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Learning Outcomes from Doctoral Education carried out in Industry-Academia Collaborations

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Elin Kollerud

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Supervisor: Magnus Gulbrandsen

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Elin Kollerud

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Abstract

Learning outcomes as well as the organisation of doctoral training are subjects to debate when it comes to ensuring adequate competence building and a proper knowledge base. Through a literature review of existing research and through a quantitative analysis of survey data, this study explores students´ skills and skills acquisition in doctoral education carried out in industry-academia collaborations. Based on innovation literature, the study sets out three theoretical assumptions, which are explored empirically; students in collaborative relationship are exposed to heterogeneous learning environments that enable the development of generic skills, they learn to apply research specific skills in new contexts in industry and they get broader employability perspectives that have impact on their career destinations. Findings suggest that collaborative students learn research specific skills. Generic skills are acquired only to a small extent. Contact with industry may enhance understanding of academic research due to real life orientation met in industry, which gives new perspectives on the students´ own research and its applicability. However, the study indicates that there is no significant relationship between industry links and skills acquisition. This would have political implications on how doctoral education is organised and how resources from industry are applied in doctoral education.

1.0 Introduction

A striking characteristic of knowledge production resulting in innovation is the fact that knowledge, in terms of skills and competences, is the most important input (Nielsen and Lundvall, in Lorenz and Lundvall, 2006:163)

The doctoral degree is the highest level of education, it renews and maintains the research system and the research itself and it represents an investment in highly qualified work force in general. Hence, doctoral education is an important mean to provide individuals with an appropriate mix of skills and competences. This thesis aims at providing further insight into skills acquisition, with a focus on transferable skills, in doctoral education.

1.1 Background

Doctoral education has a particular place and a key role being at the very centre of two interconnected pillars of the knowledge based society, namely education and research. A Ph.D. degree is the highest level of education, but normally the first stage of a research career. At the same time, doctoral education is highly individual and by definition original. The progression path of the individual is unique, in terms of the research project as well as the individual professional development. European universities have carried out wide-ranging reforms of doctoral education the last decade, rooted in the Bologna-process and the creation of a European Higher Education Area (EHEA). Similar developments can be found also overseas. EHEA seeks to be coordinated with the European Research Area (ERA). The political background of ERA consists of the Lisbon declaration (2000) where the member states aim at making the region the most “competitive and dynamic knowledge-based economy in the world”, followed up with the Barcelona objectives (2003) to invert 3 % of GDP in research, the Ljubljana process (2007) and EU Green Paper (2008) to implement the objectives in the Lisbon declaration and the COM Communication (2010) “Europe 2020 Flagship Initiative - Innovation Union”. Norway is one of 40 participants in the Bologna-process and the Norwegian system of higher education was reformed in line with the Bologna-process in 2003 with the “Quality Reform”. Norway has also endorsed EU research policy in the white papers on research of 2004-2005 and 2008-2009 and participates in the ERA on an equal footing with the other European countries through the European Economic Area (EEA) agreement (Research Council of Norway, 2011, URL:18.11).

Quality issues, scientific and societal relevance as well as the organisation of doctoral training have been, and are still, subjects to debate in the EHEA and ERA initiatives to ensure adequate competence building. A proper knowledge base is necessary to tackle major societal challenges such as climate change, food and energy security, and public health. In this context skills acquisition and learning outcomes of doctoral education is central. What skills and competences should doctoral students develop to carry out research? How should doctoral training be organised enabling the students to develop these skills and competences?

In this context, the European University Association Council of Doctoral Education (EUA-CDE) has taken initiative to promote best practise in doctoral training through the Salzburg principles and the Salzburg II Recommendations. These principles express that doctoral training should reach a critical mass, include transferable skills training, lead doctoral candidates to acquire the ability to challenge disciplinary borders and encourage doctoral students to spend some research time in industry or other relevant private/public employment sector (EUA-CDE, 2010). EUA has members in 47 countries, including Norway, and is the main voice of the higher education community in Europe (SGHRM/280911/04).

Another important aspect is that knowledge is increasingly produced in relations between industry, government and academia. This is the dynamic in the knowledge-based economy according to Leydesdorff and Etzkowitz who focus on the expanding role of knowledge in society and the universities´ role in it in their “triple-helix model”. Leydesdorff and Etzkowitz argue there are no separate institutional spheres between sectors and institutions and knowledge is generated in terms of overlapping institutional spheres where institutions are taking each other’s roles and functions, retaining from their traditional missions. It becomes a common goal for universities, industry and government to promote innovation (Etzkowitz and Leydesdorff 2000:111). Knowledge production in industry-academia-government relations has led to an increased focus on transferrable skills, which become central for individuals operating in this landscape. Researchers should not only be experts in their research field, but also master entrepreneurship, leadership, team work and team building, application for funding, communication and other skills. Another argument for an enhanced focus on transferable skills, or so-called “employability” skills, is that doctoral education must increasingly meet needs in the labour market.

The skills debate has resulted in a number of qualification frameworks around the world, which describe desired learning outcomes from doctoral education and which focus on a wide range of skills. Studies at a European level show that the shift from teaching goals to intended learning outcomes and the transmission of transferable skills and their assessment, are issues that still need to be clarified. In particular, there seem to be insecurity about appropriate assessment strategies for such skills (Kehm, 2010:5).

1.2 Research question

This thesis seeks to contribute to the debate about quality, scientific and societal relevance and organisation of doctoral training, exploring skills and skills acquisition in doctoral education. The aim is to give a description of learning outcomes in terms of skills and skills acquisition in doctoral education, particularly from education in collaborative relationships. Learning outcome from doctoral education carried out in industry-academia relations is of special interest, taking the changing landscape of knowledge production in the “triple-helix model” into account. Learning outcome is a highly individual measure. Still, knowledge about what students themselves think they have learnt is valuable to understand the output of doctoral education and serves to inform program curricula development and to attract future doctoral candidates. This led me to the following research question:

What is doctoral students´ perception of their learning outcome from doctoral education carried out in academia-industry collaborations in Norway with focus on skills and skills acquisition?

The research question will be explored in two ways; through a literature review and through an empirical study in the format of a questionnaire among doctoral students engaged in industry-academia collaborations. Learning outcome is a highly individual measure and parallels should be drawn to the wider socio-economic context to explain individual skills and competences as the most important input in innovation processes and as a foundation for knowledge based economy. Innovation literature provides a structure and an analytical framework for this purpose. I will thus lend perspectives on innovation systems, innovation and learning strategies and types of knowledge and their relation to the education system and labour market to set up a theoretical framework. Three theoretical assumptions are outlined from the innovation literature and tested empirically through the questionnaire as well as in the review of existing research.

Literature was identified through searches, based on key words, in relevant databases and journals. Searches was limited to English speaking, peer reviewed articles in the period from 2001-2011. All in all 46 articles were selected. Existing research does not take up learning outcomes from doctoral education carried out in industry-academia relations in terms of skills and skills acquisition to a large extent. This call for more research on learning outcomes in doctoral education industry-academia relations and the questionnaire in this thesis is a contribution in that sense. The identified literature body focuses on collaborative relations´ impact on students´ learning environment, on theoretical aspects of skills acquisition in research education and on empirical studies of student´s satisfaction about their education and their career trajectories. Individual learning and competence building is naturally central here.

Findings from the literature review, which includes key questions about knowledge, skills and competences in doctoral education, have been used to design a questionnaire which was sent to 241 doctoral students in industry-academia relations in Norway. Despite of a rather low response rate of 31 %, the data from the questionnaire gives indications on learning outcomes in terms of skills and skills acquisition among doctoral students.

1.3 Terminology

Skills, learning outcome, knowledge and *competence* are widely used terms in this thesis. There are, however, several definitions and in the following, I will comment upon how these terms will be applied in this study.

Traditionally there have been two approaches to the concept *learning outcome* in policy documents as well as in literature; 1) a teaching oriented approach which focuses on goals about the lecturer is expected to teach the student and 2) a learning oriented approach which focuses on what students have learnt after successful completion of their studies. Still, the learning oriented approach covers both 2a) the intended qualifications the students should acquire and 2b) the measureable results from their studies as marks and exams (Karlsen, 2011:16). In other words, there are diverse definitions that are often used interchangeably. There is also a shift from the teaching oriented approach to the learning oriented approach and the intended qualifications the students should possess after their education. Quality of higher education intuitions is for instance increasingly connected to students´ achievements and to what extent the students achieve what they are intended to achieve. The definition of 2a has been applied in the European context within the Bologna process: "*Learning outcomes describe what a learner is expected to know, understand and be able to demonstrate after successful completion of process of learning*" (Karlsen, 2011:17).

An enhanced focus on intended learning outcomes has resulted in several frameworks on knowledge, skills and competences around the world to secure effectiveness of the training as well as academe and societal relevance in the curricula. The frameworks have much in common and give a picture of what skills and competences are considered to be central. The concrete skills and competences in frameworks from the US, the United Kingdom, Australia and Norway as well as the common European framework, are presented in the Annex 1, Table 1: Specific and transferable skills. One should note that the frameworks are not entirely comparable as they have different purposes and not all address doctoral training in particular. It is out of the scope of this thesis to give an extended analysis of the frameworks. The aim is rather to give an impression of the intended learning outcomes, skills and competences that are considered to be relevant to knowledge based economy, in which doctoral education plays a key role. The frameworks apply to all Ph.D. education, inclusive doctoral training in industry-academia collaborations.

Another trend is to distinguish between research *specific* and *transferable skills*. Research specific skills refer to skills related to specific subject, research fields, research methodology and design, publishing or other ways of knowledge dissemination to the research community. Transferable skills, in their broadest sense, are skills learned in one context that are useful in another. They enable subject- and research-related skills to be applied and developed effectively. Transferable skills may be acquired through training or through work experience. This is the definition given by the European Science Foundation (2010), but these skills are also sometimes referred to as key skills, core skills, life skills, essential skills, key competences, necessary skills, soft skills, employability skills and generic skills (Commonwealth of Australia, 2010 [URL] 10.11, Karlsen, 2011:73).

The frameworks are rather coinciding in their skills presentation. Skills to carry out research in terms of giving and original contribution to one's research field by developing new theories, interpretations or applications are highlighted. Extensive knowledge in one´s research area and an understanding of methodologies and their appropriate application within the corresponding research field is also central. So are also the ability to communicate with peers and the research community. Among the transferable skills we find contribution to public understanding of one's research field, the capability to carry out critical analysis, evaluation and synthesis of new and complex ideas. Less common are interpersonal skills, as ability to cooperate, teamwork, networking, personal attributes as leadership, project management, self-management and career development, as applying external funding, demonstrate an insight into the transferable nature of research skills to other work environments and the range of career opportunities within and outside academia.

Knowledge and *competence* are other commonly used terms in literature, as well as in this study. Knowledge is often presented as a dichotomy - explicit or implicit, local, individual or collective. Explicit knowledge is available through written material, lectures, and media and has global character. It consists of know-what and know-why knowledge. Implicit knowledge, on the other hand, is tacit and local in character. This knowledge is acquired through experience and social practise, in other words, know-how and know-who knowledge (Jensen et al, 2007). Competence normally refers to a combination of theoretical and practical knowledge. I get back to knowledge and competence and their roles in learning and innovation processes in chapter 3.

The plurality of definitions makes learning outcome difficult to measure and implies several methodological challenges, which I will discuss in chapter 4. The research question of this thesis calls for a definition of learning outcome which is close up to 2b) the actual results from the studies the students have undertaken, emphasizing what the students themselves think they have learnt, not how they perform on exams, in their doctoral project or similar. However, all definitions of learning outcome are applied when looking into literature on learning outcome, skills and skills acquisition in chapter 3, since the different approaches highlight different sides of the concept. A plurality of definitions of skills and transferable skills, knowledge and competences will also be used throughout this thesis since existing research do refer to different definitions and since the boundaries between the concepts are blurring. Chapter 4 on methodology discusses implications of using different definitions.

1.4 The structure of this report

Chapter 2 starts out with the changing context of Ph.D. education in Norway to shortly set the scene in which Ph.D. education take place. Skills and skills acquisition is highly individual, but still the most important input in innovation processes as a foundation for knowledge based economy. Chapter 3 looks into the innovation literature and presents a theoretical framework from which learning outcomes in doctoral education can be understood. Research design and choice of methods can be found in chapter 4. The literature review follows in chapter 5, with a discussion of the findings. Finally, data from the questionnaire are presented and analysed statistically in chapter 6 and the findings are seen in relationship to the findings from the literature review. Chapter 7 draw conclusions and provide suggestions of further research.

2.0 The changing context of Ph.D. education

As seen, doctoral education has become a strategic research policy factor nationally and internationally. It is no longer an education for the small elite, but for a *critical mass* in a knowledge based society. In 2011 new records were set as the number of new doctoral graduates in Norway increased to 1329, from 1184 in 2010 and 1148 in 2009 (NIFU 2012 [URL] 23.03). That is beyond the political goal from 2002 aiming at 1100 new graduates by 2010, but still behind numbers in other Nordic countries. A recent report from the Ministry of Research and Education (KD) and the Norwegian Association of Higher Education Institutions (UHR) estimates a need for 1400-1600 doctoral candidates annually towards 2020 (Ministry of Research and Education and the Norwegian Association of Higher Education

Institutions, 2012:13). It is also a goal to increase submission rates and completion time. Diversity and the Ph.D. students´ connection to research groups of certain size are highlighted as success factors to enhance quality and submission rates in doctoral education.

In the following I look at recent developments in doctoral education as well as employability of doctoral holders in Norway. Research and development (R&D) activities in industry and industry´ s relationship to universities and research institutes have gained importance both when it comes to the organisation of doctoral education and employment of doctoral holders in industry. Hence, the chapter gives a short overview of R&D activities in the Norwegian research-performing sectors.

2.1 The introduction of the Ph.D. degree in Norway

In 2003, the Ph.D. degree was introduced in Norway line with the Bologna process, replacing the old system of discipline specific doctoral degrees. Norwegian Ph.D. education qualifies for research of high international standard and for other types of work where the individual needs scientific insight and analytical competences coherent with scientific practise and ethical standards. Ph.D. education includes doctoral courses with a minimum of 30 ECTS and the individual doctoral thesis produced under supervision. The Ph.D. is a three-year degree, but may be extended with one year of compulsory teaching or administrative work at the institution. The Ph.D. title is assigned when the doctoral courses and the thesis are approved and when the candidate has defended his/her thesis (UHR, 2011 [URL] 20.09). The Ph.D. degree is assigned by universities, specialised universities and a limited number of university colleges in line with the Norwegian accreditation system. Norway has 8 universities, 6 specialised universities and 25 university colleges. The universities offer more than 90 Ph.D. programs within 150 specialisations and university colleges and specialised universities 18 Ph.D. programs. In 2010 more than 20 000 doctoral degrees had been awarded in Norway since doctoral education was introduced in 1817. Many of these doctorates, 40 %, have been completed at the University of Oslo, with Norwegian University of Science and Technology (NTNU) contributing another 25 % (Research Council of Norway, 2011d: 37).

The Association of Norwegian Higher Education Institutions (UHR) provides guidelines for the Ph.D. education, upon which the institutions can build their own guidelines, both at institutional level and faculty level. Another framework provided by the UHR is the Agreement upon Admission to a Doctoral Program which includes a Part A, agreement between student and university, Part B, agreement of supervision and Part C, an agreement between university and external institution on the completion of doctoral program. The external partner will thus finance part of the doctoral education and offer appropriate infrastructure. This clearly opens for doing a Ph.D. in industry-academia collaborations. Formal agreements is however not the only mean, as there can also be looser connections to external partner. Students may also use an external partner to collect data or to secure research projects´ relevance to real life. Each HEI has accordingly much freedom when it comes to the organisation of the doctoral education. However, doctoral students´ connection to and integration into active research environments, which provide high quality learning support and supervision has proved to be key factors to success. Research schools tend to foster good learning environments. Research schools are supplementary to ordinary education and organised as networks, nationally or internationally (Research Council of Norway, 2011c:14).

A recommendation to the Ministry of Research and education (KD) on independent research institutes role in doctoral education highlights the institutes´ supervision capacity of doctoral students as well as potential recruitment of Ph.D. candidates. Secondly, collaboration between university and institutes enhances quality and relevance in doctoral education, especially within fields where institutes normally have their strengths. Thirdly, the institutes´ contribution to doctoral education may have positive impact on doctoral holders´ future career destinations as many are expected to seek employment within the research institutes. In addition, the institutes may provide doctoral students with competences in line with the National Qualification Framework (NQF), especially when it comes to management of interdisciplinary projects and the ability to assess the need for, take the initiative to and perform innovation (Research Council of Norway, 2011c:23).

NQF is being implemented at Norwegian higher education institutions from 2011 and a Norwegian Ph.D. degree should thus provide knowledge, skills and competences in line with the framework (NQF 2011). NQF serves to inform students, universities and employers about knowledge, skills and competences a candidate is expected to possess and should be used as a tool to elaborate study plans, individual careers and to facilitate lifelong learning. The qualification framework, as well as formal regulation connected to the Ph.D. degree, applies to all doctoral education regardless of research fields or interface with industry or other institutions. Attachment 1, Table 1: Specific and transferable skills, presents specific and transferable skills in several international framework and includes also NQF, cycle 3. The table shows that NQF has much in common with other frameworks, especially when it comes to specific skills. Some other frameworks are more comprehensive and include more details on transferable skills.

NQF, cycle 3, states that Ph.D. candidates should have the following learning outcome in terms of knowledge, skills and general competence.

	The candidate…
Knowledge	• is in the forefront of knowledge within his/her academic field and masters the field´s philosophy of science and/or artistic issues and methods • can evaluate the expediency and application of different methods and processes in research and scholarly and/or artistic development projects • can contribute to the development of new knowledge, new theories, methods, interpretations and forms of documentation in the field
Skills	• can formulate problems, plan and carry out research and scholarly and/or artistic development work • can carry out research and scholarly and/or artistic research work of a high international standard • can handle complex academic issues and challenge established knowledge and practice in the field
Competences	• can identify new relevant ethical issues and carry out his/her research with scholarly integrity • can manage complex interdisciplinary assignments and projects • can communicate research and development work through recognized Norwegian and international channels • can participate in debates in the field in international forums • can assess the need for, initiate and practice innovation

Source: National Qualification Framework, 2011

The recent developments in Norwegian doctoral education are being evaluated in 2011-12 by NIFU. The evaluation will take a systemic perspective to reveal differences in the doctoral education across disciplines and institutions and focus on quality aspects in the education, efficiency in the organisation of the training and the overall societal relevance of the doctoral degree. Aspects with significance to quality include skills and competences acquired to be used in different kinds of research positions inside and outside academia as well as alternative career paths before embarking on a research career instead of going straight from a master degree (Research Council of Norway 2011a [URL], 26.10).

2.2 Employability

Doctoral graduates also prove to be attractive on the labour market. Data from the period 1970-2006 indicates that around 90 % find work within a year after finishing their degree. Higher education institutions (HEIs) and independent research institutes are the main employers. In 2003 did 41 % of doctoral candidates work at HEIs, 18 % at independent research institutes/R&D intensive companies, 15 % at health institutions and 10 % in the oil and gas industry. The rest worked in other private and public sector (Olsen 2007:12-18, Thune and Olsen, 2009). Previous studies also reach similar conclusions, but the share of doctoral holders within industry has grown over time (Kyvik and Olsen, 2007). A more recent analysis of register data on 18 277 doctoral holders under 70 years showed that 94 % were employed in 2009. Only 1 % was unemployed and 5 % were inactive, which means that doctoral holders have a remarkably high participation in the labour market (Olsen 2011b).

A recent report from the Ministry of Research and education (KD) and The Norwegian Association of Higher Education Institutions (UHR) (2012) prescribes the demand and offer of doctoral positions in Norway. Estimations show a demand of 1400-1600 doctoral graduates annually from 2012-2015 and a slightly smaller number towards 2020. Within the R&D system, i.e. within HEIs and independent research institutes, 850-1050 positions a year will be free towards 2020. This is mainly due to old age pensions and outgoing mobility to other countries, to administrative positions or to industry. The highest demand is found within the STEM fields (Science, Technology, Engineering and Mathematics) (13-15). These numbers assume zero growth. Still, recent societal developments suggest that we will need more personnel with high qualifications within industry, service enterprises, health and welfare as well as public administrations due to demands of higher competences in product and service production in Norway and international competition provides increased demand of knowledge from research and development (R&D). As seen a growing number of doctoral graduates find employment in industry. In 2011 industry employed 1600 doctoral holders, which is around 10 % of the personnel involved in R&D activities in industry (Research Council of Norway, 2011d:38). Industry needs incentives to recruit doctoral holders in order to increase their absorptive capacity, i.e. the ability to make use of knowledge that stems from R&D and to engage in valuable networks with R&D institutions. However, there is a mismatch between industry´s needs of competences within the STEM fields and the offer of doctoral competences within humanities and social science, which calls for increased efforts in education at both undergraduate and graduate level within the STEM subjects (The Ministry of Research and Education and the Norwegian Association of Higher Education Institutions, 2012).

An increased number and share of the students have a non-Norwegian citizenship. While the share of foreign citizen was 9% in 1990, the number had increased to 20 % in 2003 (Brofoss and Olsen, 2007:7) and to 28 % in 2010 (NOU 2011:6:115). The numbers indicate that Norwegian doctoral training and working conditions are attractive also internationally. The high share of foreigners is mostly positively viewed as an important contribution to the global knowledge production. A main concern however, is poor recruitment of native Norwegians to the STEM fields and potential outgoing mobility of candidates with foreign citizenship, which will weaken Norwegian research. However, many foreign candidates also choose to work in Norway. Nearly half of the 919 foreign candidates who finished their degree from1990-2002 had found work in Norway in 2003. Still, only one in eight found work in private industry (Brofoss and Olsen, 2007:6). On the other hand, the numbers of doctoral holders with a non-Norwegian degree is also of importance. In 2009, more than 3400 persons under 70 years were registered with a non-Norwegian degree and 2768 doctoral holders had a foreign citizenship in Norway. This means that there are a reasonable number of Norwegian citizens with a doctoral degree from abroad working in Norway (Olsen, 2011).

More than 60 % of those who embark a doctoral degree, manage to complete their education spending 5 ½ years at an average. Within a timeframe of 10 years, 75 % finish their degree. However, the students are rather old when completing the degree. Average age varies with the research discipline, but overall it is 37-38 years (Kyvik and Olsen, 2009:28-32, Kyvik and Olsen 2007:18). Those who do not manage to finish their doctoral degree have acquired valuable research competence, which may be used at the labour market. Still, it is a political goal to increase submission rates as well as completion time and as more candidates complete their degree, it is becoming more attractive to finish the degree.

Since more doctoral graduates are expected to find work outside the academe in the future due to the growing number of doctoral candidates, career counselling has gained importance. However, studies show that only a few have received information and guidance from their institutions about different career opportunities within research (Thune and Olsen, 2009:52, Kyvik and Olsen, 2007:26). As a consequence, UHR has introduced a new recommendation in their guidelines for Ph.D. educations (2011). The guidelines demand the institution to give the Ph.D. student advice about future career possibilities within and outside academia and to make the candidate aware of the skills and competences he/she has acquired through the Ph.D. education (UHR, 2011:6). The UHR guidelines are recommendations for the HEIs own guidelines on the Ph.D. education and it is expected that HEIs establish career counselling for Ph.D. students.

