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Doctoral education as social practice for knowledge development

Conditions and demands encountered by industry PhD students

Lillemor Wallgren and Lars Owe Dahlgren

Abstract: *This article reports on an empirical study of industry PhD students in the Swedish Graduate School for Applied IT and Software Engineering. The students were questioned in semi-structured interviews about their experiences of sharing their postgraduate studies between industrial and academic environments. The results from the first analysis indicate that there are considerable differences between companies in terms of their traditions and their propensity to take part in joint knowledge development with universities. Three types of company environment were identified in this context: (a) research-intensive, (b) engineering and (c) consultancy. The focus of this study is on how the type of activity, the difference in time perspective between companies and universities, the competence of other company employees and the character of the thesis project affect the doctoral student's situation, identity, support and participation in knowledge development.*

Keywords: *postgraduate education; industry PhD students; knowledge formation; knowledge transfer; communities of practice*

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The study reported here is concerned with postgraduate education organized in an industrial research school as a cooperative project between universities and firms. Its aim is to provide a picture of this kind of postgraduate education from the perspective of the doctoral student. The emphasis is on students' experiences in three different company environments identified by Wallgren and Hägglund (2004). In short, the aim is to develop a more thorough understanding of what it is like to

be a postgraduate student coping with the different environments of the university, with its demand for a scientific thesis that conforms to a set of criteria for what is considered good research, and of the firm, whose major concern is with the illumination and solution of a difficult industrial problem.

The main issues addressed in this context are the sense of identity of the postgraduate student, the impact of the student's environment on his or her studies,

the student's expectations, the responsibilities of the various actors involved, student support, significant people and activities, and interaction between the university and the firm. The overarching aim is to provide an overall picture of doctoral students' situations in the interests of ensuring the best possible form of doctoral education in cooperation with private enterprise.

One key motivation for this study was the increasing cooperation in knowledge development between universities and other actors, which has added considerable complexity to postgraduate education. The traditional style of postgraduate education is relatively transparent, since it takes place in a relatively small and homogeneous academic environment, with the supervisor as the guarantor of the quality of the work.

Another reason for the study is that research on students' perspectives of postgraduate education supplied cooperatively by universities, government and firms is very scarce. This is partly because joint postgraduate education of this kind is relatively new, and partly because there is a lack of research-based knowledge about postgraduate education in general.

There is now, however, a growing interest in research on postgraduate education, particularly in light of the plans to integrate higher education systems across the European Union. In a 2004 report (Utbildningsdepartementet, 2004), the Swedish Ministry of Education stated that increasingly intense European cooperation in higher education made it desirable to focus on particular target groups in assessing higher education systems. The report also stated that the Bologna process provided a strong incentive for many countries to introduce higher education, since the aim was to establish a highly integrated higher education system throughout Europe – the European Higher Education Area.

Postgraduate education in Sweden

Overall regulations and structure

All postgraduate education in Sweden (in traditional as well as industry research schools) is framed by the same national statutes (Norstedts Juridik, 2004). Doctoral education comprises four years of full-time study. The minimum entry requirement is a Bachelor's degree, but in many subject areas most candidates have a Master's degree (or a half-way 'licentiate' qualification) before they embark on their PhD. Doctoral students are allowed to dedicate up to 20% of their time to departmental work (teaching, etc), in which case they have five years to complete their degree. Similarly, they may work for a company which has agreed that they can continue their PhD

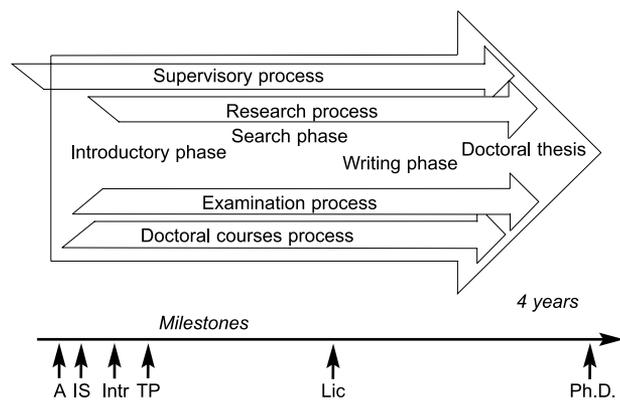


Figure 1. Overview of the four-year doctoral education process supported by sub-processes.
Source: after Bergman, 1997.

studies while in employment. The students discussed in this paper are employed partly by a company and partly by a university, and they can use their time at each for their PhD studies to an extent stipulated in a contractual agreement between the university and the company.

