctoral students’ learning systems and the factors that influence the building of these systems. Factors that relate to issues of power and overarching structures, on the other hand, are not brought to the fore by the theory. The paper has highlighted key factors in both categories that were applicable to the different schools and educational situations.

We have also highlighted key factors common to all or the large majority of the industrial doctoral students, irrespective of school. There was a common ignorance among the interviewees about research-based education and what it was like to be an industrial doctoral student when they were first accepted for the programme. There was also typically a desire for a future career in business and industry at the end of the study period.

The students had followed different boundary trajectories through their doctoral studies according to the effects of different configurations of external and internal forces – only a few of which they could influence themselves. The students thus exhibit a variety of professional identities as they leave their studies, ranging from pure researchers with possible careers in

academia to innovative entrepreneurs in industry. The purpose of industrial research schools is to bring about new kinds of encounters between academia and industry: on the basis of this study it might be concluded that this purpose has, to a large extent, been fulfilled.

## Note

<sup>1</sup>The extent of this work, as well as several other matters, are regulated by a special agreement between the university, which is responsible for the education of the student, and the company, which partially finances the student and in which he or she is expected to participate with the help of an industrial supervisor.

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