Taking into account that there is a deficit of doctoral competence, it is crucial to invest in human capital in order to reach balance between demand and offer of doctoral competence. Still, Norwegian labour market is expected to lack competence at all levels and in many fields in near future and the costs of engaging a high number of candidates in doctoral education are thus high. The Ministry of Research and UHR recommend a slow and steady growth in the number of Ph.D. positions in Norway towards 2020. Highest growth is needed within the technology with 185-235 new positions annually. Lowest growth is estimated in humanities with only 3 new positions a year (The Ministry of Research and Education and the Norwegian Association of Higher Education Institutions, 2012:45).

2.3 Funding of doctoral education

As seen, doctoral education requires high investments. Doctoral education is financed through the higher education institutions´ budget, covering 38 % of the doctoral production. 62 % come from external sources as the Research Council of Norway (RCN) funding schemes, through special schemes as the “Quota-program”, which provide grants to students from the South, through funding from private sector and through funding from public employers, like health institutions (NOU:6, 121-122, Kyvik and Olsen, 2007:18). In 2001 doctoral students changed status from students to employers in Norway and the level of funding for a Ph.D. position is comparable to an ordinary public salary. Candidates enjoy the rights and duties of ordinary employees in line with The Working Environment Act (Thune and Olsen, 2009: 39, Report of mapping exercise on doctoral training in Europe, 2011:2).

As Norwegian research policy will contribute to a knowledge based industry throughout the country, several funding mechanisms through the RCN and Innovation Norway are designed to support research-based industry and to facilitate industry-academia partnerships. Many of these schemes also include funding of Ph.D. positions. User-driven Research based Innovation (BIA) is a large-scale program, where companies may apply for partial funding of

R&D projects which are based on their own strategies and challenges, regardless of branch of industry or thematic area. Centers for Research-based Innovation (SFI) enhance the capability of the business sector to innovate by focusing on long-term research based on forging close alliances between research-intensive enterprises and prominent research groups. By 2012, 21 centers have been established. Program for Regional R&D and Innovation (VRI) is yet another mechanism to encourage innovation, knowledge development, and added value through regional cooperation and a strengthened research and development effort within and for the regions. These funding schemes also involve funding of Ph.D. positions (Research Council of Norway, 2012 [URL] 24.02).

In contrast to many other countries in Europe and worldwide, Norway has not established professional doctorates or collaborative programs to a large extent. Professional doctorates are established to address gaps between the skills and knowledge that have conventionally been associated with doctoral education and what is presently required by industries and employers in knowledge economies. An exception in the Norwegian context is the Industrial Ph.D. Scheme provided by the RCN since 2008. The industrial Ph.D. leads to an ordinary Ph.D. degree in line with the Bologna process, but the candidates are employed in firms and partly financed by the firms during their doctoral education. Around 120 candidates are currently enrolled in the industrial Ph.D. scheme (Research Council of Norway, 2012 [URL] 24.02).

Another measure taken at national level is the establishment of National Research Schools in 2008/2009 as a superstructure of different activities included in doctoral training. The scheme does not cover expenses connected to Ph.D. positions, but provides incentives to connect research groups through national networks and secure participation in international and Nordic research networks. Other research schools have been established through other funding schemes and have resulted in several inter-sectorial relationships (Research Council of Norway, 2011d:15).

A couple of recent publications suggest funding mechanisms that provide incentives to cross-sectorial collaboration on Ph.D. education. Combined positions, Professor II, in academia and research institutes with focus on doctoral education, will facilitate students´ access to competences from both sectors. Additional funding for such positions is recommended, although it is also possible to realize within existing frames. National research schools where independent research institutes are invited as partner is another suggestion and the performance based part of the financial system of both sectors should be reviewed to see how it provides incentives for cross-sectorial collaboration (Research Council of Norway, 2011c: 30). Yet another suggestion is to establish a “partnership Ph.D. for public sector”, following the same model as the industrial Ph.D. Public sector and universities will thus collaborate on doctoral educations. This is especially relevant within in health professions (The Ministry of Research and Education and the Norwegian Association of Higher Education Institutions, 2012: 47).

Industry also supports doctoral education, like VISTA, a basic research programme funded by Statoil. VISTA was established to promote the cooperation between Statoil and academia in Norway and to strengthen the capacity and quality of science in areas of particular interest in the oil and gas industry. The program supports around 25 students (VISTA 2012 [URL] 03.04).

2.4 Norwegian research-performing institutions

Norway has three research-performing sectors: the higher education sector, the independent research institutes and the business enterprise sector. Approximately 23 % of R&D activity is carried out by the higher education sector. These organisations fund R&D mainly through ordinary budgets, but obtain additional funding for programs and equipment, mainly from the Research Council. Another 25 % of R&D activity is done by independent research institutes, which are formally outside the education system. Historically, these research institutes were established in the Post World War II period as a complement to the universities and were intended to focus on developing specific kinds of knowledge. Many of these organisations began in the public sector as public R&D effort was set up to gain industry as a mean to achieve research-driven growth. Later they became private foundations although most continue to depend on public funding (Research Council of Norway, 2011d:8). Through the years, staff at both universities and research institutes has however engaged in common projects or even in teaching, so boundaries have not been absolute. Also business enterprises find partners at the institutes and the institutes have thus played an important role as a link between the different sectors. These collaborations have developed into heterogeneous links and partnerships today (Gulbrandsen and Nerdrum, in Fagerberg et al, 2009:66-78).

Finally, the business enterprise sector carries out almost 52 % of Norwegian R&D activity. Traditional industrial activities related to the extraction of raw materials and natural resources as petroleum and natural gas, fish and wood, as well as industrial processing make up a large share of the Norwegian economy (Research Council of Norway, 2011d:8). There are three distinct layers of enterprises; one with small scale enterprises operating with little knowledge accumulation, one with large scale enterprises that are knowledge intensive and rely on collaborative learning, and a third one with small R&D intensive enterprises that rely on collaborative learning with other enterprises and research organisations and likely to operate within global innovation networks. These different layers may not be unique to Norway, but this diversity intersects with a specific economic specialisation that is related to natural resources (Wicken in in Fagerberg et al, 2009:33-60). Industries related to raw material and natural resources are however less R&D intensive than industries such as pharmaceuticals and ICT and it is a goal to increase R&D activities in nature based industries.

Government-funded R&D stood at 0.83 % of GDP in 2009, compared to 0.96 for R&D funded by industry, from abroad and from other sources (Research Council of Norway, 2011d: 43). This is still behind the political goal of inverting 3 % of GDP in R&D activities, where government would stand at 1 % and industry 2 %. It is thus a clear intention to increase R&D activities especially in industry. The level of national investments in R&D is lower than desired, but annual growth has increased more in many Norwegian companies compared to the world average during the last years of general economic decline globally. The EU-Commission´ s report on investments in research for the 1000 most R&D intensive companies in the world includes 8 Norwegian companies. StatoilHydro, Telenor and Orkla are among the 300 most R&D intensive companies in the 2007 statistics. Norsk Hydro, the Kongsberg Group, DnBNOR, Eltek and Tandberg are also represented (White Paper nr. 7 (2008-2009), *Et nyskapende og bærekraftig Norge,* p. 105-106).

The forthcoming White paper on research in 2013 is expected to set out new measures to increase R&D activities in all research-performing sectors as well as public sector. Research policy should be designed in light of the knowledge-triangle which is central in the EU Horizon2020 and which requires connection between education, research and innovation. The knowledge-triangle model provides however challenges, as the education system must adapt to intellectual, industrial and societal needs. Mobility and knowledge transfer between sectors must be secured and processes between innovation and research, as well as between research and innovation must be more efficient. This calls for a research system that delivers relevant knowledge to industry, public sector and to knowledge based education (Research Council of Norway, 2011d).

As seen in this chapter, Norwegian doctoral education has undertaken several developments the last decade. Diversity is an important mean to enhance quality in doctoral education, which no longer produces candidates to solely fulfil academic positions, but in a wide range of positions across sectors. The academe´ s collaboration with other sectors in doctoral education is thus an important mean to create a good and diverse learning environment. Doctoral students themselves are strategically means to institutions as they are seen to be central in knowledge production and knowledge transfer between sectors, as well as important for maintaining networks. The function of the Ph.D. degree and the role of the doctoral student consist of being resources to produce new research, being the next generation of researchers and of being the output from the environment in which they operate. This will be discussed in more details in chapter 5. Funding system of the doctoral education, type of contract between the student and the supervising institution, training-job transition and career paths are aspects that are determined by these collaborative relations and that vary across countries (Lanciano-Morandat and Nohara in Lorenz and Lundvall, 2006:306-307).

The next chapter looks into how innovation systems determine how economies learn and will thus take up many factors that impact the organisation of doctoral education as well as the output from this education.

3.0 Theoretical framework

Skills acquisition and learning outcome is closely linked to the individual at the step to macro level and the knowledge-based economy may seem long. Still, individual skills and competences are central input in innovation processes. The innovation literature provides a structure and an analytical framework for this purpose. I thus lend perspectives on innovation systems, innovation and learning strategies and types of knowledge and their relation to the education system and labour market. I draw on insight provided by Lorenz and Lundvall (2006) on how economies learn and how innovation systems determine innovation capabilities, applying a systemic perspective on innovation. Other contributions are Jensen et al (2007) presenting two ideal models of learning and innovation and Gulbrandsen et al (2008) who use human capital theory, innovation theory and social theory to set up assumptions about competence investments in a Norwegian context.

With these perspectives as a background, I outline three assumptions about learning outcomes from doctoral education in industry-academia collaboration, with focus on skills and skills acquisition.

3.1. National innovation systems

Lorenz and Lundvall (2006) examine how European economies learn, referring to the vision of creating a European Research Area (ERA). A central notion in the ERA initiatives is that Europe will not be able to compete on relative cost advantages as the cost gap to China, India and other countries is too big, especially when it comes to wages. Instead, competitiveness is linked to dynamic efficiency, the knowledge base and to the innovation system. Europe is presented as one economy in policy contexts, but Lundvall and Lorenz (2006) emphasize the importance of understanding the fundamental differences in European economies and that attention should be paid to the national innovations system (NIS) to explain the learning economy. The learning economy refers to a situation where big shares of the labour force participate in frequent learning and forgetting processes as some knowledge become obsolete and new competence is required to solve new problems. NIS can be understood as central factors within national boundaries that have an impact on innovation processes. Economic, social, political, organisational and institutional conditions and the relationship between them determine firms´ and organisation´s ability to innovate. Literature also includes regional innovation systems (RIS) and sectorial innovation systems (SIS). NIS has developed along two different traditions, with Nelson´ s comparative cases studies across countries and with Lundvall´s focus on user-producer-relations and interactive learning. Lorenz and Lundvall apply an even broader understanding of NIS that also addresses institutions´ competence building in the economy. This includes firm´s work training and competence investments, as well as formal education and training systems, labour markets and their relation to corporate governance.

Lorenz and Lundvall indicate that there is a strong relationship between learning and innovation. Implicit here, is that the capability to innovate depends on individuals´ ability to learn and develop new competences. Innovation systems are thus systems for innovation, production and competence building (Gulbrandsen et al 2008:33). How economies learn is especially determined by transformation pressure, capabilities to innovate and how the national innovation system redistributes costs and benefits emanating from changes (Lorenz and Lundvall, 2006:1-8).

Transformation pressure denotes that there is an external pressure throughout society due to international competition that leads to people often changes jobs and positions, and that new firms are established or closed down with frequency, depending on the *capability to innovate* and adapt to changing circumstances. Innovation is normally understood as product and process innovation. Product innovations are new or better material goods as well as tangible services. Process innovations are new ways of producing technological or organisational products and services (Edquist, 2005 cited by Fagerberg et al, 2005:182). The capability to innovate is modified by how the national innovation system responds to the transmission processes, for instance how easy it is to establish interactive learning across organisational boundaries, or how risk can be tackled in entrepreneurship. *Costs and benefits that stem from the changes* are distributed differently in different countries and affect the ability to innovate. High costs tend to inhibit innovation as it creates a negative attitude to change. A too even redistribution can, on the other can, demotivate entrepreneurships as there are few incentives. Increased innovative capacity normally encourages entrepreneurship and flexible organisations, which means change oriented people and institutions.

Central here, is that differences in transformation pressure and the redistribution of costs and benefits that stem from changes explain differences in countries´ ability to innovate. However, it does not make sense to identify best practise examples, because the characteristics of society in each country are results of long, historical developments. The Norwegian national innovation system follows at *Nordic collaborative model* that can be characterised by social equality, extensive interaction between firms and public research institutions and market coordination. The model encourages especially incremental innovations and to a lesser extent radical innovation. High degree of confidence and social capital will, on the other hand, tend to foster individual learning, competence development and personal career development as well as knowledge transfer through a highly mobile work force. Extensive networking and relations between firms and institutions also disseminate knowledge. At the same time, the Norwegian system is consensus oriented and a tendency to join forces towards common goals, which likely lead to incremental innovation and perform relatively good because competence is built in a big share of the work force (Gulbrandsen et al, 2008:42-47). With the characteristics of the Norwegian innovation system in mind, one would expect doctoral training to be focused on the development of the individual, based on the individuals´ ambitions, training needs and career prospects. Ph.D. education would accordingly be highly adaptable to the individual needs.

The capability to innovate also depends on knowledge and the ability to identify exploit and absorb new knowledge. Different types of knowledge may lead to different kinds of innovation – either radical or incremental. Differences in knowledge and innovation can again be related to differences in labour market and education and training system. The following will take a closer look at knowledge as a concept, before it is linked to education system and labour market.

3.2 Knowledge

Literature often presents thinking of knowledge as a dichotomy. Knowledge can be explicit or implicit, local or global, individual or collective. Explicit knowledge is available through written material, lectures, and media and has global character. It consists of facts and artefacts, the so called know-what and know-why knowledge. Implicit knowledge, on the other hand, is tacit and local in character. This knowledge is acquired through experience and social practise, in other words, know-how and know-who knowledge.

A central contribution to the understanding knowledge and innovation is Jensen et al (2007) who present two ideal types of learning and innovation. Codified scientific and technological knowledge characterise the Science, Technology and Innovation (STI) mode, while learning by doing, using and interaction is included in the Doing, Using and Interacting (DUI) mode. Organisations that combine the STI mode with the DUI mode are the most innovative and this draws attention to the grey zone between the divisions of knowledge (680).

Learning the four types of knowledge, know-what, know-why, know-how and know-who, takes place in different ways and through different channels. The STI mode focuses on know-what and know-why, where important aspects can be acquired through written material. Specialised know-what is normally a requirement in science. The DUI-mode includes know-how and know-who. Know-how relates to high skilled workers, who practise in a given field. Know-who involves relationship and communication with peers at conferences, fieldwork and teamwork as well as dealing with customers, subcontractors or other external partners. Through know-who codes of information and social bounds develop (682). Jensen et al (2007) argue that science and technology involve all types of knowledge, but the STI-mode has been dominant in technological development. Technology consists of practice – how it is produced and used, and an understanding that supports and rationalises the technology itself. Science does not normally influence technological advancement directly, but provides a general understanding and a point of departure for further development. Know-why is therefore incorporated in technology. Still, know-why cannot fully explain practise and that is why the DUI mode is crucial for success. Practise is experienced through working in the field with the ever on-going changes and new problems that have to be faced. The workers acquire generic and specific know-how skills through this process. Learning by doing and using normally also implies working together with colleagues, partners and possibly customers, which also develop know-who knowledge. Collaboration facilitates the transition of local and tacit knowledge (683-684).

There is a tension between the STI and DUI modes both at the micro and macro level in the economy since there is a need to codify and produce explicit knowledge in formal R&D processes, while at the same time encourage learning from informal interaction within and between organisations to build competence. It is thus a knowledge management task to make strong version of the two modes to work together in order to get the most out of knowledge creation and innovation (Jensen et al, 2007: 689). Empirical findings suggest that firms are characterised either by STI or DUI learning strategies, although many firms also combine the two strategies. As mentioned, firms that combine the two strategies are the most innovative.

Increased attention is paid to DUI learning and innovation strategies, as know-how and know who knowledge is largely embodied in employees and thus beyond the firms reach when employees move (Lorenz and Lundvall, 2006). Since the DUI mode is central in innovation processes, appropriate DUI mode indicators should be developed to better describe innovation processes and R&D policy objectives and priorities should take the DUI mode into account (Jensen et al, 2007: 689).

The STI mode and the DUI mode of learning and innovation are competing, but at the same time supplementary models to explain how different types of knowledge apply to innovation processes. The four types of knowledge should be acquired by individuals and fostered in different ways through different channels. Research implies all types of knowledge and we could therefore assume that doctoral education intends to develop all types. The STI mode of learning will be an integrated part of the students´ research and dissertation. Because it is explicit and codified, it can more easily be identified and evaluated than the DUI mode. The DUI mode will vary according to how and with whom research is carried out in social practise. We would therefore expect that know-how and know-who knowledge is dependent on the research environment and the networks the students have access to. We would also expect that heterogeneous networks facilitates DUI mode learning as the students will get richer input and get socialised into different environments. Students in industry-academia relations would thus potentially access diverse research environments. Still, we can expect this to be modified with the level of integration, interaction and cooperation within the research environments.

Another central contribution comes from Lam and Lundvall, who see education systems and labour markets as key societal institutions that shape the learning capabilities and knowledge creation in firms. Knowledge at firm level can be placed along two axes; the collective and explicit versus the individual and tacit, which give taxonomy of four knowledge types that will be more or less developed in all organisations. *Embodied knowledge* is characterised of individual and tacit knowledge, which is normally acquired through practise and experience. *Embrained knowledge* is individual and explicit, depends on the individual skills and cognitive abilities and is learnt through formal education. *Encoded knowledge* is collective and explicit and shared through formal information systems in the organisation. *Embedded knowledge* is collective and tacit and built into norms, routines and habits.

Differences between organisation´s ability to develop tacit knowledge, result in different capabilities to learn and innovate. Lam and Lundvall have developed a four ways taxonomy of organisations connected to the four types of knowledge. *Professional bureaucracy* based on individual and explicit knowledge refers to highly specialised individual carrying out highly specialised tasks. Precision can be necessary in many situations, but generally professional bureaucracy will lead to a narrow focus on learning and thus limited innovation. *Machine bureaucracy* is based on collective and explicit knowledge and characterised by standardisation and control, typically required in mass production. Tacit knowledge is not fostered in this environment and as a consequence, innovation is limited. *Operating adhocracy* has an individual and tacit knowledge base and draws on individual know-how and experience in problem solving, with few control and standardisation mechanisms. This gives an explorative environment that allows individuals to accumulate knowledge, use a mix of different competences and to work autonomously and in interaction with others to solve problems, which is likely to lead to radical innovations. Finally, J-form organisations have a collective and implicit knowledge base and are characterised by shared values and an organisational culture that encourage systematically interaction across function. This leads to a stable environment and to learning by doing strategies, which normally results in incremental innovation (Lam and Lundvall in Lorenz and Lundvall, 2006:118-120).

3.3 Knowledge, education systems and labour market

Lam and Lundvall (Lorenz and Lundvall, 2006) connect firms learning strategies and abilities to innovate to differences in education systems and labour markets. Education systems provide the foundation for skills and qualifications to the labour market and have thus big influence on status of different kinds of knowledge. Labour market provides societal frameworks where knowledge can be applied in practise and incentives for knowledge to develop. Learning and innovation can thus be seen as results and mutually shaped by interdependence between different institutions in a national innovation system. Lam and Lundvall also introduce a typology of education systems and labour markets, focused on knowledge and learning. Education systems can either be narrow *professional oriented* or broad *competence based.* A competence based educations system recognizes both theoretical and practical knowledge and provides a knowledge base to a wide range of occupations in the labour market. Competence is evenly distributed among the workforce, which gives a good point of departure for interactive learning and creation of tacit knowledge. Narrow professional oriented education systems focus on formal academic knowledge and professional control with the training programs. Competence is often spread to elite, while the majority remains untrained. Knowledge is narrow and expertise highly specialised in this system. Labour markets determine individuals´ careers, career mobility and whether firms´ learning capabilities take place outside or inside the firm. An *occupational labour market* (OLM) is characterised by a mobile work force, while an *internal labour market* (ILM) have stable employment. In an Occupational labour markets knowledge and skills derived from formal education can either be applied as specific qualifications in professions and highly specialised tasks or more broadly across various settings. The individual is the owner of the knowledge and transfer of tacit knowledge relies on social networks and interactive practise. Specialised and explicit knowledge, on the other hand, can be codified. Learning in OLM is centred on the individual career and oriented towards the market. To understand how individuals learn is thus important. The internal labour market is characterised by stable employment with a single employer and career advancement is through the internal hierarchy of the firm. Formal education serves as an entry to the firm and work related skills are trained particularly in work settings. Long-term accumulation of firm-specific skills leads to advancement. Learning in ILM is therefore organisational oriented and develops together with the firm. Distinctive core competences are likely to develop in this environment, which may lead to incremental innovations.

Connecting the four types of knowledge to education systems and labour markets gives other four ways taxonomy; a Professional model, an Occupational community model, a Bureaucratic model and an Organisational community model. Professional adhocracy, i.e. radical innovation, tends to emerge from broad competence based educations systems and an occupational labour market – the Occupational community model. Mobility between firms, especially within a region as Silicon Valley, creates social professional networks, which allows transfer of tacit knowledge and thus bigger possibilities to innovate. The Organisational community model stems from a broad competence based education system, but an internal labour market. Firm specific knowledge and training develop core competences to carry out incremental innovation. Japan is an example of a country that applies the organisational community model. The Professional model is characterised by specialised and academic training, where practise as low status. Codified knowledge is of high importance and individuals move between different employers. Learning is narrow and takes place mainly between those that have a knowledge base already. Anglo-American countries are said to follow this model. The bureaucratic model has normally stable hierarchies connected to formal training and access to codified knowledge, where careers take place inside the firm. Tacit knowledge is struggled to be codified to reach competitive advantage through standardisations and price-based competition (Lam and Lundvall in Lorenz and Lundvall, 2006: 121-126).

Lam and Lundvall´ s four way dichotomy gives a clear overview of the different educational-occupational models. It can however be somewhat rigid when applied in real life. Concerning Norway, we would expect the Norwegian education system to be characterised as a broad competence based system, where students learn how to go about processes rather than learning facts. Labour market on the other hand would probably be placed towards an internal labour market with a rather stable workforce. Norway is not well-known for radical innovations, does not get a high score on innovation indicators and has few multinational companies. Still, Norwegian economy is performing rather well. Scholars trying to explain this "Norwegian paradox" draw attention to, among other factors, social equality, social networks, high degree of confidence and social capital and a generally high focus on competence building through R&D support structures to specific industries, (for example fishery, oil and gas), through the formal education system and through heterogeneous networks between firms, R&D institutions and public research organisations (Gulbrandsen et al, 2008:35). This should mean that although the Norwegian workforce may not be very mobile, there are other mechanisms, as network and interaction across sectors that disseminate new knowledge.