As illustrated in Figure 1, the four-year process of doctoral education in Sweden includes a number of milestones as the newly admitted candidate (A) works towards the attainment of a PhD. After the presentation of an individual study plan (IS), the introductory phase (Intr) is followed by a search phase which should result in a thesis proposal (TP). About halfway through the PhD process, a 'licentiate' degree (Lic) can be awarded (and this can also constitute a final qualification). As shown in Figure 1, there are four 'sub-processes', which run simultaneously throughout the programme: supervision, research, examination and course study. The course study programme may account for up to 50% of the 160 credits required for the PhD qualification (this corresponds to 240 ECTS credit points).

Industry research schools – rationale and specific features

In the mid-1990s a new kind of doctoral education was introduced in Sweden: 'industry research schools' were established as a result of cooperation between universities and companies. The main rationale was to renew existing doctoral education and at the same time to respond to the increasing need for graduates with a research degree. The doctoral candidates in industry research schools are accepted into the same programmes as traditional candidates, but their study contexts are more diverse. While traditional candidates carry out their studies entirely in a university department, the industry research candidates are

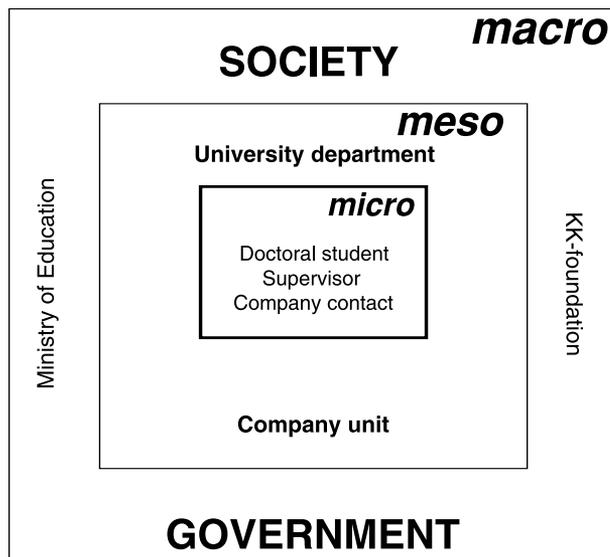


Figure 2. Configuration of the industry graduate school.

expected both to engage in interactive research with company employees and to take part in courses and seminars at the university. Like traditional postgraduate students they have an academic supervisor, but they also have an industrial supervisor. They may be seen as engaging in a kind of Triple Helix project (Leydesdorff and Etzkowitz, 1997) in which, at the macro-level, university, government and industry cooperate to promote growth. Thus the entrepreneurial role of the university is also emphasized (Etzkowitz, 2002). The company, university department and research school constitute the meso-level. Within this complex configuration, the student is expected to function as an innovative bridging resource, taking part in the formation of a new paradigm for knowledge formation (see Figure 2).

The industry research students in effect take part not only in a Triple Helix project, but also in a cooperative activity that has similar features to Barnett's (1994) learning triangle – in which knowledge, higher education and society are mutually dependent on each other in a form of dynamic interplay. Higher education produces its own concepts and definitions of knowledge, while society at large generates and diffuses knowledge outside the university environment.

According to Adler and Norrgren (2004), the notion of a Triple Helix of science policy is strongly promoted by policy makers. In Sweden, the Knowledge Foundation (denoted as the 'KK-foundation' in Figure 2), founded by the government, took the initiative in establishing the industry research schools in 1996. The Foundation offered financial support for these schools on condition that their universities established contacts with

appropriate companies for joint knowledge development and that the resulting activities were mutually beneficial. Students in the industry research schools pursue their studies in accordance with traditional curricula and are accepted, supervised and examined by their university in the same way as other doctoral candidates. The partners involved sign a special agreement which stipulates the money and time allocated respectively for study and for company work. In contrast to traditional doctoral students, the industry research students are expected to undertake a thesis project which has a close connection to the company concerned (which, of course, is partly responsible for paying them).

Theoretical frameworks and previous research

Even though there is a frustrating lack of research on knowledge development and on students' perspectives of industry research schools, there is an extensive literature on cooperation between higher education institutions and companies and public-sector organizations (Jacob and Hellström, 2000; Adler and Norrgren, 2004; Etzkowitz, 2002). A useful perspective on the comparison between traditional postgraduate education and industry research schools is provided by the distinction between Mode 1 and Mode 2 knowledge formation, as defined by Gibbons *et al* (1994). In Mode 1, the research question and the choice of theoretical perspective rest with academic researchers. The industry research school aims at a style of knowledge production that involves interplay between Mode 1 and Mode 2, in which knowledge formation takes place simultaneously in both modes and in which the doctoral student, supported by a supervisor, is a key actor.

