

The Industrial PhD

An effective tool for innovation and knowledge sharing



**Forsknings- og
Innovationsstyrelsen**

Ministeriet for Videnskab
Teknologi og Udvikling

Foreword /

The Industrial PhD – an effective tool for innovation and knowledge sharing – is one of the Council's central programmes in the spring of 2007, described in **Innovation Denmark** – the plan of action for more innovation and effective knowledge sharing published on February 8, 2007.

The Industrial PhD programme was originally established in 1970 as the Industrial Research Programme. The Industrial Research Programme was established as a two-year licentiate course. In early 1989, the programme was changed to a three-year PhD course under the Danish Council for the Promotion of Industrial Development. In 2000, it was transferred to the Ministry of Science, Technology and Innovation. This report is based on the experience gained from PhD projects completed in 1992 or later, and the Ministry of Science, Technology and Innovation database of projects that started from 2002 and on. It is the most comprehensive analysis to date of the Industrial PhD course and its effect on the surrounding society.

The Industrial PhD programme has been evaluated on an ongoing basis, and this report is a summary of the most recent analyses and studies. Some of the evaluations have not been published before. Oxford Research prepared the report for the Danish Council for Technology and Innovation.

The report shows that the Industrial PhD course functions as an extremely effective network promoter between the private business world and university circles. It is an education that contributes to sending many highly educated people out into the business world – often in management positions in research and development. The Industrial PhD programme thus contributes to growth and development within enterprises, creating new knowledge at universities and industrially relevant research in Denmark.

The analysis begins with a profile of the participating parties, e.g. enterprises, candidates and universities, and describes their experience about their involvement in an Industrial PhD project. The main emphasis of the report, however, is on describing what resulted from participation in an Industrial PhD project. Enterprises and universities were surveyed on satisfaction, financial and professional results, networking, etc., while, in the case of the Industrial PhDs, it studies their situation after the course from the employment point of view and up to 9 years after their education was completed. Finally, it describes the socioeconomic effects of the Industrial PhD programme.

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The many good results have been achieved because the Industrial PhD programme is:

- **User-driven.** The enterprise is the project owner. The research project originates from a problem that is relevant to the enterprise. The PhD student is employed in the enterprise and works full-time on the research project, but divides his or her time equally between the enterprise and the university. The enterprise is allowed to select the university it wants to collaborate with itself, and the enterprise owns the intellectual property rights to the project.
- **Research education at a highly specialised level.** The universities are responsible for Industrial PhD education being at least on a par with a traditional PhD course. Thus, the university must give academic approval to the proposed project and the candidate, is responsible for project guidance and the course, and will be responsible for evaluating the completed PhD project.
- **Quick case work.** 30 days will pass from the time an application is submitted until a decision on support is made. The fast track from application to decision is possible because we use a cross-disciplinary and independent evaluation committee, the Industrial Research Committee, as is the priority for unbureaucratic administration.

The Industrial PhD programme has proven to be particularly promising and the Danish Council for Technology and Innovation thus fully supports the government's intention to double the number of Industrial PhD projects over the next 3-4 years.

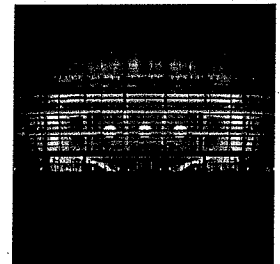
Kind regards,

Lars Mikkelsen-Jensen

Chairman, Danish Council for Technology and Innovation

Summary /

Summary



The Industrial PhD programme is attracting increased interest among masters programme students, enterprises, and universities.

Such increased interest is not surprising when one looks at the evaluation of the Industrial PhD programme as shown by the effects analysis. Basically, the Industrial PhD programme's combination of doctoral studies and business experience has generated a great deal of satisfaction.

For the Industrial PhD students, the advantages are obvious. Graduates of the course do not encounter problems in finding employment, rather, they quickly find exciting jobs as managers in the research areas of private enterprises and enjoy high salaries. Moreover, many Industrial PhD students comment that the combination of research and professional experience makes gaining a PhD more attractive.

The enterprises also express satisfaction with their participation in the Industrial PhD projects. They experience concrete results not only by way of increased revenue and increased exports, but also by way of such long-term effects as issued patents, license sales, and other types of innovation-promoting results.

The enterprises experience a tighter network within the domain of public research in Denmark and abroad. At the same time, a significant competence development takes place at the enterprises through the sharing of theoretical professional knowledge and practical improvements of processes, services, and products.