The Triple-Helix model challenges the ideal types in Lam and Lundvall´ s model. Since industry and academia tend to take each other roles in the knowledge production process and to work towards common goal of innovation, Lanciano-Morandat and Nohara point out that this hybridisation creates a new intermediate labour market divided into three segments for doctoral holders. *The hybrid occupational segment* allows researchers to circulate on temporary or permanent basis between the two sectors through the collaborative networks. Professor II (20 % part-time professorship) will gain as example. *The learning segment* can be described as the contribution from doctoral students´ enrolled in joint academia-industry programs or projects. The industrial Ph.D. is an example here, where the students normally achieve a position within the firm after their degree. *The transitional segment* between academic and industrial spheres is characterised by creation of new services or products which contribute to commercial activities. University spin-offs are typical examples. Another example is temporary employment of doctoral holders in firms, in order to carry out specific R&D related projects (Lanciano-Morandat and Nohara in Lorenz and Lundvall, 2006:281-284). Increased interaction between industry and academia is also a way for the partners involved to access human resources, expertise and competences required to generate new ideas and innovations. This is all shaped by national institutions governing the university-industry-government relations. The industry-academia innovation space, the intermediate labour market, is in this sense a result of societal practises and the mechanisms regulating this space should be seen in this social context. Networks, which play a key role in these relations, will therefore have different characteristics depending on the context (Lanciano-Morandat and Nohara in Lorenz and Lundvall, 2006).

3.4 Assumptions

The innovation literature points out conditions related to national innovation system, education system and labour market that determine how individuals learn and use their knowledge. Using the Norwegian context as a background, assumptions on learning outcomes in doctoral education can be set up. As seen, Norway is characterised of high degree of confidence and social capital in combination with extensive networking and relations between institutions. This tends to foster individual learning, competence development and personal career development as well as knowledge transfer between organisations. The Norwegian educational system is competence based, which means that learning about practises is as well as important as facts. This should mean that Norwegian doctoral education can be adapted to each individual´s training needs, ambitions and career prospect. The four types of knowledge, know-what, know-why, know-how and know-why, are embedded in research and we could therefore assume that doctoral education intends to develop all types. This knowledge should be acquired by individuals and fostered in different ways through different channels. The STI mode of learning will be an integrated part of the students´ research and dissertation. This is explicit knowledge, which probably will be related to research specific skills as specific and general knowledge about a certain area of study or discipline as well as knowledge about research methodology applying to that field of study.

Since this know-what and know-why knowledge is explicit and it is normally also formally evaluated through the doctoral thesis before obtaining the Ph.D. degree, doctoral students will probably easily identify and be able to report on skills and learning outcome related to this knowledge.

The DUI mode knowledge will assumingly be harder to identify as this knowledge is implicit and will vary according to practises and networks. Taking part in social interactions, through research groups, networks, and supervision or similar facilitates DUI mode learning, but is surely modified by the level of integration, interaction and cooperation among the people involved. Students in industry-academia relations would potentially access diverse environments and take part in diverse social practises, which would foster know-how and know-why knowledge. This knowledge would typically include generic skills as management, teamwork, self-management, lateral thinking and problem solving. Still, skills acquired through practise and experience is tacit and embodied knowledge and may be difficult to identify.

This leads to the second assumption. Students in industry-academia collaborations will probably develop know-how and know-why knowledge because they are socialised into different research environments. They acquire generic skills and apply research specific skills in new contexts in industry.

New career paths and mobility opportunities between sectors for doctoral holders emerge as contact surfaces between institutions broaden. We may see an increased use of combined positions, where researchers have for instance 80 – 20 % positions in industry- academia, just as the Norwegian Professor II positions. There may also be increased commercial activity as spin-offs. Several universities have connections to Technology Transfer Offices (TTOs), which build bridges between excellent research and technology based industry. Researchers have the opportunity to find employment in this intermediate sphere. We would expect doctoral students in industry-academia collaborations to pursue a career in the intermediate labour market.

Collaborative students will probably get an understanding of different priorities and ways of working in different research environments as well as broader employability perspectives. This will assumingly have impact on their career destinations.

4.0 Methods and research design

The question on doctoral students´ perception of their learning outcome from doctoral education carried out in academia-industry collaborations with focus on skills and skills acquisition is explored in two ways; through a review of existing research and through a questionnaire. This chapter describes the research design used and discusses some of the methodological implications, as well as reliability and validity of the study.

4.1 Choice of research design and methods

The research design and methodology should match the research question as close as possible since different questions require different methods to answer them (Punch, 2005:19). The aim of this thesis is to give a description of learning outcomes in terms of skills and skills acquisition in doctoral education, particularly from education in collaborative relationships, and discuss possible implications. The research question could thus be answered in several ways, through qualitative methods, as in-depth interviews or focus groups, or quantitative approaches as statistical analysis of data obtained through surveys. I chose a non-experimental quantitative study in combination with a literature review. To my knowledge, literature reviews on skills and skills acquisition in doctoral education has not been previously carried out. The aim was thus to shed light upon what knowledge we may extract from existing research on this topic and to identify possible gaps. The literature review also served to identify categories and to operationalize the variables *learning outcome, skills and skills acquisition*. In this way, I had a pre-specified research question, some pre-structured data and a rather structured design beforehand. According to Punch (2005), quantitative research is the most suitable in this situation (23) as qualitative approaches are better matched with more general guiding questions and loose structure. There is however a continuum between the prescribed designs and unfolding research. Punch also presents two main strands for quantitative research. Experimental and quasi-experimental designs are commonly used when exploring effects of certain causes and when comparing groups along a dependent variable of interest. Non-experimental designs or correlational surveys on the other hand look at causes of effects and mainly the relationship between variables. Simple and multiple correlations as well simple and multiple regressions are relevant statistical analyses for this type of study (122-123).

The empirical part of this study is thus a non-experimental correlational survey, which explores the relationship between learning outcome and collaborative relations as well as some demographic and professional variables.

4.2 Literature review

To find existing research on learning outcomes in doctoral education carried out in industry-academia collaborations, I have used several electronic databases. I have made searches based on different combinations of relevant key words in Taylor and Francis online, ScienceDirect, SpringerLink, JSTOR, ISI Web of Knowledge, Scopus, CRIStin and Nora. The key words included different combinations of “research”, “learning outcomes”, “Ph.D.”, “doctorate”, “industry-academia”, “Triple-Helix”, “skills”, “generic” and “transferable”, depending on each of the databases. I basically, looked for peer reviewed articles, written in English, from the period 2001-2011. I mainly searched for research on doctoral training in industry-academia relations, especially related to skills and skills acquisition. I also had a set of inclusion criteria as well as exclusion criteria. Common inclusion criteria for all searches were articles dealing with doctoral education and skills and learning outcomes as well as doctoral education and industry-academia collaborations. General exclusion criteria were articles not mentioning doctoral education, for instance those dealing with specific disciplines, as nursing or health sciences, articles speaking of industry-academia relations in general, undergraduate studies, lifelong learning and specific pedagogical techniques that were not particularly relevant for doctoral education. Below, a detailed description of the different databases and searches is presented.

ScienceDirect

First search had “industrial phd” and “skills” as key words and was limited to journal articles 2001-2012. 3978 articles were displayed. Sorted by relevancy, I read the abstracts of a few of the first articles, but found the search quite misleading. The second search included “industrial phd”, “doctorate”, “skills” and “learning outcome”, but this also gave many irrelevant hits. I tried different combination of these key words and I finally ended up with “industry-academia collaboration”, “doctorate”, “skills” and “outcome” limited to journal articles 2001-2011 and excluding topics and journals related to nursing/health. This search displayed 62 articles. Articles on skills, skills acquisition and career trajectories were included. Articles dealing with industry-academia relations without taking up doctoral education were excluded. So were articles on specific disciplines as health professions.

Taylor and Francis online

Taylor and Francis online proved to contain many relevant articles. I started out with the key words “industrial phd” and “skills” and limited to journal articles 2001-2011, which gave 4580 hits. The next intent was to narrow down the search limiting to only full access articles in education and social sciences in Routledge and Taylor and Francis. This gave 118 hits and I realised that many of the articles were relevant. In the literature review, I included those articles that somehow dealt with doctoral education in industry-academia collaborations and those that dealt with doctoral education and skills. Subjects as lifelong learning, undergraduate studies, and industry-academia relations in general without including doctoral education as well as specific disciplines without mentioning doctoral education, were left out.

JSTOR

I started with the key words “industrial doctorate” and “skills” for journal articles 2001-2011, which gave 466 hits. A first glance on some of the abstracts showed that the result was mixed concerning relevancy. I limited the search to the category *education* and added “outcome” to the key word list. This search displayed 35 articles, many of them related to gender, ethnicity and sustainable growth in the South as well as undergraduate studies and lifelong learning, which I excluded. I ended up with one article only from this search.

ISI Web of Knowledge

I tried with the key words TS=(industrial phd, skills), also in this database and limited the search to English speaking articles 2001-2011. That displayed only 2 articles. The second search was based on the key words TS=(doctorate, skills) and limited to education *educational research, education scientific disciplines* which gave 11 hits. I included the articles dealing with doctoral education, skills and its relationship to industry.

SpringerLink

“Doctorate”, “triple-helix and “learning outcomes” were used as key words, limiting the search to English speaking articles 2001-2011. 15 articles were displayed and once again reading the abstracts, I excluded the articles speaking of industry-academia relations in general, patenting, public engagement in research. Articles on doctoral education were included.

Scopus

In Scopus I tried different combinations of “industrial phd”, “skills”, “doctorate”, “and industry-academia”. I ended up with “industry-academia” and “phd”, limiting the search to English speaking articles 2001-2011. 15 articles were displayed and by reading the abstracts I excluded those I did not have electronically full access to (4 articles), those dealing with nursing/health professions.

Nora

Key words that did not display any articles were “industrial phd”, industry-academia” and “skills”. “phd” displayed more than 100 hits, which all were doctoral theses, but they did not necessarily take up my topic. However, “doctorate” gave 5 hits. Three of them were doctoral theses and were displayed out of that reason. Two other articles dealt with an alternative career track, «førstelektor» , which can be seen as a professional doctorate. Still, I found them to be out of the scope of my literature review, which focuses on doctoral education in industry-academia relations, skills and skills acquisition.

CRIStin

In CRIStin I tried various single key words, as “doctorate”, “phd”, “industry-academia”, “skills” and “learning outcome”, but no hits were displayed. I thus concluded that CRIStin does not contain relevant material.

NIFU

Beforehand, I knew that relevant literature on doctoral training in Norway could also be found on the Nordic Institute for Studies in Innovation, Research and Education (NIFU) web-site, www.nifu.no. I browsed the website and included all five reports I could find on this topic in my literature review.

Borell-Damian et al. (2010) is a widely cited article and I made single searches on "Borrell-Damian" in some of the databases, inclusive Google Scholars, which resulted in a couple of relevant hits. Among others several Australian articles already identified on Taylor and Francis online, but also some other perspectives from the Belgian context from Ghent University. The Belgian articles are thus also included in the literature review.

All in all, I included 46 articles from the literature search. A summary of the findings can be found in Annex 2, table 1 and 2.

4.2.1 Discussion

The way the literature search is set up impacts the output. The searches are constrained of the set of inclusion and exclusion criteria used, as well as the chosen key words. The rationale behind the inclusion criteria on English speaking articles is mainly due to accessibility, both when it comes to language matters and availability of articles through databases. English is used in international research publications and will thus capture relevant and recognised literature. The period 2001-2011 (present) was chosen to cover the development of doctoral education, including the reforms, that have taken place the last decade and to cover the debate on skills and generic skills, which also have been going on during the same period. Frameworks of learning outcomes, presented in Attachment 1, table 1: Specific and transferable skills, guided the choice of key words. I ended up using the words that seemed to give the most relevant hits, after testing several words by the "try-and-fail" approach in different databases.

The research question guided the exclusion criteria. Based on the abstracts, I excluded all articles that I assumed would not shed light upon my research question. There were several grey zones, for instance on skills in specific disciplines or on the organisation of doctoral education in professions, as nursing or physiotherapy. I decided to leave these contributions out because they lacked connection to industry-academia perspectives. On the other hand, I did include articles that theoretically discussed skills acquisition in doctoral education, as I believe they provide insight in learning and learning outcomes independently from the context the doctoral students operate in. Specific pedagogical techniques were however out of the scope. There were also several contributions that took up skills and learning outcomes at bachelor and master level as well as career destinations and industry-readiness of these candidates. These articles could possibly have provided useful perspectives, but since doctoral education is the scope of my thesis, I also left these contributions out.

I have not assessed quality of the articles included in the review. I have chosen peer reviewed articles from recognised journals, which should mean they have already gone through an extensive evaluation process and I thus consider this issue to be safeguarded.

When it comes to the choice of databases, I went for those mentioned above after a discussion with the library consultancy at the University of Oslo. These databases should be adequate for social sciences. I also considered ERIC, but it proved to contain very little of interest, so I decided not to spend much time on it. Instead, I paid more attention to the Norwegian sources, Nora, CRIStin and NIFU since the chance to find research related to the Norwegian context was obviously higher here than in the other databases. However, as stated above, only NIFU did provide relevant studies.

Applying the methodology described here, I have certainly also missed relevant research. First of all, I have not been able to include forefront research that is not yet available through databases and journals. I have not been to conferences, where I possibly could have known the latest developments. Secondly, due to time constraints, I stopped searching for articles at a point where I seemed to have found the most central contributions. That means there could still be some more relevant articles to include.

When it comes to the findings, these will be presented and discussed extensively in chapter 5. I have grouped the articles into theoretical contributions and empirical studies centred around four topics; 1) skills acquisitions, 2) industry-academia collaboration´ s impact on students´ learning outcome, 3) student´s perception of learning outcomes and 4) doctoral students´ career destinations. I assumed there was little research done on skills and skills acquisition among doctoral students in industry-academia collaborations. This also proved to be the case, although some studies touch upon this topic. In order to shed further light on the question a short questionnaire was sent out as a self-assessment to current Ph.D. students. Findings from the literature review were used to design the questionnaire, as presented in the following section.

4.3 Collection of empirical data

Surveys and questionnaires are common ways to collect data on learning outcomes. There are several standardised measure instruments, like the British Collegiate Learning Assessment (CLA) and the American National Survey of Student Engagement (NSSE) for undergraduate studies. In Norway StudData is widely used for the same purpose (Karlsen, 2011:10-12). There is naturally much development work embedded in existing measure instruments, which make them solid and most likely more reliable. However, I have not come across measure instruments adapted to doctoral education. A nearby solution was thus to construct an own instrument in the format of a self-assessment questionnaire. There are several methodological challenges about self-assessments, which will be discussed below. First, I will elaborate on measure techniques.

4.3.1 Measuring learning outcomes

Measurements can be seen as the process of using numbers to link concepts to indicators when a continuum is involved. There is thus a distinction between categorical variables, which vary in kind, and continuous variables, which vary in degree (Punch, 2005:86-87). Measurement involves identification of the concept to be measured; secondly to find an adequate indicator to measure the concept and lastly to obtain empirical information based on the indicators. The characteristics to be measured are normally not directly observable and must be inferred from what can be observed, and the indicators serve for this purpose. The indicator is used to infer the degree of which the trait is present. The traits and the related indicators must thus be identified and the more indicators, the better inferences can be made. Responses to the multiple items should then be summed making sure that the responses added up measure the same aspects. When it comes to measure techniques, Likert´ s summated rating procedure is the most common, whereby respondents answer to each item according to a simple response scale and the responses to each item are then summed (Punch, 2005:90-91).

To measure learning outcomes in general and transferable skills in particular, in higher education is challenging. Challenges are discussed in psychometrics - a field of study concerned with the theory and technique of psychological measurement, which includes the measurement of knowledge, abilities, attitudes and educational measurement. Psychometrics looks especially into the construction and validation of measurement instruments such as questionnaires, tests, and self- assessments. Karlsen (2011) discusses several psychometrical concerns. Firstly, *learning outcome* can be understood in different ways. The concept refers to intended learning outcomes, i.e. what students are expected to know after completing their education and to actual results, i.e. what students actually have learnt. Secondly, the dominating definition of learning outcomes is concerned about the intended results, but it is not always clear whose intentions we talk about, supervisors, administrators, students, politicians. Thirdly, it is difficult to find reliable test instruments, which can be used across different institutions and contexts. Several standard test instruments as the Collegiate Learning Assessment (CLA) and the National Survey of Student Engagement (NSSE) used in higher education aim to do so, but still lack objectivity. Fourthly, test instruments normally do not take into account the basis upon which students assess their own learning outcomes (Karlsen, 2011:10-12). Several scholars argue that learning outcomes cannot be measured in a proper way because of lack of systematic and holistic systems to document students´ final competences. Others are sceptical to self – assessments on learning outcomes because they do not include institutional practices and students´ behaviour (Astin, 1993, Ewell and Jones, 1991, Kuh et al, 1997, Pascarella and Terenzini 1991, cited in Karlsen 2011:21). Still, some measures can be said to be more valid than others. Generally speaking, students´ performance is recognised as more objective than self- assessment tests because it is hard to say if the students give correct answers in self-assessments test. Self-assessments depend on how the students understand the questions, how critically they assess their own level of knowledge, what expectations they have to their own performance and to their education and how they would like to appear to the reader of their answers. Another challenge about self-assessment tests is to measure the value added i.e. what the students actually have learnt during their education. Students enter educational programs with different levels of knowledge, skills and competences and humans are normally not clever at assessing in retrospective how and why their knowledge, skills and competences have changed during a given period of time. It is thus hard to find out what impact the education has had on the students´ knowledge, skills and competences. Longitudinal studies could remedy this challenge, by letting the students answer the questions both when the students start and finish their education and by comparing their answers (Karlsen, 2011:22). Longitudinal studies are however costly and cross-sectional data derived from self-assessments are more common even they perform lower validity. Self-assessments are still interesting because they provide useful information on student satisfaction and they are widely used along with different kinds of performance tests.

Kuh (2003) on the other hand, argues that self-assessments are valid as long as five criteria are met. First of all, the questions must be clear and unambiguous. The information asked for, must be known to the respondent and concerned about recent activities. The respondents must also feel the questions are worth wile to respond to and the questions may not be disturbing, embarrassing or threating to the respondents (3-4).

As seen, there are several methodological challenges concerning self-assessments, although they may give valuable information on students´ satisfaction and a snapshot of student´ s perception of learning outcomes. It would thus have been ideal to combine self-assessment with other measures and methods, such as interviews with students, employers and supervisors. Longitudinal studies and performance test would have been good alternatives too. However, there has been little room for triangulation of methods of this kind within the frame of this thesis due to the availability of time and resources. This study is thus limited to a self-assessment in combination with a literature review.

4.3.2 Construction of a measure instrument

As mentioned, a measure instrument was constructed especially for the purpose of the self-assessment. Punch (2005) presents six steps to construct an appropriate measure instrument: 1) What is going to be measured must be clearly defined, 2) selection of measuring technique, 3) the number of items to be included and where they should come from 4) discuss through the draft with a small group of people typical of the persons to be measured, 5) Pre-test of a modified draft, with a group of 25 individuals and analyse their responses, 6) Make the last modifications (92-93). I used QuestBack as tool to make a web-based questionnaire. Step 1-3 follows from the research question to find appropriate traits and indicators. The trait of this study is learning outcome and the indicators are mainly different skills, which have been identified in the literature review and in several qualification frameworks presented in attachment 1, Table 1: Specific and transferable skills. Each skill is measured on a scale from 1-5, where 1=to a large extent, 2= to a significant extent, 3= to some extent, 4= to a small extent, 5= not at all. In the analysis of the data the scale was turned the other way around, from 1= not at all to 5= to large extent. Industry-academia collaboration was also operationalized through categories mainly found literature. Here, the measurement was categorical yes/no

Traits	Categories	Categories
Learning outcome	Knowledge within a specific research area Broader knowledge within a research area Analytical thinking Evaluation and synthesis of complex ideas Creativity Lateral thinking/problem solving Interdisciplinary approaches Research methods applicable to specific research field Research methods in general How to develop new knowledge Entrepreneurship/commercialisation of research results Application for external funding Management of own time and resources	Project management Project development Team work Team building Understanding of the societal and political context in which research take place Knowledge about how to develop professional networks nationally and internationally Knowledge about how to develop a career inside academia Knowledge about how to develop an alternative career outside academia
Industry-academia collaboration	Doctoral education financed by industry Contractual relationship with industrial partner Ph.D. research question is relevant to industry Data and/or infrastructure provided by industry	Office/location provided by industry Student work in industry while doing a Ph.D. Student carry out research together with staff in industry

The quest also includes questions of more factual characteristics, such as questions on fulltime work previous to their doctoral education, at what stage of their doctoral degree they are, research discipline, gender, age, citizenship (Norwegian, non-Norwegian) and future career prospects. An open-ended question on the value added from education in a collaborative relationship was also included. Taking up the challenge concerning self-assessment on whether the students responds correctly or not to the question, the students were asked to indicate from what point of departure they had answered the questions on skills and competences. Do they answer from what they think they have actually learnt? From what they think doctoral student normally learn? From what is stated in curricula? They were also asked what they think is the best way to learn different skills. The overall questionnaire can be found in attachment 3.

The different categories of skills are obviously crucial in this study. However, the literature review revealed that there are different definitions of skills, and especially transferable skills, that are often used interchangeably and often with blurring boundaries. That is yet another challenge connected to measuring learning outcomes. I will briefly discuss this point based on research presented by Karlsen (2011). Skills as concept lack coherency, consistency and theoretical foundation, which make it difficult to adapt teaching leading to acquisitions of these skills by the students. Skills can be *"personal qualities", "values", particular "skills", as well as the ability to "apply knowledge and understanding"* (Holmes, 1995, cited by Karlsen, 2011:73). We talk about skills as a tool something we may not have, but can acquire, as "problem solving" or "communication" On the other hand, skills cannot be directly observed, since they exist only in our minds and become visible through social interaction and the way we interpret each other's actions and behaviour, according to Holmes (2000) (cited by Karlsen, 2011:73). Skills normally also refer to a broad range of different skills – creativity, analytical skills, communication, management, teamwork etc. which requires significant knowledge, understanding and sensitivity. It is therefore problematic to set up lists of different skills, which intend to be more or less exhaustive.

Another concern is whether research specific skills can be divided from transferable skills. Neither is it clear how skills are transferred from one context to another or what may cause transferring. Bridges (1993) suggests that three conditions must be met: 1) sensitivity on similarities and differences between social/cognitive contexts, 2) ownership of cognitive abilities to modify, adapt and further develop a certain repertoire to another environment and 3) attitudes or afflictions which contribute to fulfil the two previous points (cited by Karlsen, 2011:76). Another part of the problem is confusion about what makes a person "employable", since employability, the transfer of skills from school to work, is the ultimate goal. Holmes (2000) argues that different employers have different expectations to a newcomer at work and will thus have different understandings of what employability means. It will thus make sense to measure newcomers´ performance at work and not as students at university.