The two modes are characterized by Nowotny *et al* (2003) and analytically contrasted by Gibbons (2002) as follows:

- In Mode 1 problems are set and solved in a context governed by the largely academic interests of a specific community. By contrast, in Mode 2 knowledge is produced in the context of application.
- Mode 1 is disciplinary while Mode 2 is transdisciplinary.
- Mode 1 is characterized by relative homogeneity of skills, while Mode 2 is characterized by heterogeneity of skills.
- In organizational terms, Mode 1 is hierarchical, while in Mode 2 the preference is for flatter organizational structures.
- Mode 2 is more socially accountable and reflexive than Mode 1.

- Each mode employs a different type of quality control. Peer review certainly exists in both, but in Mode 2 it includes a wider, more temporary and more heterogeneous set of practitioners, collaborating on a problem defined in a specific and localized context. As such, by comparison with Mode 1, Mode 2 involves a much expanded system of quality control.

According to Barnett (1994), modern society requires higher education to prepare students to function effectively in society. Thus they are expected not only to possess certain skills and knowledge, but also to know how to use them.

Based on the work of Gibbons *et al* (1994), Svensson (2001) has compared two different kinds of knowledge formation, which he labels ‘traditional’ and ‘alternative’. They are not synonymous with Mode 1 and Mode 2, but rather emphasize the differences between the different environments in which knowledge development occurs (see Table 1).

Another consequence of shifting from traditional postgraduate education to industry research schools relates to what Gibbons (2002) calls ‘socially distributed knowledge’ – that is, knowledge developed in many contexts which, in turn, communicate with one another. In socio-cultural jargon, industry research graduates may be regarded as ‘brokers’ (Wenger, 1998), moving between different ‘communities of practice’, who may influence the distinct discourses in each community. In short, industry research candidates are not external PhD students attending a kind of ‘distance’ version of the programme, but rather legitimate students with a joint affiliation.

The dynamics of knowledge production lie in the flow of knowledge as such and in the formation of different knowledge networks. As interaction increases,

knowledge production becomes more heterogeneous and occurs in new contexts. Gibbons (2002) claims that universities must expand their notion of knowledge production from simply the development of ‘reliable’ knowledge to include the development of ‘socially robust’ knowledge, since it is this kind of knowledge that is needed in the developed parts of the world.

Apart from taking into account the above theoretical approaches, the industry research students’ experiences were also analysed from a socio-cultural perspective. According to this approach, learning is situated in cultural contexts and the relative importance of what is individual and what is collective is a decisive factor in all learning environments. From the socio-cultural viewpoint, learning is fundamentally synonymous with participation in a social activity – ‘social’, in this context, referring both to historical and cultural circumstances and to the relationships and interaction between individuals. The focus is on the entire system of activities – interacting individuals, situations and activities, and even more remote contexts that give meaning to what is taking place. Apart from relationships, participation, communication and the interplay between individuals are essential constituents of the learning process (Dysthe, 2003). Dysthe’s statements about the system of activities may be compared with what Gibbons (1994) has to say about Mode 2 knowledge formation. He takes the view that learning derives from interplay among people and that the linking of an individual’s experiences with those of other people is of central importance, as is the application of cross-disciplinary methods of knowledge development.

Furthermore, the socio-cultural perspective emphasizes the tension between Mode 1 and Mode 2. This tension, for example, is present in Wenger’s (1998) theory, according to which learning takes place through

Table 1. Two models for building up/increasing knowledge.

	Traditional	Alternative
Relationships	Hierarchical	Equal
Control motor	(Academic) subject	Shared knowledge, action
Aim	Theoretical understanding	Usability
Form	Institutionalized	Flexible
Time perspective	Long-term	Short-term
Attitude	Demarcated, scientific	Reflective
Responsibility	Towards the academic community	Wider, local community
Actors	Researchers, experts	Varying
Type of knowledge	General	Specific, context-bound
Focus	Result	Process-oriented
Planning	Predetermined	Dynamic
Availability	Limited	Open
Method of working	Discovery – change	Simultaneous discovery – change
Authorization	Professional rules	Varied

Source: Svensson, 2001, p 243.

participation in social activities. The participants are involved in a common activity, which builds on mutual engagement, common objectives and a common repertoire (that is, the participants have supplementary or similar competencies – Wenger, 1998, pp 4–5). Wenger proposes the following fundamental principles:

- We are all social beings.
- Knowledge in different areas is important.
- Knowledge is a matter of competence with respect to valued enterprises.
- Learning is about construing meaning.