Still, these researchers believe that we have to live with different definitions and understandings of the concepts and that what matters is agreeing upon a common definition in a given context. It is out of the scope of this thesis to shed further light upon the definition debate of different skills as well as the transferability of skills, which means that this study must be recognised with the limitations that follow from the potential differences in the understanding of skills among the respondents.

Going back to Punch´ s 6-step procedure of constructing a measure instrument, the draft was tested by some Ph.D. students, who were not included in the sample for the study. I did not have the chance to discuss through the quest face-to-face, but received their feedback by mail. On the other hand, I did discuss face-to-face with three other individuals, who were not in the target group for the questionnaire, but who had knowledge about carrying out web-based surveys as well as knowledge within the topic for this study. I received useful feedback from the test round and some of the questions were refined in order to avoid ambiguity. Some technical concerns were also clarified. Unfortunately, I did not have the possibility to check with as many individuals in the test round as suggested in literature, which thus is a weakness concerning reliability of the measurement tool.

All questions are obligatory and the respondents could not go further in the quest if an answer was missing. That has been helpful to avoid missing data. On the other hand, it forces respondents to choose between the pre-defined alternatives, even when they might think a question does not apply to them or they do not identify themselves with the categories. There seems to have been some technical problems with question number 7, as this question received different numbers of responses despite of being obligatory. This is visualised in figure 6.3 on preferred learning methods in chapter 6. I also received a message by e-mail from one of the respondents telling he had problems with the quest on this question. Unfortunately, this was not discovered in the test round, as the quest seemed to work perfectly.

4.3.3 Sample

Samples should be put together carefully in order to represent the entire population a study intends to say something about. The idea is that findings can be generalised to the whole population if the sample is representative and the study will thus be more reliable. Random selection is the most common strategy to achieve representativeness. Here, each element in a population has equal chances of being chosen and potential spurious variables are spread randomly in the sample. However, large and configured samples are often hard to get access to and it is quite common to take a sample that is available (Punch, 2005:101-102). In order to find a representative sample of doctoral students, who´ s education take place in a collaborative relationship between industry and academia, I started out with the financial instruments provided by the Research Council of Norway (RCN). User-driven Research based Innovation (BIA), Programme for Regional R&D and Innovation (VRI), Centres of Research based Innovation (SFI) and Centres for Environmental- friendly Energy Research (FME) are the bigger ones that normally include and attract a reasonable number of Ph.D. students. I went into the RCN project archive, which is available online (www.forskningsradet.no/prosjektarkiv) and looked up which research project they are currently funding within these four schemes. Several of the research projects had their own web-sites, where all employees, including Ph.D. students, were listed with names and e-mail addresses and from there I made a mailing list of Ph.D. students. The students are enrolled in doctoral programs mainly at the University of Oslo (UiO), NTNU, the University of Stavanger (UiS) and the University of Tromsø (UiT). Several faculties and entities are represented in the sample from the UiO, among others, institutes of informatics, philosophy, social sciences, chemistry and biotechnology. The NTNU and the UiT students are mainly from institutes representing natural sciences, while the UiS students belong to industrial economy. Some students have connections to other higher education institutions as the University College Vestfold, the University College Molde and the Norwegian School of Economis. Others are connected to independent research institute as SINTEF, Simula, Eastern Norway Research Institute and Norway´s Geotechnical Institute.

The sample is randomly put together, based on the availability of e-mail addresses online. Relationship to industry was not explicitly checked with each individual beforehand, so the questionnaire includes one question about what kind of collaborative relationship the students consider themselves to be in. That opens up for the possibility to get response also from students that are not in a collaborative relationship. It is also left up to the students to define *industry*, which means that not only business enterprises may be considered as industry, but also organisations like hospitals, public sector institutions or research institutes. This is clearly a weakness with the sample and the findings must be analysed with this in mind.

The questionnaire was sent to 241 Ph.D. students in total. A reminder was sent after a week. I did not receive any notification of delivery failure, which is a little surprising and I will just have to assume that everybody actually received the e-mail with the questionnaire. However, five students withdraw themselves from the study, which then gives a total sample of 236. The questionnaire ended up with a response rate of around 31 %. I have analysed the data statistically and the findings will be presented and discussed in chapter 6.

4.3.4 Analysis of data

The collected data was exported directly from QuestBack to the program Statistical Package for Social Science (SPSS) for the purpose of a statistical analysist. I have limited the analysis to a few statistics due to time constraints and due to the limited frame of a master thesis. Further on, the response rate in this study is low and more sophisticated statistical analyses should probably be reserved for bigger data sets. Firstly, data is analysed descriptively looking at single variables and their frequencies, percentages, means and standard deviations. Some variables were recoded into the same variable or into different variables. I also computed a new variable by summing the answers to the questions on relationship to links, creating a variable on weak and strong links to industry. For the 21 variables related to skills a factor analysis was done. The factor analysis attempts to identify underlying variables that explain the pattern of correlation within the observed variables related to skills. Usually a few factors will account for most of the variation and these factors can be used to replace the original variables (Hellevik, 2002, 320-321). The 21 variables on skills were reduced to five underlying dimensions in this analysis and will be discussed in chapter 5. I used Cronbach´ s Alpha as measurement of reliability of these dimensions.

Secondly, the relationship between different variables is explored. I have used cross-tabulations, where I run Pearson´ s chi-square tests. The chi-square test is testing the null-hypothesis, which states that there is no significant relationship between the two given variables. Pearson´ s chi-square values below .05 indicate that rows and columns of the contingency are dependent (Hellevik, 2002:402-406). I run a t-test of the variables connected to industry-links and to four dimensions on skills. The same test was also run with variables on work experience and research discipline. An independent sample t-test compares the mean scores of two groups and assumes that the two groups are independent of one another, that the dependent variable is normally distributed and that the two groups have approximately equal variance on the dependent variable. Levene´s test for equality of variances examine whether the variance of the two groups is equal. Significance values above .05 indicate that the variance is equal. The independent sample t-test also sets out a null hypothesis claiming that the means of the two groups are not significantly different. The alternate hypothesis says that the means of the two groups are significantly different (Hellevik, 2004:408-409).

4.4 Reliability and validity

Reliability and validity are two technical criteria that say something about the qualities that are built into a measuring instrument. Reliability refers to consistency both over time and internally. Consistency over time, or stability of measurement over time, means that we should get the same results repeating the measurement in a different time, but under the same conditions. The instruments would be unreliable if we get different results. Reliability can be assessed through two administrations of the same instrument at two points in time, with the so-called test-retest reliability. Internal consistency relates to the concept-indicator idea and assess to what extent the different indicators are consistent with each other. Indicators working in different directions are not consistent. Internal consistency can be estimated with split-half techniques, as the coefficient alpha (Punch, 2005: 95). Measures with a high reliability produce scores that are closer to true scores and that control for errors. A good measure instrument with high reliability also picks up variance in scores produced by respondents. The questionnaire as a measure instrument has not been tested for its reliability in this way. It would thus have been an advantage to use existing survey tools, but since such tools do not seem to be available, a questionnaire was developed especially for this purpose. The indicators chosen in the questionnaire are, however, well founded in literature as well as in several skills framework. Another challenge is that self-assessments should be run in combination with performance tests or at two different points in time with the same respondents in order to get more reliable data on learning outcomes. On the other hand, the questionnaire included a question about what point of departure the students had taken when answering the questionnaire. 94 % said they answered from what they think they actually have learnt during their Ph.D., 3 % said they answered from what they think Ph.D. students normally learn and yet another 3 % said they answered from the explicit learning goals stated in curricula and courses. The high number that indicated they answered from what they actually learn strengthens the reliability of their answers on skills and learning outcome. The questionnaire also looks into what stage of their doctoral degree the students were. Less than 20 % reported to be at the beginning of their doctoral education, which means that more than 80 % were either half way or about to finish their degree. The students are thus likely to give reliable answers about their learning outcomes as they can tell from actual experience and that further strengthens reliability.

Validity refers to the extent to which a measurement is well-founded and corresponds accurately to the real world. Do we measure what we intend to measure? This relates to the extent to which an indicator empirically represents the concept to be measured and includes content validity, criterion-related validity and constructs validity. Researchers should be concerned with both *external* and *internal* validity. External validity refers to the extent to which the results of a study are generalisable to a bigger population. Internal validity refers to the rigor with which the study was conducted, as the study's design, and to the extent to which the study takes into account alternative explanations for any causal relationships (Campbell and Stanley, 1963).

According to Pascarella (2001), cross-sectional data lack internal validity since they do not reveal causality between variables. Studies with a cross-sectional design do not provide insight in the value added from education since students´ knowledge when they were recruited to the education is unknown and it is thus impossible to say what effect the socialisation process through education has had (Pascarella, 2001 cited by Karlsen, 2011:67). There is however ways to overcome this challenge when measuring learning outcomes. Longitudinal studies are, as mentioned, one of them. Using a control group that has not entered in higher education is another possibility that will indicate how knowledge and skills have evolved in the group that has entered into the study program versus the group that has not. Yet another strategy is conducting interviews with employers, asking which skills and competences they would like recently graduated employees to possess and then afterwards check with the employees whether they consider these skills and competences to be crucial in their new jobs and what role their last education has played in developing these skills and competences (Rochester et al 2005, cited by Karlsen, 2011:70).

As mentioned, the empirical part of this study does not take advantage of triangulation of methods as described here, due to lack of time and resources within the frame of a master thesis. The questionnaire would thus have weak internal validity, which means that results must be interpreted carefully, especially when it comes to causality and generalisations to a bigger population. The results say first and foremost something about the respondents and their perception of their own skills acquisition. I come back to this question in chapter 6. On the other hand, the study includes a literature review, which would make findings from this study more solid. Considerations about the methodological aspects are described in paragraph 4.2.1.

4.5 Ethical concerns

All researchers, including master students, at the University of Oslo (UiO) must be familiar with, and follow, UiO´ s Guidelines for ethical practice in research (UiO, 2012 [URL], 02.03), which is based on guidelines from The National Committee for Research Ethics. With regard to this thesis, I will comment upon two concerns, which I think are especially relevant: Research on internet and the solidity of the research results.

The National Committee for Research Ethics in the Social Sciences and the Humanities (NESH) draw up guidelines for research ethics in the social sciences, law, the humanities and theology. NESH has also approved guidelines for internet research. Internet can be used as a tool within research or internet can in itself be subject to research. I used internet as a tool for getting in contact with potential respondents for my questionnaire, both when making the list of e-mail addresses and when sending out the questionnaire. All studies involving persons should ensure that the informants get appropriate information about the study, especially how their answers are going to be used. The informants should also give their consent to participation and have the possibility to withdraw from the study whenever they want. This also apply to research on internet (NESH, 2012 [URL], 02.03). Regarding my study, the potential respondents received an e-mail, sent as an invitation with a short description of the purpose of the questionnaire, ensuring that their answers were going to be anonymous. It was up to each student to click on the questionnaire in order to participate. The informants could also withdraw themselves from the study, which three of them also actually did. I therefore consider the study to have undertaken relevant ethical concerns in this respect.

The other point on ensuring that one’s scientific results are solid enough to justify one´ s conclusions and that the raw data/materials on which one´ s publications are based remain intact and available is probably weaker in my empirical study (UiO, 2012 [URL], 02.03). As already mentioned, there are methodological weaknesses choosing a survey-design that provide cross-sectional data, based on self-assessments. Secondly, my study had a low response rate, which means that conclusions must be drawn carefully. On the other hand, I believe that the results from the literature review are more solid, as it covers a reasonable body of existing research within the field. Literature on skills and skills acquisition in doctoral education carried out in industry-academia collaborations is however scarce and that should be kept in mind.

5.0 Literature review

Research on doctoral training in industry-academia collaborations with focus on skills and skills acquisition mainly groups into four topics. A small literature body looks into which role doctoral students play in industry-academia relations and how these relations have impact on the student´ s learning environment. Other scholars theorize skills acquisition at Ph.D. level, highlighting the doctoral degree as a learning process and pointing out core skills that are acquired through practising research, often in social interaction. There are also several empirical studies looking into student´ s satisfaction of their doctoral studies and their perception of the benefit of different skills. The last category of literature provides insight into students´ career prospect and career trajectories both in academia and industry.

The findings from the identified literature are presented below, followed by a discussion on the findings in relation to the theoretical assumptions set out in chapter 3.

5.1 Doctoral training in industry-academia collaboration

There are several contributions looking into how industry-academia collaborations impact doctoral students´ learning environment and thus also the outcome. Thune (2009) did a literature review of published research on graduate student-industry relationships and focused on the doctoral students´ role in these relationships. She concluded that doctoral students are seen to be central in knowledge production and knowledge transfer between the two sectors, as well as important for maintaining networks. Student –firm collaborations are heterogeneous with different types of organisation, partners and resource exchange that affect students´ experiences in different ways (639-641). Academic standard is still the most important requirements to meet for all students and in this sense collaborative and non-collaborative students are much alike. Collaborative students are however exposed to a much more heterogeneous environment than non-collaborative students when it comes to the physical surroundings, supervision, the research projects they work on and the norms of conduct they must follow (Thune, 2009:645-646, Mendoza, 2007:93, Hakala, 2009:512). Thus, collaborative students are normally left with an enhanced understanding of different priorities and ways of working in different research environments as well as with broader employability perspectives by learning to apply skills and knowledge acquired through research in industry. They learn academic standards, but with strategic value for industry. This is seen as an indication of high research quality. The industry-academia collaboration cannot be said to have great impact on the outcomes in terms of productivity realised during the Ph.D. period. Collaborative students have the same productivity, both publishing and patenting, as non-collaborative students and the students´ satisfaction about their studies tend to be the same. Industry-academia collaboration has, however, long term impacts on career patterns (Thune, 2010:480, Morris et al 2011).

Students, whose projects are funded by industry, are often more positive to industrial funding and believe to a larger extent that research in this way meets societal needs. They also appreciate access to a broader network and diverse job opportunities (Mendoza, 2007). Students who need to continuously apply for external funding for their Ph.D. project tend to be socialised into senior tasks, as writing application, manage projects and publishing from a very early stage. They develop management and collaborative skills as well as self-management of own time and resources. They do however, risk getting delayed with their thesis (Hakala, 2009:508). Also supervisors tend to be positive about partnerships with industry referring to own research enhancement and to their students' potential for increased employability, access to data, research being applied to real-life issues (Malfroy, 2010:581). Industry-academia collaborations tend to rely much on personal connections for both for initiation and success (Watson, 2011:139, Malfroy, 2010:581). Previously successful industry relationships are often used for new research partnerships. Former doctoral graduates working in industry are also used to open new doors. Inviting industry supervisors to seminars or student presentations, and to participate in joint publications are other strategies. Doctoral students could also be the reason itself for collaboration. Representatives from industry and academia have to find a common denominator in fostering the intellectual and personal growth of the student. Industry-academia collaboration is thus not only about production, but also about the growth of an individual. This requires normally a face-to-face meeting and involves a socialisation process, not only between the supervisor and the student, but also between the industrial and the academe supervisors. Knowledge transfer between the two sectors takes place in this space and these social experiences are thus of vital importance for achieving processes of knowledge creation according to Mode 2 (Salminen-Karlsson and Wallgren, 2008:91-91).

There seem to be diverse results concerning potential challenges in industry-academia collaborations and its possible impact on students´ learning experience. Some studies connect challenges to the need for dealing with several supervisors and handling requirements for different reporting systems, which can also lead to compromises in selecting and fixing the research topic. Suggested solutions are for improved methods for discussing academic standards and industry needs of research, appropriate ethical guidelines for research, clarification of the timelines and responsibilities of the Ph.D. process (Malfroy 2010:582, Borell-Damian et al, 2010:508). Others show that these challenges are non-existing for the doctoral students, mainly due to the well-established and formally and informally regulated relationship between the university and firm (Thune, 2010: 478, Salminen-Karlsson and Wallgren, 2008).

A few studies take up different skills firms normally would like the doctoral students to possess. Findings from Borrell-Damian et al (2009) show that when firms recruit staff with Ph.D. qualifications they particularly emphasize the creative ability of being able to integrate knowledge from different disciplines and sectors to create new or improve existing solutions. This is technical skills, analytical thinking, and scientific knowledge and research skills as such. Firms also emphasize transferable skills, such as communication skills, leadership skills, project management skills, ability and willingness to change, creative abilities, personal effectiveness and the ability to handle complex problems (Borell-Damian 2009, de Grande et al, 2010). Conventional doctoral programs have been criticized for educating students too narrowly, not enabling them to develop key professional skills, such as collaborating effectively and working in teams or organisational and managerial skills (Nerad, 2004:187). Professional doctorates or collaborative programs have thus been established with the aim to provide students with a broader set of skills and heterogeneous learning environment. However, some studies show that firms, universities and doctoral students may have different views on the concrete outcome in terms of skills from collaborative doctoral programs. While universities tend to report that collaborative programs do not leave students with extra skills, industry thinks there is a high added value. Students have a more mixed view as some still associate collaborative programs with weak theoretical research (Borell-Damian et al, 2009:509).

An increasing value on professional skills, such as communication, teamwork, problem solving, lifelong learning, intercultural understanding, entrepreneurship and leadership, reflects an instrumental view on these skills and a growing interest in the role of research degrees in labour markets. Some scholars argue that this may lead to a reduction of research as a profession. Barnacle and Dall´ Alba (2011) highlight the need to understand the term generic skills as a skilful practice and know-how that arise within particular disciplinary, social and technological practices. Doctoral education should assist student in raising awareness about in what ways they can improve their practice and develop their know-how (468). Other scholars welcome the increased focus on standardised learning outcomes and extended curricula on transferable skills and see this development as evolutionary. Park (2005) argues that the doctoral degree needs to adapt to fast going changes in its circumstances in order to survive. The drivers of change include a growing emphasis on skills and training, on submission and completion rates, on quality of supervision, and changes in the examination of doctoral research (202). As a consequence, the existing Ph.D. changes and new types of Ph.D. degrees appear. The inclusion of transferable skills creates new opportunities of doctoral education in disciplines and professions where the Ph.D degree has traditionally not been given, as tourism, nursing or physiotherapy (Pearce 2005). Pearce defines transferable skills as "the abilities, capacities and knowledge to function as a successful professional in an information rich, globally connected society" (38) and as such, these skills foster management capabilities in a wide range of position inside and outside the academe, they trigger learning in general and motivate lifelong learning and they make individuals tackle complex tasks even beyond research (40).

The emergence of professional doctorates can, according to Servage (2009), be explained by human capital theory, which posits that the current, global expansion of higher education reflects the need within a post-industrial or knowledge economy for workers with higher levels of skill, creativity and innovation. Professional doctorates are thus designed to address gaps between the skills and knowledge that have conventionally been associated with doctoral-level learning and what is presently required by industries and employers in knowledge economies, including an emphasis on interdisciplinary and applied knowledge, stronger and more explicit alignments with industry and defined workplace competences, emphasis on reflective practice, and alternatives to the dissertation as a culminating project. Professional doctorate can also be seen as a form of accredited professional development (Servage, 2009:766). Professional doctorates constitute a rather strong trend in the USA, UK and Australia, and similar patterns of expansion have occurred in these three countries, although there is no common definition of the concept. Canadian universities tend to make the Ph.D. more flexible rather than establishing new doctoral programs. In Australia and the UK governmental initiatives have been crucial in the development of professional doctorate programs, whereas in the US, these programs response to market demands (Chiteng and Hendel, 2011).

Other scholars warn against what is referred to as the "employability discourse", which is built on a *deficit* model being used to push workplace skills training for students. These scholars argue that there is not necessarily a skills mismatch between students and firms. Different employers have different expectations about which skills doctoral holders should possess (Craswell, 2007:388). Students are also highly heterogeneous and some have extensive labour experience before embarking a Ph.D. (Pearson et al, 2011). When students are asked which skills they think are crucial for future employment, they emphasize research skills, scientific knowledge and analytical skills at the expense of technical skills. Social skills and teamwork, independence and presentation skills are also central. General management skills are lower ranked (de Grande et al, 2010:5). There tend to be more variation in the response patterns among doctoral candidates than among employers concerning which skills are considered to be crucial for employment. Still, scientific knowledge, analytical thinking and teamwork are the most common desirable skills.

Some scholars also problematize the term "skill" demonstrating that the terms competence, attribute, quality, ability, capacity capability and skill are used interchangeably in literature (Cumming, 2010:410) and calling for a multifaceted and holistic approach to skills as different skills are interdependent (ex. project planning, project management, project evaluation) and vary with degree and context (Gilbert et al 2004: 384).

5.2 Industry-ready students - career prospects and career trajectories

Academic research career has traditionally been what doctoral students are heading for. However, less than one third of the students actually achieve an academic position. Roach and Sauermann (2009) examine whether there is self-selection in the sense that scientists with a weaker taste for science are more likely to enter the industrial sector while those with a strong taste for science pursue careers in academia. Students have preferences for particular job attributes and different expectations of what is waiting in an academe versus an industrial career. Students preferring industrial employment show a greater concern for salary, access to resources, and a stronger interest in downstream work, while students preferring academic employment are concerned about academic freedom to choose projects and ability to collaborate across organisational boundaries. Availability of different types of jobs, did not affect students´ career preferences (433). Other studies partly support Roach and Sauermann, but found that steady employment in industry opposed to temporarily contracts in academia also was part of students´ motivation for choosing industry (de Grande et al, 2009:4).

There are also several studies looking into employment destinations of doctoral graduates. Data from Australia show that 90 % of all graduates found work within six months, half of them at HEIs and around 18 % in industry. Similar findings can also be found at an international level (Neumann and Tan, 2011:607). When it comes to the Norwegian context, findings from a study carried out in 2003 show that 41 % of doctoral candidates worked at HEIs, 18 % at independent research institutes/R&D intensive companies, 15 % at health institutions and 10 % in the oil and gas industry. The rest worked in other private and public sector (Olsen 2007:12-18, Thune and Olsen, 2009). These numbers are very much in line with the students´ own perception of their career prospects and ambitions for their own career (Thune and Olsen, 2009, Kyvik and Olsen 2007). A survey carried out among doctoral student members of the Norwegian Association of Researchers, shows that the majority want to continue research after their doctoral training. Around 50 % aim at a career within academia and around 20 % wish to work in the institute sector. Only a few seek a career within private companies and industry. Students within natural science and technology are somewhat more optimistic about their opportunities than students in humanities and social sciences. Students who wish to work in academia or private sector are more pessimistic than students who wish for a career in public sector or in the independent research institute (Thune and Olsen, 2009: 51-52). Another survey examines, with similar findings, doctoral candidates´ perception of their training in light of the labour market respectively two and five years after having completed their degree (Kyvik and Olsen, 2007). Both surveys also show that only a few have received information and guidance from their institutions about different career opportunities within research from the institution responsible for the Ph.D. degree and that closer collaboration with private industry in the doctoral project, would have been received positively (Thune and Olsen, 2009:52, Kyvik and Olsen, 2007:26).

5.3 Theoretical approaches to skills acquisition

Several scholars theorize the purpose of doctoral education, how skills are developed and what doing research actually involve. A doctorate is described as dual in its nature. First, it enables graduates to make original contributions to their respective disciplines and second, it provides professional research training to become independent researchers (Lee et al, 2009: 871). A Ph.D. is thus both a product and a process, where the students acquire knowledge in the discipline as well as competences about knowledge creation. Virtually all scholars make a division between doctoral education as a product and a process and emphasize research as a contextualised social practise. Still, not all sees the doctorate as a system comprised of inputs, for instance physical and human resources, and outputs, like theses and graduates, but rather as a holistic and integrated concept of many components that are interdependent as well as interrelated. An alternative integrative model of doctoral enterprise, presented by Cumming, includes the extent to which doctoral practices and arrangements are mutually constituted. The model emphasizes doctoral practises, rather than the individuals, as practises embrace concepts as skilful performance, artistry and know-how. This gives an enhanced focus on the student as a skilful performer. Rather than someone who can list their skills, a skilful performer is someone who not only knows about what to do but knows how to apply that in practice Cumming´s concept of contextual performance builds on the notion that skills are executed in different settings based on the individuals´ behaviour, and they are thus context-dependent. As a consequence, candidates should be enabled to work, learn and develop skills in authentic contexts in accordance with the concept "contextualised performance "(Cumming, 2010:35-38).

Adopting a sociocultural perspective, Hopwood (2010) argues that skills are not acquired through teaching and externally defined learning outcomes. Instead, human development is founded upon social interaction in cultural practices. Learning is attributed to the sharing of experiences through discussion and social interaction. Empirical studies on doctoral students' experiences of teaching, student journal editing and career mentoring show that a number of skills are learnt through practising in interaction with others. Practising gives first-hand experience, for instance on giving constructive feedback to others, to negotiate meaning and to put one´s knowledge into words and enhances awareness in other socially mediated situations as job interviews, approaches to time management, grant applications, writing and decision making relating to work–life balance and family life (Hopwood, 2010:837-841, Maxwell and Smyth, 2009:409). Intellectual, behavioural, personal and emotional impacts of doctoral study should not be seen as separate processes and outcomes, but as integrated and interrelated attributes. The point is that members of students' personal and professional networks provide information about and perspectives on the academic community and expected roles. Students measure their success in learning to enact these roles by seeking and receiving validation from network partners. Learning, skills acquisition and development of professional identity go thus hand-in-hand and are embedded in social practises (Baker and Lattuca, 2010: 821)

Several studies take up skills development through social interaction. Creativity is one of these skills. Creativity is seen as a requirement to produce an original contribution to the research field, to find new research questions and to link new ideas together. Sharing thoughts means that ideas are shaped and re-shaped and new concepts appear. The interaction and relationship between the doctoral student and the supervisor is seen as a process where creativity can flourish. The process is however moderated by interpersonal climate, how the supervisor encourages risk taking to think "out of the box" and shares his/her experience with the student as well as how the supervisor challenge problematic ides to help the student find new solutions (Whitelock et al, 2008). Creativity interconnects with writing skills as academic writing also implies being creative in order to make complex concepts easily understandable to the reader. Besides, academic writing is itself a central skill acquired through a doctorate. Academic writing involves uniqueness of writing in diverse disciplinary contexts with respect to thought processes and ways of communication (Zhu 2004:38). At the same time, academic writing largely entails the transfer of general writing skills, as audience awareness, logical organisation, paragraph development, clarity, sentence structure and grammar, to different contexts.

The final aim of academic writing is dissemination through publishing. Publishing implies in itself developing a range of skills and it is a way to get recognised for those skills and competences (Bender and Windsor, 2010:157). This includes skills and competences in the research field as well as writing and communication skills. Further on, students learn to prepare and submit research papers, answer to journal criticism of their papers, communicate with editors of peer-reviewed journals and to select journals appropriate to their articles.

Inspired by Aristotelian theory; Mowbray and Halse describe the purpose of the Ph.D. as the acquisition of interrelated intellectual virtues. Personal resourcefulness skills enable students to become more assertive, resilient, confident and resolute in determining how to progress their Ph.D. while meeting the contingencies of everyday life. Cognitive skills make students develop creativity, ability to think critically and to scrutinize and synthesize information and ideas. Research and other skills provide experiences in management, written and oral communication, achieving deadlines, producing outcomes within limited budgets – in short it is about moving from technicians to craftsmen (Mowbray and Halse, 2010:5-7). This individual learning trajectory must be approached holistically, where new knowledge on how to do research well has to fit into what the individual already knows. It can however be challenging to locate new learning and that is where supervision has its potential. To reach excellence in research there must thus be a focus on developing both the supervisor and the supervisee. Wray and Wallace argue that many skills can only be developed through practise, integrating inputs to each individual´s research practitioner repertoire. It is hard, if not impossible, to realise the potential for formal training to do so. Pedagogical and managerial expertise is a strategic means of developing research expertise of others and efforts should be made to develop learning support in the research project and research environment of the individual (Wray and Wallace, 2011).

5.4 Empirical contributions - How students value skills

Surveys among doctoral students to investigate the students´ perception of the usability of different skills acquired during the Ph.D. seem to reach similar conclusions. A broad knowledge in the research field and knowledge about the process of doing research rank higher than specialist knowledge in the Ph.D. topic and specific knowledge about research methodology.

Pole´s (2000) examination of learning outcomes among doctoral students suggests that craft knowledge that understands how to manage all aspects of the research process from formulating an initial research design to the publication, dissemination and exploitation of the research is highly valued by the students. So are also technical skills as systematically thinking, find things, read, write, write concisely and construct arguments. The substantial knowledge created within the doctoral project has less importance to the students (Pole 2000:101). Zellner (2003) reach a similar conclusion suggesting that non-specific knowledge that is analytical skills for the recognition, formation and solution of complex problems, broad and general knowledge of and familiarity with the research discipline and the application of information technology is highly valued. Specific knowledge, as insight and theories gained from ones research field, methodological knowledge about experimental procedures and research techniques have less usability (Zellner, 2003, Lee et al, 2009). Analytical skills are highly valued especially for functions related to R&D, production, management, consulting and marketing. A broad knowledge base is especially relevant for R&D, production and marketing. IT skills scores middle for all functions, while the science specific skills are less valued

Doctoral students enrolled in professional Ph.D. programs appreciate financial management skills, understanding of intellectual property and commercialization issues, entrepreneurship, environmental awareness and the ability to work in interdisciplinary context more than conventional Ph.D. graduates. Conventional Ph.D. graduates value critical judgement and analytical thinking, in-depth knowledge of the field of study and teaching skills more (Manathunga et al, 2011: 8). Ph.D. graduates also reported possession of a number of these attributes prior to undertaking the Ph.D., which has implications for the ways in which Ph.D. programmes recognise, capitalise on, and develop these pre-existing abilities (Manathunga et al, 2009:95). Harman (2004) compared students` satisfaction at Cooperative Research Centres (CSC) in Australia with traditional science-based departments, and found that CRCs appear to be more satisfied with their education in terms of access to equipment and financial resources, library holdings and services, frequency of contact with supervisors and readiness to work with industry (401). Morris et al (2011) examined students´ perception of supervision in collaborative programs versus traditional programs and found that students with two supervisors, one from academia and one from industry, meet more often face-to-face with their supervisor, but the overall satisfaction is the same as for the non-collaborative students (Morris et al, 2011: 14). Industry research unit can offer significantly more personal support for students as well as supporting students' acquisition of knowledge and skills and creating a more favourable learning climate for doctoral education than the university setting (Morris et al 2011:15).

Motivation for embarking a professional doctorate includes, not unlike a conventional Ph.D., the enrichment of practice, being able to make a contribution to knowledge in the field of study, to learn new research skills, to enhance the professional regard of adult education, to enhance a present position/salary in education, the intrinsic drive to learn, the desire to write and the desire to speak on educational matters with confidence and authority. However, students highlight the supportive element of being in a cohort of students, where they need to exhibit self-discipline in order to get the work done (Loxley and Seery, 2012)

Bienkowska and Klofsten (2011) concludes similarly after having examined Swedish PhD students' opinions on commercialisation and entrepreneurship and their perceptions of the supportiveness of university context in this regard, as well as the role of mobility and collaborations with external actors in PhD education. On average all students expressed interest, engineers most and students from humanities less. Students thought university was supportive both at the hierarchical top and the bottom. Concerning mobility, students who had spent some time in a firm were more positive than those who had been to other institutions and the non-mobile researchers.

Self-assessment of students´ perceptions of various skills carried out in Australia show a positive correlation between skills acquired and post-PhD productivity and to subjective evaluations of the value of the PhD experience. No relationship was observed between skills acquisition and completion times, productivity during the Ph.D. education, job acquisition or current salary. There were some, although not significant, demographic differences (Platow, 2012: 114-115). Other studies intend to measure the outcome of skills training courses. Before-and-after inventory tests have found differences in pre- and post-course scores in areas pertaining to group work, communication skills, planning and project management and personal awareness. Students are also more positive to transferable skills training in general after attending a course (Alpay and Walsh, 2008: 592).

NIFU Step has performed several surveys among doctoral students in Norway and given analyses of their working conditions, career prospects and overall satisfaction with their degree. Most students think the skills and competences acquired from their doctoral education are relevant for future jobs not only within research, but also in non-research positions. Only around 10 % think their doctoral experience will have little relevance for their further career (Thune and Olsen, 2009:52, Olsen 2007, Research Council of Norway, 2002). Data collected from doctoral student members of the Norwegian Association of Researchers show that the overall satisfaction with the training, supervision and the knowledge and skills acquired is fairly good. Potential improvement is first of all connected to the doctoral courses and their relevance for the thesis and the degree as a whole (Thune and Olsen, 2009: 7). The overall impression is that students who work alone are less positive about their experiences than students who have been part of a bigger research team. Most students have gained experience about several ways to disseminate their research topic as publishing articles, writing book and taking part in conferences. Project work, teamwork and other forms of collaborations are common ways to undertake research. However, just around 50 % of the students have gained experience in teamwork, collaborations in projects and collaborations with industry. This applies to a less extent to students within humanities than other disciplines (Thune and Olsen, 2009:29, Brofoss and Olsen, 2007:6). Networking with peers is yet another important purpose of doctoral training to make the students establish their own relations and to achieve integrity into the research field. Around 50 % of the students think they have achieved a national or international network (Kyvik and Olsen, 2007:22).

When it comes to skills, most students have gained insight into theoretical and methodological questions, including ethical issues and they have been trained in analytical thinking to deal with complex ideas. Just a few have acquired leadership and project planning and management skills. These skills are however, highly valued by the students who have had the opportunity to take part and practise in research projects (Thune and Olsen 2009, Kyvik and Olsen, 2007). Students would have liked to gain better insight into research management, project planning and management and research methodology and see potential improvements in these fields. They would also have liked to work more in team across disciplines and to have spent more time on networking with peers nationally and internationally.

Commercialisation and entrepreneurship are attractive skills to those who have found other types of work than research (Kyvik and Olsen, 2007:26-27).

5.5 Discussion

Industry-academia collaborations

The first category of papers looks specifically into doctoral education in industry-academia collaborations. Doctoral students´ role in industry-academia collaborations has been examined by several scholars. There are indications that doctoral students are involved in knowledge transfer between the sectors, they maintain networks and they produce new knowledge, although the studies conclude that more empirical studies have to be done (Thune, 2009, Mendoza, 2007, Hakala, 2009, Morris et al, 2011). The students may also be the reason itself for maintaining the collaborative relationship. Firms and the academe have to cooperate in order to foster a good learning environment for the individual Ph.D. student and in this way knowledge is transferred between the two sectors (Salminen-Karlsson and Wallgren, 2008). Collaborative relationships have potentially negative impact of the learning environment in terms of different reporting systems, different norms of conduct, possible contradictory advice from the two supervisors or simply less involvement by the firm leaving the students their own. Studies seem to conclude somewhat differently on this question. Two papers show that collaborative relationships often are formally and informally well-regulated, which protect students from getting involved in potential conflicting issues (Thune, 2010: 478, Salminen-Karlsson and Wallgren, 2008). Still, students may experience that the firm does not to take much interest in their research project and that they do not become sufficiently integrated in the industrial research environment. Two other papers claim that potential conflicting issues may lead to compromises, for instance about the research project, which leave nobody really satisfied with the outcome (Malfroy 2010, Borell-Damian et al, 2010).

A central question, however, is what students actually learn through doing their Ph.D. in a collaborative relationship with industry. On the one hand, students are exposed to a heterogeneous learning environment, which normally provides diverse perspectives and possibilities to apply knowledge, methods and skills across contexts. On the other hand, collaborative students do not differ from non-collaborative students when it comes to publishing and patenting and it is still the academic standards that are the most important requirements to be met for all students (Thune, 2009, Mendoza, 2007, Hakala, 2009). Skills that enable students to produce a piece of original research and to put this knowledge into wording would thus assumingly be the most central learning outcome also for students in collaborative relationships. Research specific skills include technical skills, analytical thinking, and scientific knowledge as well as academic writing. Collaborative students get a high score on these skills and that supports assumption number one from the theoretical framework. Know-what and know-why knowledge is explicit and thus easy to identify. Besides, students have to meet academic standards as the main requirement to obtain their degree.

In addition, it seems to be fair to conclude that collaborative students have gained broader employability perspectives by learning to apply skills and knowledge acquired through research in industry. Still, scholars focusing on the students´ role in industry-academia collaborations have not examined skills and skills acquisition to a large extent, so the conclusion must be drawn carefully. Findings are scarce and do not really provide a sufficient basis to say much about the second assumption from the theoretical framework about the acquirement of know-how and know-who knowledge as well as generic skills.

On the other hand, scholars that take up collaborative doctoral programs do focus on skills. An enhanced focus on employability skills has led to the development of collaborative doctoral programs, which leave student with a doctoral degree meeting academic standards, but also with a broader set of skills and contacts to external partners. Several scholars discuss these rather recent developments, taking mainly two perspectives; 1) collaborative and professional doctorates are results of an evolutionary development of doctoral education that meet future societal, intellectual and economic needs (Pearce, 2005, Servage 2009, Chiteng and Hendel, 2011) or 2) collaborative and professional doctorates are diluting the concept of the doctoral degree, reducing it to a “profession” (Barnacle and Dall´Alba, 2011, Craswell, 2007). Scholars taking this second perspective often criticize the collaborative programs of being built upon a deficit model, which assumes that there is a skills mismatch between firms and students (Craswell, 2007, Pearson et al, 2011, Grande, 2010). This is obviously subject to debate. Doctoral students are heterogeneous and many have several years of full-time work before embarking their Ph.D., which means they will enter doctoral education with different levels of skills. Employers will also have different expectations about which skills and competences doctoral students should possess. The most extensive study on Ph.D. education in industry-academia collaborations carried out by Borrell-Damian et al (2009) takes up skills firms normally are looking for when recruiting staff. Firms tend to prefer candidates with both strong research skills as technical skills, analytical thinking, and scientific knowledge and transferable skills, such as communication skills, leadership skills, project management skills, ability and willingness to change, creative abilities, personal effectiveness and the ability to handle complex problems (Borell-Damian 2009, de Grande et al, 2009). These findings indicate that a mix of research specific and generic skills is most attractive on the labour market, which implies that doctoral education should facilitate the development of these skills.

Career destinations

The second group of papers take up career trajectories. Studies show that doctoral education carried out in industry-academia collaborations has an impact on students´ career destinations as more collaborative students chose industry than non-collaborative students (Thune, 2010:480, Morris et al 2011). Career choices are naturally also about personal attributes and preferences as concerns for salary, access to resources, interest in downstream work and academic freedom. Possibility to find steady work in industry opposed to academia may also influence career choices (Roach and Sauermann, 2009, de Grande et al, 2009). Studies carried out in different parts of the world show that as much as 90 % of doctoral students find work soon after graduation and that about half of them end up in academia. The studies provide similar findings on employment in industry, with a share of around 20 % of the graduates in different positions in firms. The rest find work in other types of research institutions and in non-research employment. The numbers are much in line with the students´ own perception of their career possibilities (Neumann and Tan, 2011, Olsen, 2007, Thune and Olsen, 2009, Kyvik and Olsen, 2007). These findings indicate that doctoral education carried out in industry-academia collaboration will have a positive effect of the students´ careers, in terms of increased job opportunities. More graduates are expected to find work in industry in near future as more Ph.D. students are educated and the number of academic positions is limited. This could also possibly lead to more mobility between sectors as well as increased use of part-time professorship positions, as the Professor II positions in Norway. This also supports the theoretical assumption set out in chapter 3 about collaborative students seeking a career in industry or in the intermediate labour market.

Theoretical contributions

In the third category we find a reasonable body of literature that theorize the purpose of doctoral education and skills acquisition in doctoral training, focusing on the formative development of the students. Many scholars highlight the duality of the doctorate, seeing the

Ph.D. both as a product and a process (Lee et al, 2009, Cumming, 2010, Hopwood, 2010, Mowbray and Halse, 2010). However, it seems to be mainly two views on the link between the product and the process. Supporters of human capital theory see the doctorate as a system of inputs and outputs, where human resources is the main input and new knowledge as well as graduates are core output. Supporters of sociocultural theory on the other hand apply a holistic approach, with several components that are interdependent and interrelated (Cumming, 2010, Hopwood, 2010). Some of these papers seek to provide an alternative framework to the more instrumental view on students´ development as an accumulative product of different skills. Further on they can be seen to represent a critical voice of the many policy motivated frameworks of desired learning outcomes and the formalised training opportunities on various skills, claiming that not all skills can be acquired through formal training. These scholars are typically from the United Kingdom or Australia where qualification frameworks and skills training have been particularly debated.

Within the sociocultural orientation the individual and the research practises are at centre. Research is defined as a contextualised social practise, which implies that certain skills can only be acquired through practising, and especially in interaction with others (Hopwood, 2010, Maxwell and Smyth, 2009). Skills acquisition is characterised as an integrated and inseparable part of research production, which implies gaining first-hand experience *in situ*. This requires individual performance and personal engagement by the doctoral students, which puts the individual at centre (Baker and Lattuca, 2010). Alternatively, practises are at centre, as practises embrace concepts as skilful performance, artistry and know-how (Cumming, 2010). The papers thus conclude that many skills cannot be taught independently from the research activities in which the individual doctoral student takes part. Creativity, writing skills, interpersonal skills, project management, entrepreneurship, teamwork/collaboration, problem solving and the combination of different skills are mentioned as concrete skills that must be acquired through practising and social interaction. Supervision is an important component of the social practise, assisting the doctoral student in the skills acquisition process (Whitelock et al, 2008, Zhu 2004, Bender and Windsor, 2010).

Three papers (Barnacle and Alba, 2011, Mowbray and Halse, 2010, Wray and Wallace, 2011) emphasize the need for proper learning support in order to foster skills acquisition. Input should be integrated into each individuals´ research repertoire through practise. Moreover, doctoral students should be made aware of how they can improve their practises and develop further their know-how. In this way, the ownership of the skills development process is put by the individual student, who has to identify and articulate own training needs. Learning support must then offer appropriate tools to help the student identify these needs. This will have implication for how doctoral education is organised, which tools are offered and how concepts of learning, skills development and competence building are embedded in doctoral education.

All in all, the theoretical contributions from this literature review support the innovation literature when it comes to know-how and know-who knowledge being developed through practise and social interaction. Moreover, the DUI mode of learning and innovation is highlighted as facilitator for skills development in general, including know-what and know-why knowledge. This is in line with Jensen et al (2007), who set out that increased attention should be paid to the DUI mode of learning and innovation as an innovation strategy and to access knowledge embodied in people.

Empirical contributions

The last category of papers looked into how students value skills. The overall conclusion seems to be that generic and transferrable skills are most valued (Pole, 2000, Zellner, 2003, Lee et al, 2009). This is probably due to the fact that specific knowledge such as theories, methods, procedures and techniques gained from ones research field have less usability than generic skills that can be used in many contexts. There also seem to be difference between collaborative students and non-collaborative students, when it comes to how they value skills. Management skills, understanding of intellectual property and commercialization issues, entrepreneurship and the ability to work in interdisciplinary are higher valued by the collaborative students (Manathunga et al, 2009, Manathunga et al, 2011, Bienkowska and Klofsten, 2011). In general, students who develop certain skills, tend to value these skills higher than students who do not report to have developed the same set of skills (Alpay and Walsh, 2008, Thune and Olsen, 2009:52, Olsen 2007). The extent to which students develop employability skills seem to vary, also in programs that aim to provide students with these skills. Findings also indicate that students in collaborative programs enjoy better learning support, since they have two supervisors and have generally better access to resources in these programs (Harman, 2004, Morris, 2008, Loxley and Seery, 2012). Students who receive much learning support and who work in teams are generally more satisfied and report higher learning outcome than those who work alone (Alpay and Walsh, 2008, Platow, 2012, Thune and Olsen, 2009:29, Brofoss and Olsen, 2007). It seems to be fair to conclude that appropriate learning support is a key factor to success both when it comes to the overall student satisfaction and the development of skills. The student being part of a bigger research team seem to get higher learning outcome probably due to richer input and to the fact that practise in interaction with others fosters development of skills, know-how and professional identity as research in this literature review suggest.

The papers represented apply a range of different methods. The theoretical contributions mainly use human capital theory, network theories and sociocultural theories (Baker and Lattuca, 2010, Barnacle and Dall´Alba, Cumming, 2010, Gilbert et al, 2004, Hopwood, 2010, Mowbray and Halse, 2010, Servage, 2009, Wray and Wallace, 2011). Some also review literature (Park, 2005, Pearce, 2005, Thune, 2009). The empirical studies apply statistical analyses of existing data in registers (Brofoss and Olsen, 2007, Chiteng and Hendel, 2011, Kyvik and Olsen, 2009, Olsen, 2007) surveys/questionnaires/self-assessments (Bienkowska and Klofsten, 2011, Borell-Damian et al, 2009, De Grande et al., 2009, Nerad, 2004, Kyvik and Olsen, 2007, Lee et al, 2010, Manathunga et al, 2009, Manathunga et al, 2011, Morris et al, 2011, Pearson et al, 2011, Platow, 2012, Roach and Sauermann, 2009, Thune and Olsen, 2009, Zellner, 2003) interviews (Harman, 2004, Loxley and Seery, 2012, Malfroy, 2010, Mendoza, 2007, Pole, 2000, Salminen-Karlsson and Wallgren, 2007, Thune 2010, Zhu 2004, Watson 2001, Whitelock et al 2008) and case studies (Hakala, 2009, Neumann and Tan, 2011). Many studies combine different theoretical approaches, methods and include more than one target group, for instance students and supervisors, study programs and firms. They typically use large data sets from national survey or existing databases. In this sense, the papers represent diverse perspectives and shed light upon learning outcomes, skills and skills acquisitions in doctoral education in general and in doctoral education in collaborative relationships in particular from different angels. This should make the findings rather robust. However, some of the methodological challenges discussed in chapter 4 could also apply to several of these studies. Skills as a concept are basically not problematized, although many papers discuss skills and skills acquisition. There are also only a couple of examples of longitudinal studies.