Wallgren and Hägglund (2004) identified a number of contextual factors that had a significant impact on students' progress in an industry research school. The nature of the company's business and, in particular, of the work unit involved, seems to have a major influence. Other key factors are the type of activity the doctoral student undertakes, the time perspective in the company, the research competence of other employees and the nature of the research project. Deeper analysis

shows that three different kinds of company environment can be identified, based on the extent to which doctoral education occurs or is recognized in it. From this classification, three categories of work culture can be described: a 'research-intense' environment (Type 1), an 'engineering' environment (Type 2), and a 'consultancy' environment (Type 3) – see Table 2 for a description of these categories.

A further outcome of the analysis was that the respondents felt that research education in an industry research school was something quite different from that experienced by a traditional doctoral candidate. This motivated a further search in the empirical material for factors that had influenced the respondents' construction of their identity as research students.

Study design: perspective, core questions and analysis

For the present study, 23 doctoral candidates engaged in semi-structured, in-depth interviews in 2001. They

Table 2. Characteristics of the different environments.

	Research-intense	Engineering	Consultancy
Type of activity	This environment is most commonly found at companies with a dedicated R&D department. The company has a tangible product, but the doctoral students are not involved in production, and the R&D department tends to remain relatively separate from other parts of the business.	In this environment the product is central. The doctoral students are closer to production than in a research-intense environment. The company often has an interest in using the student's research for product development.	There is no actual production, but services are sold. The workplace is sometimes on the company premises and sometimes at the client's place of business. The company's motivation for employing doctoral students is often to enhance their image of expertise and to demonstrate that they have competence in particular areas.
Employees	Many employees have doctoral degrees and there are several doctoral students in the group. Most often, however, the supervisor is located at the university. There is little cooperation with others, especially outside the research group.	There are significantly fewer people with a doctoral education and fewer doctoral students than in the research-intense environment. The supervisor is most often a company employee. There is usually substantial contact and collaboration with other employees.	There are few employees with post-doctoral education and few other doctoral students. In fact, the doctoral student is often the only person familiar with doctoral education. Only occasionally is there an assistant supervisor at the company. There is typically little significant collaboration with other employees.
Time perspective	The time perspective is often long-term and there is an understanding of the timescales needed for research.	Shorter than in the research-intense environment and highly product-related – in terms of production phase and delivery time.	Significantly shorter than in both the research-intense and the engineering environments. Time is measured more in hours than in years and is directly related to cost, as the customer pays time-based charges.
Research project	The research project is usually independent of and distinct from production.	Usually closely related to the product, so that the applicability of the result, which is dependent on the production process, is potentially high.	Empirical findings for the thesis are gathered outside the company and usually from a customer's business operations.

were all enrolled at an industry research school – the Graduate School for Applied IT and Software Engineering at Linköping University. As already described, the purpose of the study was to document their experiences and to identify problems and factors relevant to their development during their studies and their roles as company employees. In addition, any significant implications for continuous cooperation between the university and industry were also to be identified and analysed.

In the empirical study the students' experiences of their situation are analysed from a socio-cultural perspective, by categorizing the different research environments in industry as set out by Wallgren and Hägglund (2004) and as described in the previous section. The concepts of Mode 1 and Mode 2 knowledge production also played a central role in the analysis. The focus was on the following issues (Tables 3–7 summarize the findings, which are discussed later):

- How do students in the three different environments construe their identity?
- What are the doctoral students' expectations, readiness for action and needs in relation to their industry research activities?
- What kind of support, relationships and responsibility do the students experience and whom do they regard as most significant in their particular environment?
- What types of activity, encounters and interaction between the university and the company do the students generate by their participation?

These questions also function as distinctive areas of analysis, and the results section below is organized accordingly.

Results

It is important to bear in mind that the results presented here originate from the study of a single industry research school at one university in Sweden. However, while we cannot assert that the results are

generalizable, they derive from a qualitative analysis of 23 interviews and highlight various issues that are clearly significant. The extent to which the results are relevant to other environments may vary, but nevertheless this is a detailed description of how one group of students experienced their postgraduate studies.

How do students in the three different environments construe their identity?

Under the company–university agreement, both company and university are expected to allocate students' time such that they can complete their tasks at each location. This is the formal aspect of the industry research student's daily life, but a central empirical question is what that daily life is like in reality for such students – how their time is actually allocated, where they are physically located and where they feel they belong. An analysis of the empirical data shows that there is a connection between the kind of research environment the respondents reported themselves to be in and the basic features of their sense of identity – that is, where they felt that their workplace and research environments, respectively, were located and where they chose to spend their time. Furthermore, it appeared that students with different opinions about various contextual factors also differed in terms of their identity formation. Table 3 summarizes these differences.