Summing up

Skills that enable students to produce a piece of original research and to put this knowledge into wording seem to be the most central learning outcome for students in collaborative relationships. In addition, they seem to have gained broader employability perspectives by learning how to apply skills and knowledge acquired through research in industry. On the other hand, there does not seem to be clear evidence of generic skills development. Studies conclude differently on acquisition of entrepreneurship, commercialisation, project development, management, team work, networking among other skills. Still, both employers and the students themselves seem to be most satisfied with a mix of both research specific and generic skills, which indicates that individuals possessing a certain skills mix are the most attractive on the labour market. The degrees to which students acquire an appropriate skills mix seem to vary according to what extent the students have received proper learning support. New input should ideally be integrated into each individuals´ research repertoire through social practise of carrying out research.

The next chapter looks into the empirical findings of this study and the main question is then whether students´ connections to industry has an impact on their skills and skills acquisition, aiming to shed further light upon learning outcomes from doctoral education in industry-academia collaborations.

6.0 Analysis of empirical findings

This chapter gives a presentation of the data collected through the questionnaire. The data has been analysed statistically with Statistical Package for Social Sciences (SPSS) and the analysis is limited to a descriptive analysis of frequencies and percentages, cross-tabulations, construction of new variables, factor analysis and t-tests.

Further statistics could be carried out to check possible relationship between skills acquisition, industry links and even other variables. A regression analysis typically includes many techniques for modelling and analysing the relationship between several variables and would be suitable for the research question of this thesis. The regression analysis also controls for potential effect from other variables, which would also be relevant. Still, the data set of this study is a little too small to provide strong evidence on statistical relationships and I would not think further statistics on this material will provide further insight. Hence, it will be up to future studies with access to extensive data sets to give a closer examination of this question.

6.1 Expectations about findings from the questionnaire

The most central question in this study is whether students´ connections to industry do have an impact on their skills acquisition. Assumptions derived from the innovation literature in chapter 3 indicate that students in collaborative relationships learn both explicit and implicit knowledge due to heterogeneous learning environment. Being in a collaborative relationship would in this way have a positive impact on the student´ s skills and skills acquisition. The literature review confirms that students particularly learn how to apply research specific skills in industry and that they get broader employability perspectives. The literature review also shows that skills enabling students to produce a piece of original research and to put this knowledge into wording is the most central learning outcome for any doctoral student regardless of links to other sectors. This knowledge is explicit and easy to articulate, which means it is easy to report on. Further on, as seen in chapter 2, Norwegian doctoral education follows the same standards and guidelines, with the doctoral thesis as the main output. Findings would therefore probably show high scores on research specific skills, including knowledge within a specific research area, broader knowledge within a research discipline, analytical thinking, lateral thinking/problem solving, synthesis and evaluation of new ideas, creativity as well as specific and general research methods.

A commonly used argument for doctoral training in collaborative relationships is that industry, and even independent research institute and public sector, would provide the students with additional skills related to project development, management and team building. Industry is also focused on entrepreneurship and commercialisation and students would assumingly get insight into these matters too. However, findings from the literature review do not entirely support this assumption. To what extent the students also acquire generic skills seem to vary with the learning support they receive. Hence, I would expect lower scores on generic skills, but still being a central learning outcome. I would thus also expect a relationship between connections to industry and the skills acquired.

When it comes to career prospects, the literature review reveals that connections to industry have great impact on students´ career choices as they get to know different working environments and how to apply research specific skills in different settings. Findings from the questionnaire will most likely confirm this notion. On the other hand, previous studies show that students do not learn to a large extent how to build a research career, within the academe or in other sectors. Career counselling is scarce and there is little focus on employability during the Ph.D. degree. Low scores on these skills could therefore be expected.

Further on, skills connected to an understanding of the wider societal and political context in which research takes place would probably receive medium scores. Doing a Ph.D. implies to get to know research which means that the students also get to know the context to various extents. However, it is probably hard to tell to what extent one knows the context. It is also a big question, which requires a bit of an answer that probably would fit better with a qualitative research design and not a questionnaire. Still, the score may give an indication on this question. Skills concerning application for external funding could be linked to an understanding of the research context as societal and political relevance of the research is central in most calls of proposals. Scores on this question would therefore assumingly be similar to the scores on the question concerning the research context.

The questionnaire includes one question about preferred learning methods, since a rather big body of literature emphasize that skills acquisition takes place when carrying out research in social interaction with others. Students most likely prefer different learning methods, since we all have personal preferences, but findings may indicate whether a major part of the students do think that carrying out own research actually is the most central method for acquiring different skills.

6.2 Responses

The questionnaire was sent to 241 doctoral students. Five of the students withdraw themselves from the study, which gives a total sample of 236 possible respondents. The sample was not evenly distributed across institutions, as seen in table 6.1, since a major part belongs to NTNU. Many students have also connections to Simula. This may explain the high number of respondents within technology. There were 73 doctoral students responding to the questionnaire, which gives a response rate of around 31 %. This is not a high response rate and interpretations must be done accordingly. More than half of the respondents are students at NTNU and almost one in ten are connected to Simula. Both the sample and the respondents are thus somewhat biased and the findings first of all say something about Ph.D. students at these two institutions. Hence, inferences to a bigger population must be done carefully.

Table 6.1	Respondents to questionnaire on learning outcomes in doctoral education			
All	Respondents	Not answered	N	Response rate
	73	163	236	30,9 %
AHO	0	5	5	0,00 %
HiBu	1	0	1	0,42 %
HiMolde	0	1	1	0,00 %
HiVe	0	3	3	0,00 %
NGI	1	0	1	0,42 %
NHH	5	3	8	2,12 %
NORUT	3	3	6	1,27 %
NTNU	39	65	104	16, 53 %
Simula	9	30	39	3,83 %
SINTEF	3	10	13	1,27 %
UiO	5	16	21	2,12 %
UiS	0	10	10	0,00 %
UiT	4	16	20	1,70 %
Østfoldforsk	2	0	2	0,85 %
Vestforsk	1	1	2	0,42 %

On the other hand, the respondents can be said to provide quite reliable data. The questionnaire looks into at what stage of their doctoral degree the students are. Less than 20 % reported to be at the beginning of their doctoral education, which means that more than 80 % were either half way or about to finish their degree. The students are thus likely to give reliable answers about their learning outcomes as they can tell from actual experience. The questionnaire also included a question about from what point of departure the students answered the question on skills and competences. 94 % said they answered from what they think they actually have learnt during their Ph.D., 3 % said they answered from what they think Ph.D. students normally learn and yet another 3 % said they answered from the explicit learning goals stated in curricula and courses. This further strengthens the reliability of their answers on skills and learning outcome, since the majority answered from what they think they actually have learnt.

6.3 Data

Demographic characteristics

Respondents to questionnaires are often quite young. This is also the case in this study. We find as much almost 2/3 of the respondents in the age group of 25-32 years. Only around one in ten is in the two upper categories of 38-44 and 45+. The remaining 1/4 are in the age group 33-38. Mainly men answered to this survey. Only 1/3 of respondents were women and that is a little surprising taking into account that 46 % of doctoral students in Norway today are women (NIFU, 2012).

Table 6.2	Demographic characteristics and disciplines				N
Gender	**Men**		**Women**		
Citizenship	Norwegian	Foreign	Norwegian	Foreign	
<u>Disciplines</u>					
Humanities/Social Sc.	3	0	7	2	12
Technology/Agriculture	8	14	3	2	27
Natural sc./Life sc.	3	8	4	1	16
Business/Management	8	2	3	5	18
N	22	24	17	10	73
Asymp. Sig. (2-sided): 0,007 (Pearson´s Chi-Square)					

However, gender can truly be linked to the high percentage of the respondents within technology/agriculture and natural sciences/life science, which are disciplines dominated by males. 37 %, and close to 22 %, were respectively within these disciplines. Women normally dominate humanities/social sciences and here we find 16 % of the respondents. The last category is business/management where there are nearly 25 %. More than half of the respondents are Norwegian citizens living in Norway before embarking their Ph.D. Around 30 % are foreign citizens coming to Norway in order to take a Ph.D. and the remaining 15 % are foreign citizens living in Norway even before they started their doctoral education. This gives a share of more than 45 % of foreign citizens, which is more than the overall percentage of foreigners in today’s Norwegian doctoral education. Data provided by NIFU show that 33 % of all doctoral students in Norway had a foreign citizenship in 2011 (NIFU, 2012). Again, this may be linked to the high share of respondents within technology and natural sciences, where the share of native Norwegians is low. Recruitment of Norwegian to technology/natural science tends to be scarce also at undergraduate level, which may partly explain the big share of foreigners at the Ph.D. level. Norwegians are to be found within humanities/social sciences, which can be characterised as more nationally oriented disciplines that attract nationals mainly. A Pearson´ s chi-square test indicates that there is a dependency relationship between the variables gender, citizenship and discipline. The relationship between these variables can most likely be explained with the uneven recruitment of Norwegians versus non-Norwegians to different disciplines.

Work experience

When it comes to work experience outside academia before embarking a Ph.D., the respondents allocate themselves neatly into three groups. Almost 1/3 of the respondents had more than 5 years' work experience. On the other end of the scale, we find the other 1/3 of respondents with no work experience at all. 20 % had 1-2 years and 15 % had 3-4 years' work experience. The younger students have generally less work experience than the older, which of course is natural. However, we find 20 %, or 15 respondents, in the age group 33-38 with more than 5 years' work experience.

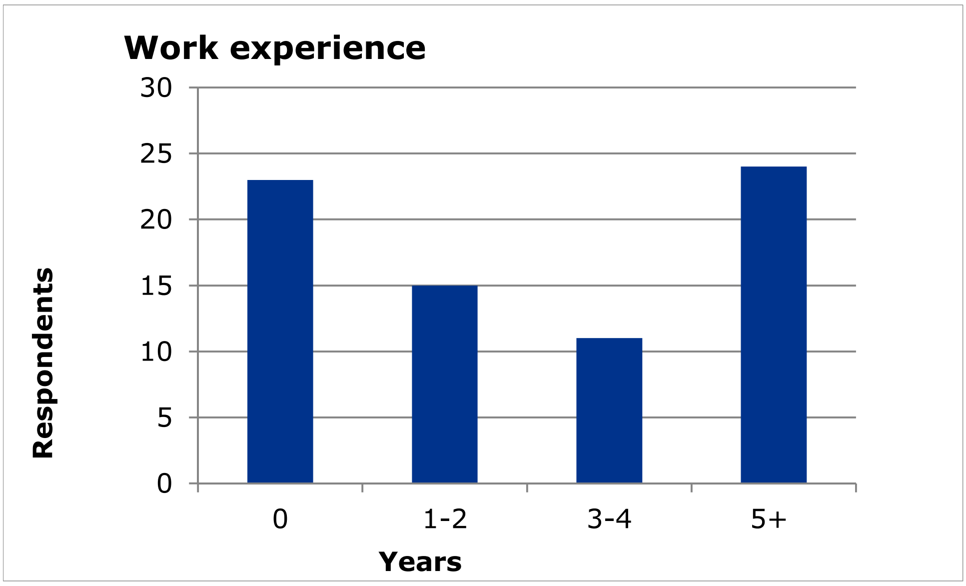

Figure 6.1: Number of years of work experience previous to Ph.D. education

Skills and learning outcomes

When it comes to the reported skills, we can see from figure 6.2 that, as expected, research specific skills get the highest scores. Knowledge within a specific research area and research methodologies that apply to that area are the most central. Broader knowledge within a research discipline and research methods in general are also acquired by most of the respondents.

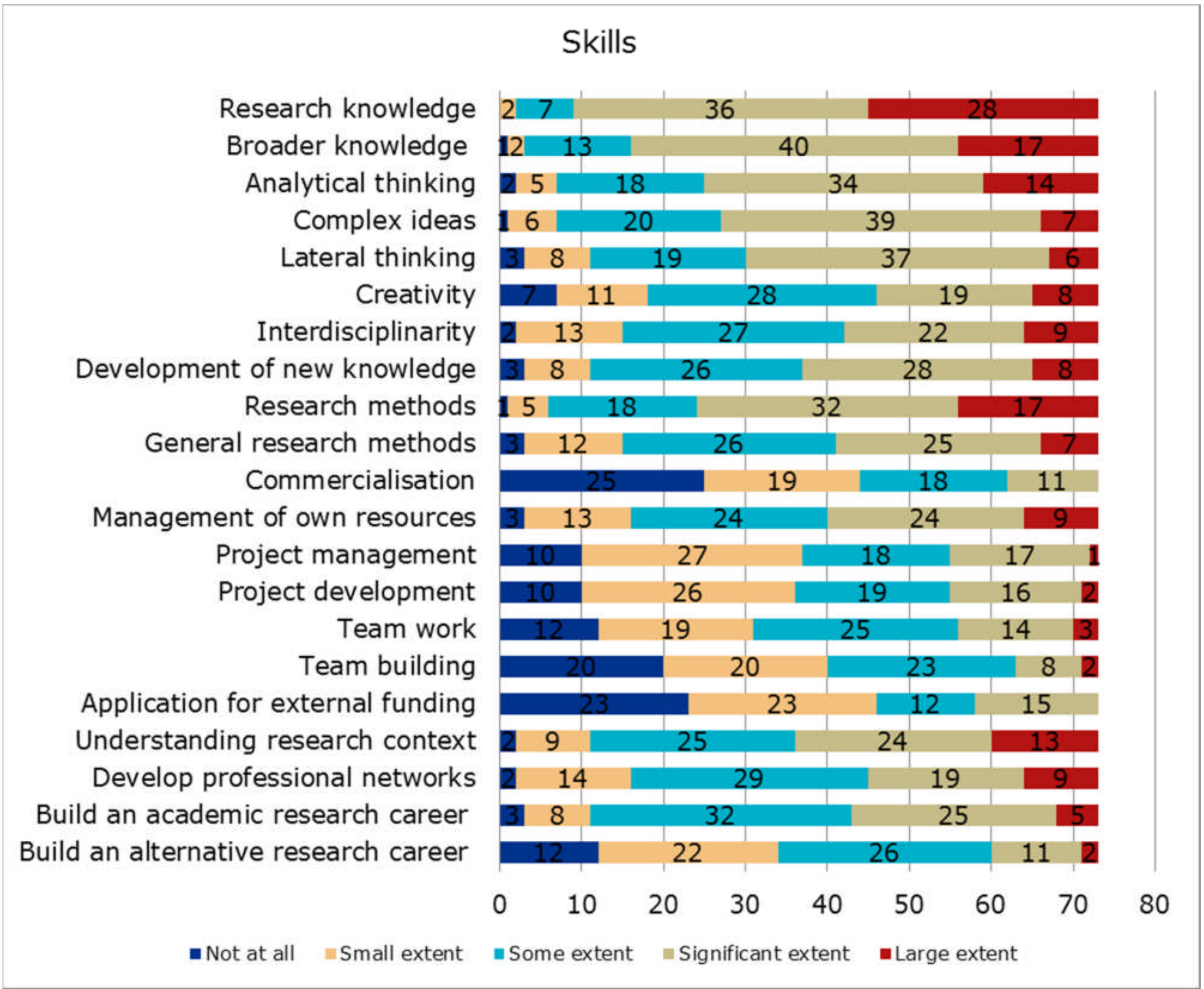

Figure 6.2: Specific and generic skills acquired in Norwegian Ph.D. education

Further on, skills connected to carrying out research, as analytical thinking, problem solving and evaluation and synthesis of new and complex ideas, are also important outcome of doctoral education. These findings are in line with findings from the literature review (Thune, 2009, Mendoza, 2007, Hakala, 2009). Academic standards are the most central to be met and students learn research specific skills. It may also follow from the common guidelines and regulation for all doctoral training in Norway as described in chapter 2. Besides, it can be said that these skills are embedded in research itself and especially in the practise of research. The findings thus confirm that research specific skills are a central output from doctoral education carried out in industry-academia collaboration. High scores are also found on the understanding of the societal and political context in which research takes place. Only 10 respondents answer “not at all” or to a “small extent” on this question.

On the other end of the scale we find application for external funding and entrepreneurship/commercialisation with quite low scores. Only one in four reports they have learnt something about entrepreneurship/commercialisation to some extent or to a significant extent. Taking into account that most of the respondents had a relationship to a sector that works with commercialisation and entrepreneurship, this finding is somewhat surprising. It suggests that most of the doctoral students have not been involved in commercialisation processes in the firms. Low scores on application of external funding is, on one hand, quite natural as most Ph.D. students have funding for their education already in place and do not need to spend time on applications at this stage. On the other hand, one could also think that high scores on understanding of the societal and political context would have given high scores on application for external funding, as funding instruments often are designed to enhance research that responds to a wider societal and political context.

Creativity, interdisciplinary approaches and creation of new knowledge get similar scores in the middle of the scale, which means that these skills are acquired to a rather big extent. Producing a doctorate requires creation of new knowledge and it thus seems reasonable to have acquired skills about how to develop that knowledge. Creativity goes in line with the process of creating new knowledge. Similar scores on these two skills is an expected finding and confirms findings from previous studies (Malfroy 2010, Borell-Damian et al, 2010). Similar scores on interdisciplinary approaches are more surprising due to the fact that doctoral education most often is carried out within a specific discipline. Disciplinary traditions are still dominating in research, although different initiatives have encouraged interdisciplinary the last years (Research Council of Norway, 2011). Hence, a possible explanation could be diversified input from different research environments in a collaborative relationship. I come back to the question in paragraph 6.5, where I will look into differences in scores on skills between students with weak links to industry and students with strong links to industry. Management of own time and resources is also a skill with rather high scores, which probably shows that doctoral education has a disciplinary effect on students´ effectiveness and routines in order to fulfil the goals of their education.

Project management, project development, team work and team building are reported as skills that are acquired to a more limited extent than other skills. “Not at all” and to a “small extent” are the response alternatives chosen by half of the respondents and only 1-3 individuals give top score here. These findings confirm that academic and research specific skills still are the most central in doctoral education regardless of connections to other sectors. Project management and development as well as team work and team building are often understood as skills that are more central in industry than in academia, which should mean that there is still further potential to take advantage of competences found in industry in doctoral education to enhance students´ skills acquisition.

When it comes to building a career within research, more students report that they have learnt how to build an academic career than an alternative career outside academia. Close to 90 % thinks they have learnt to build an academic career, while half of the students report to know how to build an alternative career. Finally, development of professional networks, nationally and internationally, receives fairly high scores. This differs from previous studies, where students report to have rather weak professional networks (Thune and Olsen, 2009, Kyvik and Olsen 2007).

Learning methods

The literature review shows that many researchers are engaged in the question on what is the best learning method for acquiring skills. Most researchers argue that learning take place when practising research, especially in social interaction with others. The questionnaire included one question on learning methods, inviting the respondents to rank different learning methods. Unfortunately, this question has a lower response rate than the other question, as there turned out to be a technical problem with the quest. Table Figure 6.3 resumes the total of responses, which vary from question to question.

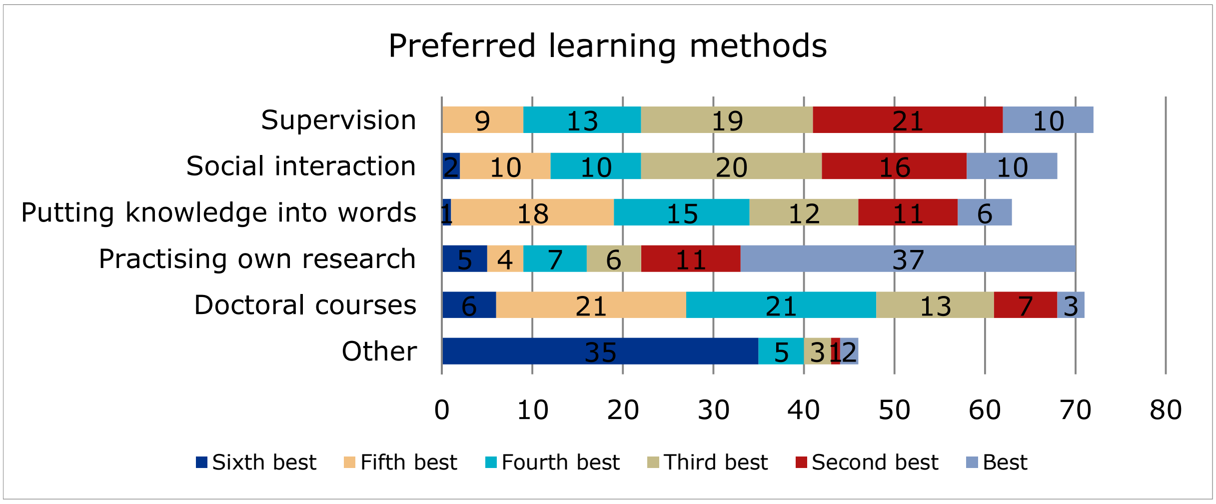

Figure 6.3: Students´ preferred learning methods

However, the figure confirms that indeed, practising own research in social interaction, negotiation of meaning with peers and supervision make up the top three preferred learning methods. As much as 2/3 of the students hold these learning methods for the three preferred methods. The list of learning methods is not exhaustive and includes an "other" category to see whether students would prefer a totally different method of learning. In spite of few respondents, the figure clearly shows that "other" was the less preferred method. About one in four had doctoral courses among their top three learning methods, while putting ones knowledge into words was ranked among the top three of about 1/3 of the students.

Little in this material can indicate whether the students think they have received proper learning support. According to findings from the literature review, input should be integrated into each individuals´ research repertoire through practise and students should be made aware of how they can improve their practises and develop further their know-how (Barnacle and Alba, 2011, Mowbray and Halse, 2010, Wray and Wallace, 2011). Students should in this way take ownership of the skills development process and learning support must then offer appropriate tools to help the student identify training needs. Again, little in this material can indicate whether the students themselves take an ownership to their own skills and skills acquisition process and whether they actively seek to get insight into project management, team building, leadership, commercialisation processes and so on. Being in touch with industry probably provide opportunities to learn these skills, but may still not be explored by the students. Further research would be needed to determine proper learning support for doctoral students in industry-academia collaborations. Still, findings from this questionnaire indicate that practising own research is a central way of learning, which means that students should be made aware of possible skills that could be acquired through that process and of how industry possibly could assist in their acquisition of these skills.

Links to industry

Students have several connections to industry. As seen in figure 6.4 below, the relevance of Ph.D. research question for industry is a common link. As much as 2/3 of the students carry out research with importance to industry.