Expectations, readiness for action and needs

The doctoral students are the key actors and the aim of the programme is that, under supervision, they should end their studies with a PhD. In the Swedish Statutes of Higher Education (Norstedts Juridik, 2004, p 14), it is explicitly stated that the education programme should provide the necessary knowledge and skills for the candidate to take on a research task independently. The administrators of the postgraduate programme must also provide acceptable social conditions during the study period.

Since research education in cooperation with private enterprise is a relatively new phenomenon in

Table 3. Students' identification of their roles, sense of belonging and time allocations.

	Research-intense environment	Engineering environment	Consultancy environment
Workplace	Split between three locations: company, home and university.	Split equally between university and company.	Typically, the company.
Research environment	The international research community.	(1) University; (2) university and company.	University.
Allocation of time	No particular allocation reported.	Very distinct allocation of time throughout the week.	No particular allocation.
Identification	Company.	University and company.	Problematic and unclear.

Table 4. Relationship between expectations, readiness for action, and needs and experiences of industry research students.

	Expectations, readiness for action, needs	Experience
Research-intense environment	<p><i>Motives:</i> Formalizing own development in the field. <i>Aims:</i> Doctoral degree as a door opener. <i>Status of degree:</i> High. <i>Important traits:</i> Like traditional doctoral students. <i>Earlier experience:</i> Some experience of doctoral studies, long-term experience of private enterprise and the company in question. <i>Responsibility for doctoral studies:</i> (1) doctoral student; (2) supervisor, in following up and guiding towards the goal; (3) company manager, for creating the right conditions in the company.</p>	<p><i>Company environment:</i> Stimulating; research is an important part of the company's activities. <i>Role and acceptance:</i> Great resource, positive attitude from others. <i>Being a student:</i> Fun; something to be valued; an opportunity. <i>Most significant people:</i> (1) Supervisor and other researchers in the field; (2) other researchers; (3) company manager. These people meet each other when there are common projects.</p>
Engineering environment	<p><i>Motives:</i> Relationship to industry. <i>Aims:</i> Knowledge, experience. <i>Status of degree:</i> Good. <i>Important traits:</i> Discipline, ability to plan, stress tolerance. <i>Earlier experience:</i> No previous research education, no or just short-term experience of industry. <i>Responsibility for doctoral studies:</i> (1) supervisor; (2) student.</p>	<p><i>Company environment:</i> Shows interest in the progress of the student. <i>Role and acceptance:</i> Resource and link to the university. <i>Being a student:</i> Good, tough, stressful and close to products. <i>Most significant people:</i> (1) Supervisor; (2) student colleagues; (3) employees. Student has regular meetings with all these.</p>
Consultancy environment	<p><i>Motives:</i> Circumstances and practical/economic solutions. <i>Aims:</i> Knowledge and the degree. <i>Status of degree:</i> Doubtful. <i>Important traits:</i> Interest. <i>Earlier experience:</i> Some experience of doctoral studies, long-term experience of industry and of the company. <i>Responsibility for doctoral studies:</i> Unclear.</p>	<p><i>Company environment:</i> Rejection; lack of understanding of the importance of research. <i>Role and acceptance:</i> Not visible; regarded as problematic. <i>Being a student:</i> Demanding, split, positive, developing. <i>Most significant people:</i> If there are any at all: supervisor; student colleagues; chairman of the graduate school; company manager. These people seldom meet each other.</p>

Sweden, assessing the degree of consistency between what is stipulated in the Statutes and the students' actual experiences is of particular interest. We thus focused on the correspondence between expectations and experience in the different environments regarding readiness for action, needs and the challenge of being a research student in a company. The results are set out in Table 4.

Support, relationships, responsibility and significant people

Since research education in industry research schools is a relatively new arrangement with a number of different actors involved, it is appropriate to examine where responsibility lies in the programme and who provides student support. Depending on the type of environment, the variation in opinions and experience is considerable – see Tables 5 and 6.

Activity, encounters and interaction

The aim of industry research schools is to promote cooperation between universities and business by means of a shared responsibility for the research students. Thus the frequency and the nature of interaction between companies and university

departments are critically important. The various types and degrees of interaction reported by the respondents are summarized in Table 7.

Discussion

As is evident from Tables 3–7, only the students in the 'engineering' environment identify themselves as and act like 'brokers', to use Wenger's (1998) terminology. They perceive both university and company as their research contexts and workplaces, and they plan for active participation in both. They engage in many different activities at the university as well as at the company, and they interact with several key people. They describe their participation in knowledge formation as coinciding with Mode 2.

It can be seen from Table 4 that the students' motivation in applying to the industrial postgraduate programme was to obtain a postgraduate education in cooperation with industry. As far as the company was concerned, the student was both a resource and a link to the university. In the engineering environment, in contrast to the other two environments, the supervisor was based in the company (see Tables 5 and 6). Furthermore, the doctoral students in this

Table 5. Support, relationships and responsibility in the three company environments.

Research-intense environment	Engineering environment	Consultancy environment
<p>The students regarded themselves as primarily responsible.</p> <p>It was the supervisor's responsibility to follow up and guide the student towards final and intermediate goals.</p> <p>Several students reported that the company manager was responsible for providing the appropriate conditions for them to carry out their doctoral studies in parallel with their work at the company.</p>	<p>Responsibility for the studies remained with the supervisor.</p> <p>Some emphasized that the students themselves also shared the responsibility.</p> <p><i>Comment:</i> The supervisors were wholly or partly located at the company.</p>	<p>Respondents provided an unclear and ambiguous picture of responsibility for doctoral studies.</p> <p>One respondent reported that the student was solely responsible, another that the supervisor was responsible and yet another that the student had a great deal of the responsibility but that the supervisor should support the student.</p> <p><i>Comment:</i> All supervisors were based at the university.</p>

Table 6. Most significant people in the research studies.

Research-intense environment	Engineering environment	Consultancy environment
<p>The most significant person was perceived to be the <i>supervisor</i>, although some respondents also mentioned other researchers active in the field.</p> <p>After the supervisor, most respondents regarded other researchers in a relevant field as significant, regardless of where in the world they were active. Some also mentioned their immediate manager, since this was the person who set the conditions for carrying out the doctoral research.</p> <p><i>Comment:</i> Some mentioned that their manager had never been present when they had met with their supervisor, while others reported that all the people involved met regularly to discuss the project or in the course of routine activities. However, no formal meetings were scheduled between the student, the supervisor and the company contact person/manager with specific regard to the doctoral studies. The supervisors were, with one exception, stationed at the university.</p>	<p>The supervisor was ranked as the most important person, followed by fellow doctoral students and other company employees. Meetings with these people normally took place at the student's university department.</p> <p><i>Comment:</i> The supervisor had a strong affiliation with the company (working for it full-time or employed by both company and university) and was the key contact.</p>	<p>Only a few respondents identified the supervisor as the most significant person, and one person reported that there was no significant person at all as far as the doctoral studies were concerned.</p> <p>One respondent mentioned fellow students, since they worked together in a research project at the university and another identified the person in charge of the whole research school.</p> <p>Another mentioned the company manager. The company manager/contact, the supervisor and the student were reported to have met in a couple of instances, whereas other respondents reported no such meetings.</p>

environment considered the supervisor to be the person with the main responsibility for their education. They also emphasized the importance of cooperating with other company employees for their knowledge development. Their thesis work was generally part of a larger production project within the company. The cooperation between the university and the company was also more intense and closer than in the other cases.

To summarize, the students in the engineering environment partake in knowledge production that is consistent with Mode 2, as defined by Nowotny *et al* (2003). Mode 2 knowledge is embedded in the expertise of individual researchers as well as in research teams.

Another characteristic feature of Mode 2, consistent with the kind of knowledge formation reported by

the students in the engineering environment, is that knowledge is developed in different spaces – in this case the university and the company. Furthermore, there is a high degree of reflection; that is, there is a continuous dialogue between the actors and the subject in the research process (in other words, the doctoral students discuss their thesis work as a part of the production project with engineers at the company). The interaction in which these students are involved functions according to the 'learning triangle' (Barnett, 1994) – that is, the relationships between higher education, knowledge and society are mutually beneficial. This means that knowledge is developed in the university and in society at large and that higher education takes place both in universities and in the community. The industry PhD students are engaged in postgraduate education, they carry out research

Table 7. Type of activity, meetings and interaction between university and company.

	Research-intense environment	Engineering environment	Consultancy environment
University	Almost exclusively meetings with the supervisor.	Many different activities: doctoral studies, teaching, etc.	Almost exclusively doctoral education. (Meetings with supervisor for some.)
Company	Participating in a research team. Involvement in the doctoral project. Company research and doctoral studies closely interconnected. Doctoral project sometimes separated from production.	Many different activities: taking an active part in projects, supervision of Master's theses, acting as a contact person, marketing, and engagement in the thesis project (which formed part of a larger production project).	Very few doctoral student activities. The thesis work was often a private enterprise and the empirical data were often generated from sources outside the company.
The international research community	Intense interaction. Networking within the research field.	No interaction with the research community outside the university was reported.	No cooperation outside the university was reported.
University–industry cooperation	Some cooperation, as some thesis projects were of mutual interest.	Intense and close cooperation through courses, other projects, conferences, report writing, etc.	No cooperation at all.

work and they are involved in a research project that is industry-oriented. In other words, they are engaged in a typical Mode 2 project for knowledge development.