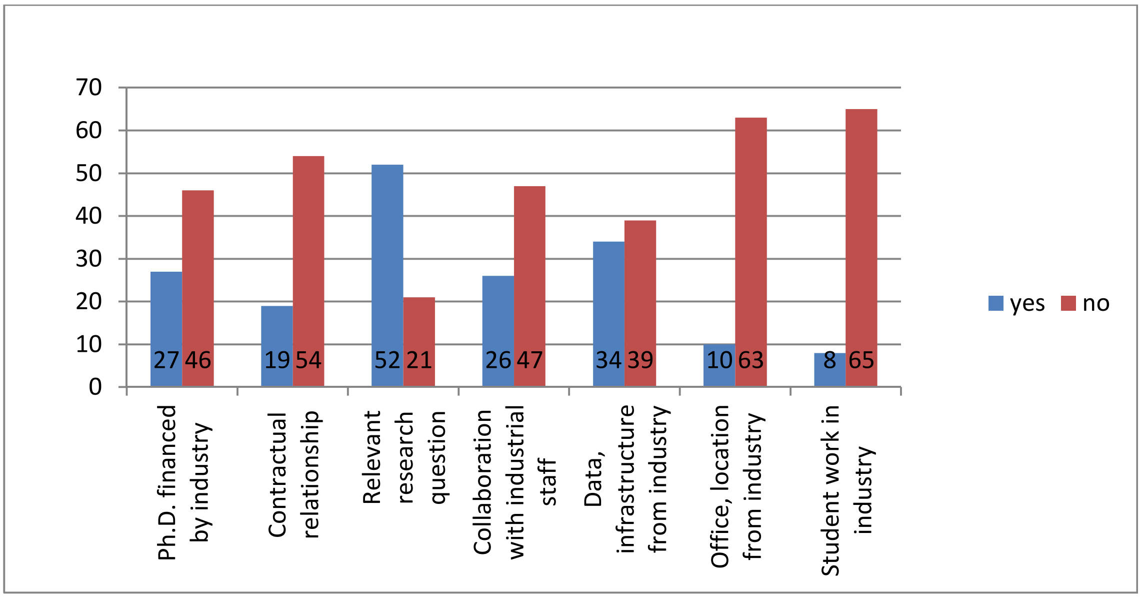

Figure 6.4: Links to industry

Around half of the students use data or infrastructure provided by industry, an aspect which is also likely to be connected to the research question´ s relevance to industry. However, only ten students take advantage of office or other forms of location provided by industry. Hence, students do not necessarily stay physically close to an industrial partner although their research is relevant to industry. An exception is of course those who work in industry while doing their Ph.D., but that counts for only 8 of the respondents. On the other hand, collaboration with staff in industry is quite common as 1/3 report that they carry out their research in cooperation with industrial staff. Finally, the more formal relations to industry are found in contractual relationships and industrial finance of doctoral education. Around 1/3 of the respondents report their education to be financed by industry and about one in four has a contract with an industrial partner. All in all, the informal links to industry are more typical than formal links among these respondents.

Career prospects

The students were also asked about their future career prospects and the respondents spread into all categories. In fact, almost 1/3 wishes for a career as researchers within industry. One in four would prefer the independent research institutes, while only about one in five says they would go for a career within academia. Doing research in other sectors as governmental institutions or organisations is most attractive to only a few of the students and the remaining 13 students are not planning to continue research.

Table 6.3	Career prospects and disciplines		N
Disciplines	Humanities/ Business	Technology/ Natural sc.	
<u>Career destinations</u>			
Academic career	7	5	12
Institute sector	6	13	19
Private industry	8	15	23
Research, other sector	2	4	6
Other type of job	7	6	13
N	30	43	73
Asym sig (2-sided): 0,465 (Pearson´ s Chi-Square)			

These numbers differ from previous studies, which showed that half of the students wish for an academic career, one in five wishes for a job in an independent research institute and only a few prefer to work in industry (Thune and Olsen, 2009, Kyvik and Olsen 2007). This may be an expression of the students´ directing themselves towards secure and permanent jobs, as job opportunities within academia are scarce. There is however differences according to research discipline, although they are not very big. Students within technology and natural science/life science generally wish for a career in industry or in the independent research sector, while students within humanities/social sciences and business/management generally prefer industry or academia. This can probably also be explained by available job opportunities to researchers within technology/natural sciences, as there are more technological institutes. There are also more students within humanities/business than among the students within technology/natural sciences that do not plan to continue research. The data set is small and the finding can be random. It could however also indicate that researchers within humanities/business think they can use their competence as well in other jobs as well as within research.

There are also a few differences according to citizenship. Among the students with a foreign citizenship 35 % go for a career in industry, 12 % prefer an academic career and 32 % wish for a career within the independent industry sector. Among the Norwegians 28 % prefer industry, as much as 20 % will try an academic career and another 20 % will work in the institute sector. This differs from previous studies, where more foreigners aim at a career within the academe, while Norwegians tend to be disposed to a career elsewhere. Again, this may be explained by discipline rather than citizenship. In this study there are more Norwegians within humanities/business, which seems to direct students towards an academic career. The share of students that want to drop out of research is about the same regardless of citizenship.

Finally, the students were asked if they think they are better prepared for a career in industry with a Ph.D. compared to holding a Master degree. Half of the students think they will do a better job having completed doctoral education. Only one in six thinks they are as good with a Master degree. The last 1/3 report that they do not know. Since rather few thinks a Master degree prepares them well enough for work in industry, it seems to be fair to say that students recognise the value of their Ph.D. degree and that they probably consider employers to do the same. Still, quite many are insecure about the question, which may indicate lack of awareness about what competences a Ph.D. holder actually possesses as well as doubts about the employer´ s ability to take advantage of these competences.

Value added from collaboration with industry

One open-ended question on the value added from doing the Ph.D. in a collaborative relationship was included in the questionnaire. The answers mainly touched upon four different aspects. Firstly, many students are motivated by the reality orientation and applicability of research that industry provides. Industry gives the opportunity to implement and develop solutions in real applicative contexts. As one respondent puts it:

"Theory without practice is not that relevant, so industry helps to better understand academic research" (Quote from questionnaire)

Secondly, there were a reasonable number of respondents highlighting industry´ s use and benefit of the Ph.D. research results. Improvement in product quality, increased efficiency of the production and finding solutions to industrial challenges or bottlenecks were mentioned as examples. A third aspect is the Ph.D. students´ benefit from industry such as access to data, learning how industry works, new ways of thinking and learning in-depth methods commonly used in industry. Some also mentioned project planning, management and economic aspects of research projects.

A fourth group of comments focused on the integrative and social part, in which the students find themselves with industry. Central here is getting to know people in industry, keep in touch with useful contacts, networking and potential job opportunities. Many also point out industry´ s positive impact on their research.

“I've learned a great deal of what is needed in the research project in which I am involved, and through other meetings with external industry partners. It serves both as a significant motivating factor, as well as steers my research to be meaningful for real world applications” (Quote from questionnaire).

The students´ comments give a more nuanced picture of the learning outcome from being in a collaborative relationship. The ability to see how the students´ own research is applicable in the real life seems to be a key word. An enhanced understanding of research and the research process also seems to be a key outcome, as well as access to and maintenance of useful networks.

6.4 Underlying dimensions of skills

For the 21 variables connected to skills, a factor analysis was carried out to examine the possible interdependent relationship between these skills and to see whether the different variables could be reduced down to a few important dimensions due to their interdependency. I did not have any theoretically or empirically founded assumptions about potential underlying dimensions among these variables. The factor analysis is thus explorative and the result is accordingly interpreted. The analysis pointed out five underlying dimensions as seen in table 6.4 Rotated Component Matrix.

Rotated Component Matrix[a]					
	Component				
	1	2	3	4	5
Research specific knowledge	-,001	,093	-,022	,838	,017
Broader knowledge within a research discipline	,344	,519	-,194	,561	,107
Analytical thinking	,813	,111	,208	,139	,074
Evaluation and synthesis of new and complex ideas	,764	-,117	,215	,314	,232
Lateral thinking/problem solving	,720	,052	,323	,359	,151
Creativity	,747	,247	,293	,070	,174
Interdisciplinary approaches	,606	,486	-,065	-,187	-,133
Specific research methods	,330	,127	,348	,743	,051
Research methods in general	,429	,351	,349	,420	,376
How to develop new knowledge within your research field	,228	,129	,568	,537	,263
Management of own time and resources	,023	,077	,713	,187	,299
Project management	,367	,214	,762	-,005	-,282
Project development	,399	,304	,737	-,035	-,215
Team work	,330	,457	,517	,144	,124
Team building	,419	,513	,384	,032	-,042
Understanding of the research context	,166	,053	-,013	,086	,860
Develop professional networks	,164	,771	,173	,213	-,005
Build an academic career	-,132	,870	,042	,178	,102
Build an alternative career	,081	,702	,315	-,079	,127
Commercialisation/Entrepreneurship	,353	,357	,556	,021	,473
Application for external funding	,239	,517	,333	,221	-,018
Cronbach´ s Alpha	,854	,799	,816	,796	

Table 6.4 Rotated Component Matrix.

There was a data loss of 28 %, which means that these dimensions explain 72 % of the variance. A factor should generally meet the following requirements: 1) Variables that share correlation with several factors should not be included. Correlation of .30 corresponds to 10 % variance that overlap with the other variables 2) The variance an observed variable share with the other variables in the factor should be .40 or higher. 4) A factor should include at least three single variables with a factor loading of minimum .30, preferably .50 and higher 5) Factors with a Cronbach’s alpha of at least .70 are said to represent variables with sufficient correlation and internal consistency (Costello and Osborne, 2005).

All factors have a Cronbach´ s alpha of more than .796. The other requirements are however, met to different degrees by the five factors. The most clear cut factor is the first one, which could be called a cognitive factor. It includes the variables on analytical thinking, synthesis and evaluation of new ideas, lateral thinking, creativity and interdisciplinary approaches with factor loadings of at least .606. However, lateral thinking, and interdisciplinary approaches also correlate with other factors with loadings of .359 and .486. Still, I believe the correlation with the cognitive factor is sufficiently stronger to be included here. Skills belonging to this cognitive dimension could be seen as naturally linked together as they concern cognitive abilities. Students possessing any of these skills would most likely also possess the others. The variable concerning research methods in general has also its highest correlation with the cognitive dimension, but in fact, it correlates with all five factors with loadings of at least .349, which means it does not meet the first requirement and should thus probably be excluded.

The second factor could be named the structural factor as it concerns more structural aspects. The underlying dimension here seems to be the ability to strategically build certain constructions, it being a team, a network, an application for funding or a career. Variables with high loadings along this dimension are especially networking with peers, knowledge about building an academic career as well as an alternative career with loadings of at least .702. The variables on application for external funding and team building have also their highest loading in this factor, although they correlate with other factors too. Broader knowledge within a research discipline has a factor loading of .519 on this dimension, while at the same time correlating a little stronger with factor number four. This variable does not seem to correlate with factor number two for some particular reason. On the other hand, one would think that team building and team work naturally link together. Team work does correlate with this dimension, but it correlates even stronger with the third factor, which can be seen as a management and innovation factor. A nearby explanation could be that team building requires a different type of ability linked to strategically planning opposed to team work, which requires abilities of more social characteristics. Another curiosity is that project development does not correlate strongly with this structural dimension. It would seem natural to see this skill as an ability to create a project. Instead this skill correlates stronger with the third factor on management and innovation.

The third factor includes management of own time and resources, project management, project development, team work as well as creation of new knowledge and entrepreneurship/commercialisation, all with a loading of at least .517. Management of own time and resources, project development and project management are the most clear cut variables. Communalities between these variables seem to be the ability to create something new and to handle this process. It would imply strategically thinking and acting to achieve ones goals and working together with others could be crucial in this process. Entrepreneurship/commercialisation correlates with all factors apart from the fourth factor on research specific skills. This finding is expected as entrepreneurship/commercialisation has little to do with research specific skills. On the other hand, it seems to share characteristics on cognitive abilities, structural aspects as well as the contextual dimension of research.

Research specific skills characterise the fourth factor, where we find knowledge about a specific research area and specific research methods applying to one´ s research discipline with especially high loading. In addition, broader knowledge within a research discipline has its highest loading on this dimension, although it also correlates with the second dimension. This factor highlights the peculiar characteristics of research specific skills, being different from all other kind of knowledge. The fact that we find broader knowledge within a research discipline and research methods in general correlating with more factors, probably demonstrates that skills and knowledge related to research specifically is interrelated with other types of abilities and knowledge at a more general level.

Finally, the fifth factor is about the understanding of the context in which research takes place and would thus be the contextual factor. No other variable has its highest factor loading along this dimension and the factor is not really useful for reduction purposes. This variable sticks out probably because it has a different character than the others in terms of being a rather complex question with potentially diverse answers. In the following, this variable and factor will be excluded. The four remaining factors are used in a T-test to examine a possible relationship and dependency between links to industry and skills acquisition.

6.5 The relationship between skills acquisition and links to industry

In order to examine the relationship between connections to industry and skills acquisitions, the variables connected to industry links were divided into two groups of weak and strong industry links. The questionnaire counted seven yes/no questions to detect doctoral student´ s links to industry. The "compute variable" functions in SPSS counted for the total number of "yes" answers to these seven questions. As seen in table 6.5 on weak and strong industry connection, as many as 15 students answered "no" to all questions, 13 students had answered "yes" to one of the questions, 14 students to two of the questions and so on.

	Frequency	Per cent	Strength
No links	15	20,5	Weak
One link	13	17,8	Weak
Two links	14	19,2	Strong
Three links	12	16,4	Strong
Four links	7	9,6	Strong
Five links	5	6,8	Strong
Six links	3	4,1	Strong
Seven links	4	5,5	Strong

Table 6.5: Strong and weak industry connections

The responses were further divided into two groups based on the number of links to industry. Those with weak links are characterised with no link at all or only one link to industry. Those with strong links have from two links to seven links to industry. Type of link to industry is however not counted for, so this measure does not say anything about a potential impact of formal versus informal links to industry. Future studies with bigger data sets should probably look deeper into this question.

I have used an independent sample T-test to compare the mean scores of two groups 1) weak industry links and 2) strong industry links on the four factors related to cognitive abilities, structural aspects, management and innovation and research specific skills. A T-test assumes that the two groups are independent of one another, that the dependent variable is normally distributed and that the two groups have approximately equal variance on the dependent variable. Levene´s test for equality of variances examine whether the variance of the two groups is equal. Significance values above .05 indicate that the variance is equal. The test with the variable connected to weak and strong industry link shows that the lowest value was .090, which then indicates that the variance of the two groups is equally distributed (Hellevik, 2004:408-409).

Further on, the independent sample T-test sets out a null hypothesis claiming that the means of the two groups are not significantly different. The alternate hypothesis says that the means of the two groups are significantly different. The T-test for weak and strong industry links demonstrates a non-significant result. Lowest significance value is .370, which means that the null hypothesis is supported. In other words, students with strong links to industry do not acquire skills differently from students with weak links to industry.

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
Weak and strong industry links		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Diff.	95% Confidence Interval of diff. Lower	Upper
Cognitive	Equal variances assumed	,754	,388	-,202	71	,841	-,216	1,071	-2,351	1,919
	Equal variances not assumed			-,213	66,896	,832	-,216	1,014	-2,239	1,808
Structure	Equal variances assumed	,018	,892	-,903	71	,370	-,830	,920	-2,664	1,004
	Equal variances not assumed			-,890	54,889	,377	-,830	,932	-2,699	1,038
Management and innovation	Equal variances assumed	2,954	,090	-,504	71	,616	-,553	1,098	-2,743	1,637
	Equal variances not assumed			-,526	65,315	,600	-,553	1,051	-2,651	1,545
Research specific	Equal variances assumed	2,573	,113	,233	71	,817	,141	,607	-1,068	1,351
	Equal variances not assumed			,222	48,791	,825	,141	,636	-1,138	1,420

Table 6.6 Independent sample test, weak and strong industry links

The same t-test was run with two other dependent variables; work experience opposed to no work experience and the research disciplines technology/natural sciences versus humanities/business against. The same four dimensions on skills were used. Levene´ s test for groups with respectively work experience and no work experience was not significant, as the lowest value was .275. Variance should thus be equally distributed between the groups.

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
Work experience		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Diff.	95% Confidence Interval of Diff. Lower	Upper
Cognitive	Equal variances assumed	,272	,603	,858	71	,394	,957	1,115	-1,267	3,181
	Equal variances not assumed			,830	39,564	,411	,957	1,153	-1,374	3,289
Structure	Equal variances assumed	,123	,727	-,440	71	,661	-,425	,967	-2,353	1,503
	Equal variances not assumed			-,429	40,261	,671	-,425	,992	-2,430	1,580
Management and innovation	Equal variances assumed	1,211	,275	,654	71	,515	,751	1,148	-1,538	3,041
	Equal variances not assumed			,606	35,888	,549	,751	1,241	-1,765	3,268
Research specific	Equal variances assumed	,282	,597	-2,174	71	,033	-1,337	,615	-2,564	-,111
	Equal variances not assumed			-2,227	45,422	,031	-1,337	,601	-2,547	-,128

Table 6.7: Independent sample test, work experience versus no work experience

The t-value was, however, significant on the dimension related to research specific skills. This can assumingly be explained by the fact that individuals with working experience possess know-how knowledge and know-who knowledge. Practising often facilitates acquisition of other skills, also research specific skills. This is in line with the DUI mode of learning, which claim that know-how and know-who knowledge facilitates learning of know-what and know-why knowledge, as seen in chapter 3. Another possible explanation is the accumulation of knowledge, which most likely happens when individuals have work experience in addition to education. Research specific skills are highly specialised and advanced skills. Individuals with work experience are also often older and may be more mature than the younger with less work experience, which also may influence acquisition of research specific skills. Learning through work experience also contrast with the academe way of learning and these students may think they learn something especial with the research specific skills opposed to younger students that may experience the Ph.D. as a continuation of their Master degree.

When it comes to research disciplines, the t-values are significant on three of the four factors on skills. The t- value is not significant on the dimension related to research specific skills, which is logic since doctoral students carry out research no matter which discipline they belong to.

Independent Samples Test

Research disciplines		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of diff.	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Diff.	Lower	Upper
Cognitive	Equal variances assumed	2,038	,158	-2,026	71	,047	-2,085	1,029	-4,138	-,033
	Equal variances not assumed			-1,940	52,446	,058	-2,085	1,075	-4,242	,072
Structure	Equal variances assumed	1,062	,306	-2,023	71	,047	-1,798	,889	-3,571	-,026
	Equal variances not assumed			-2,094	68,937	,040	-1,798	,859	-3,512	-,085
Management and innovation	Equal variances assumed	,376	,542	-2,397	71	,019	-2,507	1,046	-4,593	-,421
	Equal variances not assumed			-2,416	64,299	,019	-2,507	1,038	-4,580	-,434
Research specific	Equal variances assumed	,038	,845	-,563	71	,575	-,337	,598	-1,531	,856
	Equal variances not assumed			-,562	61,825	,576	-,337	,600	-1,538	,863

Table 6.8: Independent sample test, technology/natural science versus humanities/business

However, the significance is highest on the dimension connected to management and innovation. It is reasonable to believe that students within technology/natural sciences acquire these skills to a larger extent than students within humanities/business. There is generally tradition to work in teams with bigger projects, compared to humanists who often carry out research independently from others. Research within technology/natural sciences may also by nature be more applicable and the way to entrepreneurship and commercialisation may be shorter. Technologists and natural scientists are potentially also good at managing their own time and resources. At least they generally achieve their Ph.D. degree in shorter time than humanists/social scientists. On the other hand, business is also associated with many of these skills, such as management, project development and commercialisation, which should mean that also the other group would acquire these skills. Differences between the groups would therefore most likely not only be made up of differences in the disciplines´ nature.

Summing up

As seen in this chapter, the statistical analysis could not reveal any significant relationship between industry links and skills acquisition, which to some extent is a surprising finding. However, conclusions must be drawn carefully since data is scarce and the statistics carried out give somewhat simplified output. Type of relationship to industry (formal and informal) and learning support from both academia and industry are not sufficiently addressed. There are good reasons to believe this will have impact on students´ skills acquisition. Future studies should take these aspects into account.

Still, it seems to be fair to conclude that connections to industry reinforces acquisition of skills related to the research process since research specific skills is a central learning outcome. Contact with an industrial partner seem to provide further understanding of academic research because real life orientation met in industry gives new perspectives on the students´ own research and its applicability.

7.0 Conclusions

This thesis sets out three theoretical assumptions based on the innovation literature on innovation systems, innovation and learning strategies and types of knowledge and their relationship to the education system and labour market. The first assumption was confirmed through both the literature review and the empirical study. This concerns know-what and know-why knowledge, which is acquired through the research process, and which is formally evaluated through the doctoral thesis. This is also certainly linked to formal and explicitly stated requirements for the Ph.D. degree, which are equal to anybody regardless of collaborative relationship with non-academic institutions and research environments. These aspects of the doctoral education, perhaps in combination with time constraints, might prevent the students to engage in developing a broader set of skills through other types of tasks.

The second assumption is partly supported. Both the literature review and the empirical study show that students acquire research specific skills and that they most likely also learn to apply these skills and knowledge in industrial settings. This means that they mainly develop know-what and know-why knowledge. Still, there is little evidence that they learn a broad range of generic skills from being in a collaborative relationship with industry. As seen, research discipline and work experience have a significant impact on skills acquisition in contrast to industry links. In other words, we may have too much faith in collaborative relationships and their impact on learning outcomes and skills acquisition in doctoral education. This should be taken into account when designing doctoral programs and in the organisation of doctoral education. As this study shows, it is first and foremost traditional doctorates that are produced through the schemes User-driven Research based Innovation (BIA), Programme for Regional R&D and Innovation (VRI), Centres of Research based Innovation (SFI) and Centres for Environmental- friendly Energy Research (FME), which all have an industrial component.

This will also have implications for how the National Qualification Framework (NQF) is operationalized. Some skills stated in the NQF, especially management of interdisciplinary projects and the ability to assess the need for, take the initiative to and perform innovation, are expected to be better developed in collaboration with non-academic institutions, but as seen, being in a collaborative relationship is not enough in itself to acquire these skills. Appropriate learning support is a key factor to success, which means that in order to take advantage of the competences, found in collaborative organisations, these organisations should also be engaged in designing that learning support. This requires a clear understanding of how concepts of learning, skills development and competence building are embedded in doctoral education. Existing research points out that input should be integrated into each individuals´ research repertoire through practise and that doctoral students should be made aware of how they can improve their practises and develop further their know-how. In this way, the ownership of the skills development process is put by the individual student, who has to identify and articulate own training needs. Learning support must then offer appropriate tools to help the student identify these needs.

Main concerns about today´s doctoral education are the students being too old when they finish their Ph.D. as well as the big share of foreign citizens among the doctorates. As this study shows, older students seem to get more out of their Ph.D. when it comes to skills, which could nuance the debate a little. Investing in mature candidates may lead to higher learning outcome, which in the second round has scientific and societal relevance. When it comes to foreign citizens, this study does not provide much insight, but the same question on learning outcome applies to this group. There may be different ways of return from their education in terms of being attractive employees to Norwegian industry, door opener to international research collaboration for Norwegian research institutions or partners in networks. In these contexts their skills are relevant.

Finally, the third assumption is quite heavily supported, especially through the literature review. There seems to be no doubt about collaborative students getting an understanding of different priorities and ways of working in different research environments as well as broader employability perspectives. This has impact on their career prospects, as more collaborative students want a research career in industry. The empirical findings also show that many are heading for a career in industry or the institute sector, a choice that may be influenced by contacts with industry during Ph.D. education, but which may also be explained by the somewhat biased sample with a majority within technological disciplines.