Moreover, the Triple Helix seems to work only in the engineering environment. This environment is characterized by common activities among and close cooperation between universities, companies and state-supported postgraduate education.

The doctoral students in the other two environments experienced different conditions and operated in a different mode. In the research-intense environment, the students identified with the company. They regarded the international research community as their research context and they wanted a doctorate because they saw the degree as a door-opener to that environment. They conceived of themselves as an important resource for the company and regarded their supervisor and other researchers as significant people. Nevertheless, they felt that, as doctoral students, they themselves were responsible for their education. They attended the university to meet their supervisor, but did not take part in other activities at the university. At the company, on the other hand, they participated actively in research teams, although their thesis work was sometimes separate from production. There was, however, a certain degree of cooperation between the university and the companies: doctoral students in such a situation are not identified as 'brokers', but rather as 'actors' in knowledge development according to Mode 1.

Regardless of the company-related character of the thesis work and the fact that they are physically situated at the company, these respondents can be compared

with traditional doctoral students. This assertion is supported by the fact that they do not regard postgraduate education in cooperation with industry as significantly different from traditional postgraduate education. As indicated above, these doctoral students are situated in contexts that correspond to academic research departments comprising several researchers, a thorough understanding of postgraduate education and a time perspective that is relatively long (particularly by comparison with that of the other two environments). They do not take part in any common knowledge formation with the universities but, rather, interact independently with the research community, which results in another kind of Triple Helix from that in which the students in the engineering environment are involved. Consequently, the university in question does not become a 'learning' university and knowledge development at the local level is different.

The doctoral students in the 'consultancy' environment cannot be regarded as 'brokers'. They faced difficulties in being accepted into the environment, and this meant that they found it very difficult to construe their identity. Hence they were not supported in their research studies at the company but, rather, were regarded as problematic and made 'invisible'. For these students, it was often unclear where the responsibility lay for their postgraduate studies and the supervisory arrangements were inadequate. Their supervisors were located at the university and the students merely took courses and attended supervision sessions there. Writing the thesis was perceived as a private project and the empirical data were often generated in the course of their

consultancy work with customers. Because they worked for long periods with customers, they did not even have a permanent workspace at their company. There was no cooperation between the company and the university. In this environment, there is no joint knowledge development and no functioning of the Triple Helix at all. In spite of these shortcomings in the consultancy environment, however, the doctoral students did report that their work was stimulating and had contributed to their development.

Conclusion

It appears, then, that the company environment has a profound impact on the doctoral student's situation on the whole, as well as on the postgraduate education process. The difficulties inherent in belonging to different communities of practice are also in evidence. Not all postgraduate students become 'brokers' and so cannot take advantage of what such a role could offer. The company environment also determines the nature and intensity of the cooperation between the university and the company. Doctoral students do, however, identify themselves and act differently in the different environments, partly because of their own individual characteristics. Such differences can also be decisive in their respective abilities to cope with their roles as industry PhD students.

Clearly, a number of dilemmas arise in all three environments for various reasons and impact on both the students and knowledge development. One factor, for example, is the time perspective. The content and form of the thesis also affect the type of knowledge developed and help to determine whether or not there will be any joint knowledge development. In the engineering environment the knowledge is context-related, which means that the postgraduate education process is dependent on the production process in the company.

Adopting the terminology of Bowden and Marton (1998), the PhD students in this study may be involved in 'learning at the individual level', 'learning at the collective level' and 'learning at the local level'. By involving PhD students in industry, the universities may impart as well as obtain valuable knowledge and experience – thus becoming what Bowden and Marton characterize as a 'university of learning' and a 'learning university'. Responsibility for the knowledge developed is unclear and varied in the present study. In the research-intense environment, knowledge is assessed through peer review. In this environment, there is learning 'at the collective level', while in the engineering environment the learning takes place at a local level. The consultancy environment is closer to 'learning at the individual level'.

Mode 1 as well as Mode 2 knowledge development occurs if the student is in an engineering environment: as the doctoral students proceed through their postgraduate education the supervisors, who also have a strong connection to the company environment, assess their progress. Mode 2 is also present in the research-intense environment, but the mutual exchange between company, university and wider community is much more limited. The exchange with the international research community is, on the other hand, intense. Thus the research-intense environment shares significant features with the traditional academic environment, and so Mode 1 tends to dominate in this cooperative context. In the consultancy environment, there is no common knowledge development with the university. The doctoral students are given all the responsibility for the postgraduate education process, as well as the product.

Our conclusion is that both Mode 1 and Mode 2 knowledge formation occurs in industry research schools. The doctoral student is expected to develop knowledge in close cooperation with the company, but also to take part in conventional postgraduate education and thereby to comply with the traditional criteria for 'scientific knowledge' in academia.

Both Mode 1 and Mode 2 knowledge formation are largely dependent on a range of contextual and individual factors and relationships among organizations and individuals. It is obvious from the study that a large number of actors, relationships and the fact that knowledge production takes place in a context of application do not guarantee *per se* that Mode 2 knowledge formation will occur. What other factors that may be critical in this respect and in promoting university–industry cooperation in postgraduate education could usefully constitute a topic for further research.

References

- Adler, N., and Norrgren, F. (2004), 'Collaborative research', in Adler, N., Shani, A.B., and Styhre, A. eds, *Collaborative Research in Organizations*, Sage, London.
- Barnett, R. (1994), 'Part I: knowledge, higher education and society', in *The Limits of Competence*, London: Society for Research into Higher Education, London, pp 11–24.
- Bergman, B. (1997), *Forskarutbildningsprocessen [The Postgraduate Education Process]*, Department of Mechanical Engineering, Quality Technology and Management, Linköping University, unpublished manuscript.
- Bowden, J., and Marton, F. (1998), 'Part I: a place for learning', in *The University of Learning*, RoutledgeFalmer, London, pp 3–19.
- Dysthe, O. (2003), 'Sociokulturella teoriperspektiv på kunskap och lärande' ['Socio-cultural perspectives on knowledge and learning'], in Dysthe, O., ed, *Dialog, samspel och lärande [Dialogue, Interaction and Learning]*, Studentlitteratur, Lund.

- Etzkowitz, H. (2002), *MIT and the Rise of Entrepreneurial Science*, Routledge, London.
- Gibbons, M. (2002), 'Globalisation and the future of higher education', paper presented at conference on 'Globalisation: What Issues are at stake for universities?', Université Laval, Québec, 20 September 2002.
- Gibbons, M., Limoges, C., Novotny, H., Schwarzman, S., Scott, P., and Throw, M. (1994), *The New Production of Knowledge: the Dynamics of Science and Research in Contemporary Society*, Sage, London.
- Jacob, M., and Hellström, T., eds (2000), *The Future of Knowledge Production in the Academy*, Open University Press, Buckingham.
- Leydesdorff, L., and Etzkowitz, H. (1997), 'A Triple Helix of university–industry–government relations', in Etzkowitz, H., and Leydesdorff, L., eds, *Universities and the Global Knowledge Economy: a Triple Helix of University–Industry–Government Relations*, Pinter, London.
- Norstedts Juridik (2004), *Universitet och högskolor – Utbildningsväsendets författningsböcker [Universities and University Colleges – Statutes for the Education System]*, UFB 3, 2004/05, Norstedts Juridik AB, Stockholm.
- Nowotny, H., Scott, P., and Gibbons, M. (2005), 'Rethinking science: Mode 2 in societal context', in Carayannis, E.G., and Campbell, D.F.G., eds, *Knowledge Creation, Diffusion, and Use in Innovation Networks and Knowledge Clusters: a Comparative Systems Approach Across the United States, Europe and Asia*, Praeger, Westport, CT.
- Svensson, L. (2001), 'Att forska och utveckla tillsammans – om gemensam kunskapsbildning mellan forskare och praktiker' ['Doing research together for development'], in Backlund, T., et al, eds, *Lärdilemman i arbetslivet [Dilemmas in Workplace Learning]*, Studentlitteratur, Lund.
- Utbildningsdepartementet (2004), *Högre utbildning i utveckling – Bolognaprocessen i svensk belysning [Higher Education in Development – The Bologna Process from a Swedish Perspective]*, Ds 2004:2, Utbildningsdepartementet, Stockholm.
- Wallgren, L. (2003), *Skilda världar: Företagsdoktoranders upplevelser av forskarutbildning [Different Worlds: Industry Doctoral Students' Experiences of Doctoral Education]*, licentiate thesis, Department of Behavioural Sciences, Linköping University, Linköping.
- Wallgren, L., and Hägglund, S. (2004) 'The industry doctoral student – an educational challenge for academia and industry', in Hemlin, S., Allwood, C.M., and Martin, B.R., eds, *Creative Knowledge Environments: the Influences on Creativity in Research and Innovation*, Edward Elgar, Cheltenham.
- Wenger, E. (1998), *Communities of Practice: Learning, Meaning, and Identity*, Cambridge University Press, Cambridge.