The empirical study of this thesis has a limited data set and the study itself was carried out with a simplistic research design in the format of a self-assessment. Future research on learning outcome from Ph.D. education should be designed as longitudinal studies and when possible be combined with other methods. Perspectives from different stakeholders, as students, employers, supervisors and course administrators, should be explored in the same study in order to provide a more complete picture of the learning outcomes from doctoral education. Future studies should also seek to reveal whether there is a skills mismatch between what employers expect Ph.D. holders to know and what Ph.D. students actually learn. Further research is also needed to map where Ph.D. students end up, in which organisations they get employed, what tasks they carry out and how they use their knowledge, skills and competences acquired through their doctoral education. This applies, perhaps in particular, to foreign doctoral holders in Norway looking at different ways of return from their education.

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Figures and tables in the text

Annexes

Annex 1

Table 1: Specific and transferable skills

	EU, European Qualification Framework, 3rd cycle	UK, Researcher Development Framework	Australia, Qualification Framework, Level 10	USA, Equipped for the Future	Norway, National Qualification Framework, 3rd cycle
Cognitive skills	Capable of critical analysis, evaluation and synthesis of new and complex ideas;	Ability to critically analyse and evaluate one's findings and those of others Original, independent and critical thinking, and the ability to develop theoretical concepts Ability to recognise and validate problems Apply effective project management through the setting of research goals, intermediate milestones and prioritisation of activities	Systematic and critical understanding of a complex field of learning and specialised research skills for the advancement of learning and professional practise. Engage in critical reflection, synthesis and evaluation	Solve problems Reflect and Evaluate Observe Critically	Deal with complex ideas that challenge established knowledge and practises within a research field
Research specific skills	Systematic understanding of a field of study and mastery of the skills and methods of research associated with that field Ability to conceive, design, implement and adapt a substantial process of research with scholarly integrity Make an original contribution through research that extends the	Knowledge of recent advances within one's field and in related areas Understanding of methodologies and their appropriate application within one's research field Design and execute systems for the acquisition of information through the effective use of appropriate resources and equipment Identify and access appropriate sources of relevant information and ability to summarise, document, report and reflect on progress	Expert, cognitive specialised and research skills in a discipline are Systematic and critical understanding of a substantial and complex body of knowledge at the frontier of a discipline or area of professional practise Generate original knowledge and understanding to make	Learn Through Research Use Math to Solve Problems and Communicate Use ICT	Possess in-front knowledge within a research field, master theoretical and methodological aspects of the research Develop new knowledge, theories, interpretations and methods within the research field Ability to identify new and relevant ethical

	frontier of knowledge by developing a substantial body of work, some of which merits national or international refereed publication	Use information technology appropriately for database management, recording and presenting information Justify the principles and experimental techniques used in one's own research Demonstrate appreciation of standards of good research practice in their institution and/or discipline Be creative, innovative and original in one's approach to research Understand the process of academic or commercial exploitation of research results	substantial contribution to a discipline or area of professional practise Develop, adapt and implement new methodologies to extend and redefine existing knowledge or professional practise		issues and Perform research with professional integrity Perform complex and interdisciplinary projects Develop research questions, plan and carry out research of high standard internationally
Communication	Communicate with their peers, the larger scholarly community and with society in general about their areas of expertise Ability to promote, within academic and professional contexts, technological, social or cultural advancement in a knowledge based society	Write clearly and in a style appropriate to purpose Construct coherent arguments and articulate ideas clearly to a range of audiences, formally and informally through a variety of techniques Constructively defend research outcomes at seminars and viva examination Contribute to promoting the public understanding of one's research field Effectively support the learning of others when involved in teaching, mentoring or demonstrating activities	Disseminate and promote new insight to peers and the community	Read with Understanding Convey Ideas in Writing Speak so that others can understand	Disseminate research through recognized national and international channels. Able to assess the need for, take the initiative to and perform innovation.
Interpersonal skills		Show a broad understanding of the context, at the national and international level, in which research takes place Develop and maintain co-operative networks and working relationships with supervisors, colleagues and peers		Collaborate with others Resolve Conflict and Negotiate Guide others Listen actively	

		Understand one's behaviours and impact on others in formal and informal teams Listen, give and receive feedback and respond perceptively to others			
Personal attributes		Demonstrate flexibility and open-mindedness Demonstrate self-awareness and the ability to identify own training needs Demonstrate self-discipline, motivation, and thoroughness Recognise boundaries and draw upon/use sources of support as appropriate Show initiative, work independently and be self-reliant	Demonstrate autonomy, authoritative judgement, adaptability and responsibility as an expert and leading practitioner or scholar	Plan Take responsibility for learning Make decisions	
Career development		Appreciate the need for and show commitment to continued professional development Take ownership for and manage one's career progression, set realistic and achievable career goals, and identify and develop ways to improve employability Demonstrate an insight into the transferable nature of research skills to other work environments and the range of career opportunities within and outside academia Present one's skills, attributes and experiences through CVs, and interviews			

Annex 2

Table 1: Theoretical studies, literature review

N	Paper	Research focus	Findings	Population	Approach	Source
1	Baker and Lattuca, 2010	How Ph.D. students' participation in multiple, varied and overlapping social contexts and networks influences their learning and sense of identity	Students' personal and professional networks provide information on the academic community and expected roles. Students measure their success in learning to enact these roles by receiving validation from network partners.	Contexts: students, departments, interpersonal networks	Sociocultural learning and network theories	Taylor and Francis online
2	Barnacle and Alba, 2010	research degrees as a form of professional education	generic skills initiatives may render graduates less capable of engaging with knowledge that arises through their own practice and know-how	Contexts: students, departments, interpersonal networks,	Developmental networks and sociocultural perspectives on learning	Taylor and Francis online
3	Bender and Windsor 2010	Early publishing enables doctoral students to develop skills and gain experience	Supporting students through co-publishing, negotiation with journals, facilitating discussion among peers.	None	Discussion	Taylor and Francis online
4	Craswell, 2007	The employability discourse is blurring skills training. Criticizes the *deficit* model being used to push workplace skills	Ph.Ds are mass-education and students heterogeneous, some with extensive labor experience. Programs need flexible design and delivery and adapt to the specific target group/population	Skills debate in Australia and globally	Discussion, analysis of doctoral programs	Taylor and Francis online
5	Cumming, 2010	Analysis of three conceptual frameworks to reframe the skills debate	Enactment of skills in a variety of authentic settings and challenging circumstances.	None	Theorizing concepts	Taylor and Francis online

6	Cumming, 2010	Development of a model that highlights the evolving nature of doctoral practices/arrangements.	Model emphasizes doctoral practises that embrace concepts as skilful performance, artistry and know-how. Candidates to be enabled to work, learn and develop skills in authentic contexts	Australian doctoral students	National survey + 30 interviews	Taylor and Francis online
7	Gilbert et al, 2004	Review literature and debate on generic skills	Need to clarify concepts, terminology around skills, which skills naturally belong to doctoral education	Skills debate in the UK and Australia	Theorizing concepts	Taylor and Francis online
8	Hopwood, 2010	How and what doctoral students learn through teaching, student journal editing and academic career mentoring	Students are agentic in their engagement in activities, and in their response to challenges they encounter in those activities. Learning is embedded in particular practice contexts, culturally mediated and rooted in social interaction.	33 doctoral students	Sociocultural theory + interviews and focus group	Taylor and Francis online
9	Maxwell and Smyth, 2009	Three foci in supervision: the learning and teaching process, developing the student and producing the research project/outcome as a social practice	Development of a research management matrix to facilitate discussions during supervision. Framework identifies what, when, how, how well and why	8 UK doctoral students	Testing the framework	SpringerLink
10	Mowbray and Halse, 2010	Theorizing the purpose of doctoral education, framework inspired by Aristotelian theory to understand skills acquisition	Conceptualising skills as intellectual virtues captures students' experiences of skills development as a process	Australian Ph.D. students	Theorizing + in depth interviews	ISI Web of Knowledge
11	Park, 2005	Drivers of change in doctoral training. Emergence of new doctoral programs	Key drivers for change include skills and training, submission rates and quality of supervision, thesis examination, introduction of national benchmarking.	Ph.D. programs in the United Kingdom	Review of historical development of Ph.D. education	Taylor and Francis online
12	Pearce, 2005	Effect of Ph.D. education on tourism	Transferable skills` introduction in Ph.D. programs is result of an	Ph.D. programs in Australia	Literature review	Taylor and Francis online

			evolutionary process. Ph.D. in tourism develops the field and help tackling professional challenges.			
13	Servage, 2009	Drivers behind professional doctoral programs	Reforms of doctoral education due to 1) preparation of career-entry professionals to meet the needs of employers, 2) growth of the professional doctorate as a form of accredited professional development.	Professional doctorate programs	Human Capital theory + credentialism and corporatization of higher education	Taylor and Francis online
14	Thune, 2009	Theoretical assumptions and empirical evidence about the role Ph.D. students are expected to fill in industry-academia collaboration	Ph.D. students are central for knowledge production, knowledge transfer and maintenance of network university-firm Weak evidence on increased productivity, commercial activities. Similar outcome as non-collaborative students	Internationally published research on graduate student—industry relationships	Literature review	SpringerLink
15	Wray and Wallace, 2011	Individual learning processes	Need to support individual learning processes by building on the individuals´ existing knowledge – need to train the trainer.	Social science in the UK	Theorizing	Taylor and Francis online

Table 2: Empirical studies, literature review

N	Paper	Research focus	Findings	Population	Approach	Source
1	Alpay and Walsh, 2008	Impact of a transferable skills development course for first-year postgraduate researchers	Enhanced skills in group work, communication skills, planning and project management and personal awareness.	Students at Imperial College in a 3 day course in transferable skills	Before-and-after skills perception inventory, self-assessment	Taylor and Francis online
2	Bienkowska and Klofsten, 2011	PhD students’ attitudes towards commercialisation and	Most students were positive, engineers most. Students who had	1126 Swedish doctoral students	Web-based questionnaire	SpringerLinks

		Entrepreneurship? Are mobile students and students involved in collaborative projects more positive other PhD students?	spent time in a firm, were more positive than others			
3	Borell-Damian et al, 2009	Nature of industry-academia collaboration in Ph.D. education Inter- and intra -sectorial mobility and career paths Development of skills is Ph.D. education Impact of systematic data collection in universities	Students left with broader understanding of different research environment, broader set of skills, more inter- and intra-sectorial mobility Industry and academia share interests and view of opportunities and challenges	82 organisations, including 33 universities, 31 enterprises and 18 other stakeholders from 19 European countries.	Extensive questionnaire	Taylor and Francis online
4	Brofoss and Olsen, 2007	Foreign citizens with a Norwegian doctoral degree and their careers after graduation	9 % foreigners among graduates 1990-2005, most in natural sc. 60 % of foreign graduates have found work in Norway. Expectations to education mostly met	Ph.D holders with foreign citizenship graduated from Norwegian institutions	Comparison of data from different data registers + survey	www.nifu.no
5	Chiteng and Hendel, 2011	The development and growth of professional doctorates in the US, UK, Canada, and Australia.	Similar patterns of expansion, governmental initiatives in the UK and Australia, market demands in the US.	Comparison of professional doctorate in the USA, UK, Canada and Australia	Analysis of public statistics	Taylor and Francis online
6	De Grande et al., 2009	Is there a skills mismatch between industrial expectations and students´ perception?	More variation in response patterns on skills among students than among firms. There is a certain mismatch.	4878 students + 2597 Flemish firms	Survey of Junior Researchers (SJR) and interviews	Ghent University Academic Bibliography
7	Hakala, 2009	Socialisation processes of Ph.D. students	Continuously search for funding makes Ph.D. students engaged in senior tasks as project management, publishing, application for external funding	Two Finnish centres, in collaboration with industry	18 interviews, case study	ISI Web of Knowledge
8	Harman, 2004	Compare “industry-readiness” of doctoral students graduated from Cooperative Research	CRC students believe industry not to be a threat to academe values, wish career in industry, more	2 samples of Ph.D. students, one at CRC and one at regular	Questionnaire + in depth interviews	Taylor and Francis online

		Centres (CRC) versus from regular faculty	optimistic of own career goals, more satisfied with education	faculty in Australia		
9	Kyvik and Olsen, 2007	The relevance of doctoral training (thesis, coursework and generic skills) for a career in the labour market	Skills most relevant for academia Coursework less relevant for all work Employees outside academia value generic skills	2 cohorts of Ph.D. holders graduated from Norwegian institutions	Survey	www.nifu.no
10	Kyvik and Olsen, 2009	Comparison of submission-rates of Ph.D. students across periods, disciplines, funding mechanisms, countries	Submission-rates have increased, but students spend long time completing their degree	Ph.D. students in Norway	Comparison of data from different data registers	www.nifu.no
11	Lee et al 2010	Career trajectories of doctoral holders in Science and Engineering	For S&E Ph.D.s academic research positions have become a secondary career type. Specific and transferable skills valued by type of position	Ph.D. graduates from Manchester University, 1998-2001	Survey	Science Direct
12	Loxley and Seery, 2012	Students´ motivation for and outcome of professional doctorates	Creating knowledge for public good, higher salaries in industry, supportive element in a cohort of students, discipline.	27 students enrolled in an Irish professional doctorate	Interviews	Taylor and Francis online
13	Malfroy, 2010	Supervisors' experiences of industry-based research partnerships and doctoral education in PhD programs	Supervisors find links to industry useful for their own research and for the students´ intellectual enhancement. Sometimes different expectations about procedures, progress and outcomes	15 Australian doctoral supervisors	Extended life-history interviews	ISI Web of Knowledge
14	Manathunga et al, 2009	Are Cooperative Research Centres (CRC) producing 'industry-ready' graduates?	Students possessed many of the attributes/skills prior to the Ph.D. and found no added value of the CRC concerning employability.	115 graduates from three Australian CRCs and non-CRCs	Research Education Questionnaire (REQ)	Taylor and Francis online
15	Manathunga et al 2011	Comprehensive study of graduate preparation and employment outcomes of the Cooperative Research Centre (CRC) program.	Skills appreciated by industrial Ph.D. holders: financial management skills, understanding of intellectual property and commercialization issues,	4122 students from the CRC program and a university (non-CRC) program 1995-2005	Survey	Taylor and Francis online

			entrepreneurship, environmental awareness and the ability to work in interdisciplinary context			
16	Mendoza, 2007	Industry-funded Ph.D. projects and its impact on the students´ socialisation	Students are positive to industrial funding and believe societal needs are met + give access to network and career opportunities. Publishing keepsbeing the most prestigious.	American Ph.D. students funded by industry	Ethnographic interviews	JSTOR
17	Morris et al, 2011	Do Ph.D. students with two supervisors, one from academia and one from industry have different experiences than those with only one supervisor?	Student satisfaction with industry research unit due to personal support, skills acquisition and learning climate	2176 Australian Ph.D. and master students	Web-based survey	Taylor and Francis online
18	Nerad, 2004	Explore criticism of the US Ph.D. degree and outline possible changes	Need for interdisciplinary problem-oriented and theme-based doctoral programs, including employability skills. Provide funding for students and not for faculty.	4000 doctoral students + all doctoral students in the US and Canada + 6000 doctoral holders 10 years after	Existing data from 3 national surveys	Taylor and Francis online
19	Neumann and Tan, 2011	Employment destinations of Australian Ph.D. graduates	90 % employed in 6 months after graduation, 18 % in private sector, 50 % in HEIs. This is in line with similar international studies.	Australian Ph.D. graduates, 2000-2007	National Grad. Destination Survey + institutional case study	Taylor and Francis online
20	Olsen, 2007	Analysis of Ph.D. holders´ employability status, sector and location in general and within research in particular	90 % found work within 1 year after graduation. 63 % are employed in public sector, within education, health, administration 37 % are in private sector within R&D, services, oil/gas,	Ph.D. holders graduated from Norwegian institutions 1970-2006	Comparison of data from different data registers	www.nifu.no
21	Pearson et al, 2011	Doctoral students´ experience with their degree.	Much variation in student population – age, submission rate, previous experience, full-time vs half time studies, hours spent per	Ph.D. students, firms, co-funders.	National web-based survey	Taylor and Francis online

			week on their thesis, modes of attendance			
22	Platow, 2012	To observe the potential relation-ship between self-perceptions of skills acquisition and a variety of objective and subjective outcomes commonly employed as indices of PhD success.	Positive correlation between skills acquired and post-PhD productivity, but not completion time, productivity during the Ph.D., job acquisition or salary.	Australian doctoral graduates from 1999-2001	Questionnaire, quantitative self-assessment study	Taylor and Francis online
23	Pole, 2000	Student self-perception of value and outcomes of doctoral study, knowledge and craft skills.	Craft skills most valued – how to manage the whole research process. Substantial knowledge less valued	50 UK doctoral holders	Qualitative interviews	Taylor and Francis online
24	Roach and Sauermann, 2009	Career choices of academically trained students	PhDs preferring industrial employment show a greater concern for salary and access to resources, and a stronger interest in downstream work.	400 US doctoral students in Science and Engineering at three Research 1 universities	Survey	Scopus
25	Salminen-Karlsson and Wallgren, 2007	How do representatives from academia and industry cooperate to educate a doctoral student? How does knowledge transfer take place in this context?	Industry and academe supervisors engage in social interaction while following up students. In this space knowledge transfer and Mode 2 production take place	9 Swedish graduate students two industrial research schools + 11 academic and 10 industrial supervisors	Exploratory, semi-structured interviews	SpringerLink
26	Thune and Olsen, 2009	Working conditions and career prospects of doctoral holders	The students´ overall satisfaction with their education is high, with the exception of coursework. Research specific and dissemination skills are highly valued. Most students wish a career within academia	Employed Ph.D. holders among the members of the Norwegian Association of Researchers	Web-based survey	www.nifu.no
27	Thune, 2010	University–industry collaboration as a context for researcher	Academic performance still most important – industry does not impose challenges here. Firms´	25 Ph.D. students in industry-academia collaborations in	Exploratory interview study	SpringerLink

		training	size, R&D intensity and involvement in the Ph.D. project affect the training. Collaboration is due to personal contact between supervisor and firm	Norway		
28	Zellner, 2003	What kind of knowledge is transferred from basic research to innovation processes?	Researcher mainly transfer knowledge that underlie complex problem-solving strategies, rather than theoretical insight	569 former researchers at Max Planck society, that had left for industry	Survey-questionnaire	ScienceDirect
29	Zhu, 2004	faculty views on academic writing and writing instruction	Academic writing largely transfer general writing skills, and writing instruction to be provided by writing/language teachers. Academic writing entails unique thought and communication processes	10 faculty members in engineering and business	Qualitative interviews	ScienceDirect
30	Watson, 2001	Provide understanding of how Engineering doctoral programs can better prepare graduates for careers in industry.	Engineering doctoral programs do prepare students for a career in industry, but students lack interdisciplinary teamwork skills and understanding of economic issues in industry. Seminars in transferable skills raise students awareness about industrial needs	35engineering programs within the US + graduated students from these programs.	Review of Engineering doctoral programs. Interviews and survey with candidates	SpringerLink
31	Whitelock et al 2008	Enhancing creativity skills through supervision	Strategies to develop creativity skills moderated by the role adopted by the supervisors, student – supervisor relationship and the students' management of their own development in the creative process.	Doctoral students and their supervisor	Interviews	ScienceDirect

Annex 3: Questionnaire

Study outcomes in Ph.D. education(1)

1) * In which of the following disciplines will you place your doctoral project/degree?

- Humanities/Social sciences
- Technology/Agriculture
- Natural Sciences/Life Science
- Business/Management

2) * At what stage of your doctoral training are you?

- I have just begun
- I am approximately half way
- I am about to finish my degree

3) * How many years of full-time work outside academia did you have before embarking your Ph.D.?

- 0
- 1-2
- 3-4
- 5+

4) * Below you find a list of different, knowledge, skills and competences. Please, indicate for each of them to what extent do you think you have acquired these skills during your doctoral training

	Large extent	Significant extent	Some extent	Small extent	Not at all
Knowledge within a specific research area					
Broader knowledge within a research discipline					
Analytical thinking					
Evaluation and synthesis of new and complex ideas					
Lateral thinking/problem solving					

Creativity	○	○	○	○	○
Interdisciplinary approaches	○	○	○	○	○
Research methodologies that apply to your field of study	○	○	○	○	○
Research methods in general	○	○	○	○	○
How to develop new knowledge (for example theories, interpretations, methods) within your research field	○	○	○	○	○
Entrepreneurship/Commercialisation of research results	○	○	○	○	○
Management of your own time and resources	○	○	○	○	○
Project management	○	○	○	○	○
Project development	○	○	○	○	○
Application for external funding	○	○	○	○	○
Team work	○	○	○	○	○
Team building	○	○	○	○	○

5) * During your Ph.D., to what extent do you think you have acquired:

	Large extent	Significant extent	Some extent	Small extent	Not at all
An understanding of the societal and political context in which research takes place	○	○	○	○	○
Kowledge about how to develop professional networks nationally and internationally	○	○	○	○	○
Knowledge about how to go about building a research career within academia	○	○	○	○	○
Knowledge about how to go about building an alternative research career outside academia	○	○	○	○	○

6) * When you answered the two previous questions on skills and competences, what did you take as point of departure?

○ What you think you actually have learnt during your Ph.D

○ The explicit learning goals stated in curricula, courses etc.

What you think Ph.D students normally learn

7) What is the best way for you to learn relevant skills that develop you into a professional researcher? Please, rank (1=best, 2=second best etc.)

Through supervision

Taking doctoral courses

Practising your own research

Social interaction and negotiation of meaning (with peers)

Putting your knowledge into words

Other

Here, the aim is to see whether your Ph.D. education is taking place in a relationship to an industrial partner, i.e. any other institution apart from Higher Education Institutions and Independent research institutes.

8) * Which of the different academia-industry collaborations apply to your Ph.D. education? (Multiple choice)

	Yes	No
My doctoral training is financed by industry		
I am in a contractural relationship with a partner in industry		
The research question in my doctoral project is relevant to an industrial partner		
I carry out my research in collaboration with staff employed in industry		
I use data and/or infrastructure provided by an industrial partner		
I use an industrial partner´s office/location to do my research		
I work in industry while I am doing my Ph.D.		

9) * What do you consider to be the value added (=what you have learnt) from doing your Ph.D in relationship to industry?

10) * Are you better prepared for a career in industry with a Ph.D. compared to holding a Master degree?

Yes

No

I don't know

11) * What does your future career look like?

I wish to work as a researcher in academia

I would like to work as a researcher at an independent research institute

I hope to work as a researcher in industry

I want to do research in another sector (governmental, non-profit etc.)

I do not plan to work as a researcher

12) * Gender

Male Female

13) * Age

25-32

33-38

39-44

45+

14) * Mobility and citizenship

I am a Norwegian citizen living in Norway before starting my Ph.D

I am a foreign citizen moving to Norway to do my Ph.D

I am a foreign citizen living in Norway even before I started my Ph.D