Summary /

Through the Industrial PhD programme, Danish universities achieve a distinctly improved sense of the research-relevant needs of the industry. This leads to improved skills on both theoretical and practical levels at the university, but also through intensive networking with private enterprises, which continues even after an Industrial PhD project has ended. The Danish universities extend their network to other research institutions and to foreign research environments, which also get involved in the Industrial PhD project.

The Industrial PhD programme also has a positive impact on society in general. A very rough estimate shows an increased turnover of DKK 640 million, an increase in exports of DKK 150-200 million and up to 335 new jobs as a result of the 50 Industrial PhD projects that are included in the socioeconomic study.

The public sector investment is approximately DKK 70 million in 2006 for around 90 Industrial PhD projects initiated. This also means that the expense to the public of Industrial PhD projects is less than half of an ordinary PhD. With an aspiration to increase the number of research education posts in the future, this is a major benefit to the country. In this way, Industrial PhD projects show important economic results for society in general.

Introduction



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Through the Industrial PhD programme, Danish universities achieve a distinctly improved sense of the research-relevant needs of the industry. This leads to improved skills on both theoretical and practical levels at the university, but also through intensive networking with private enterprises, which continues even after an Industrial PhD project has ended. The Danish universities extend their network to other research institutions and to foreign research environments, which also get involved in the Industrial PhD project.

The Industrial PhD programme also has a positive impact on society in general. A very rough estimate shows an increased turnover of DKK 640 million, an increase in exports of DKK 150-200 million and up to 335 new jobs as a result of the 50 Industrial PhD projects that are included in the socioeconomic study.

Moreover, there is a significant private co-financing amount of approx. 170 million DKK in 2006, based on approx. 90 projects launched. This also means that the expense to the public of Industrial PhD projects is less than half of an ordinary PhD. With an aspiration to increase the number of research education posts in the future, this is a major benefit to the country. In this way, Industrial PhD projects show important economic results for society in general.

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1.1 The purpose of the Industrial PhD programme

An Industrial PhD is a research course that strives to educate PhD students at the highest international level. In this respect, the Industrial PhD course does not differ from a regular PhD course. What is special about an Industrial PhD project is that it is a form of research education that is directed more towards the business world, where students divide their time between the university and the host enterprise.

The purpose of the Industrial PhD programme is, firstly, to educate researchers at the highest level with an insight into business aspects of research and innovation. Secondly, the Industrial PhD programme strives to promote growth in the world of Danish business through closer collaboration on research and innovation between enterprises and universities. Finally, the programme strives to develop and strengthen the personal network between enterprises and researchers in Denmark and the rest of the world.

For this reason, the department to which the Industrial PhD student is affiliated must be geographically located in Denmark.

On the other hand, there is no requirement that the university be either Danish or foreign, nor is there any requirement for the student's nationality. However, a supervisor from a Danish university or research institution must oversee any studies completed at a foreign university.

Target groups for the Industrial PhD programme:

The Industrial PhD programme is directed at three groups: students, business and research environments.

The student target group is people at Masters level with qualifications necessary to complete a PhD project. This means that they must be among the best students in the Masters programme.

The business target group is enterprises that can professionally support a 3-year business-oriented research and development project.

The research target group is universities and their faculties and institutes who would like to collaborate closely with private enterprises, regardless of the area of specialisation.

1.2 The spirit of the Industrial PhD plan

The Industrial PhD programme's distinguishing feature is its mixture of "business" and "PhD". The combination of research and the business world is exactly what is needed to create an educational combination that can support enterprises' research and innovation at the highest level.

The spirit of the education is to create good employees with strong professional skills, relevant professional networks and a knowledge and understanding of the real business world and its ground rules.

The intention is also that the Industrial PhD course should in itself make a substantial contribution to promoting cooperation between enterprises and universities.

The course supports this important collaboration through content with both parties seeing concrete results:

- The enterprise gains an employee who is educated to a high level and is also working on a project that can contribute to the enterprise's growth.
- The university gains a PhD candidate education with the associated scientific publications and communication tasks.
- Candidates, enterprises and universities gain a reciprocal network and shared research environment. The network can be used for many things from knowledge sharing about the collaboration on applying research results, to the university being able to send Bachelors and Masters students on visits to enterprises or on internships.

A central element of the Industry PhD education is "Business", because the specific goal of the course is to educate research candidates who are particularly well-suited at resolving research and development problems out in the business world. This is the factor that makes the course unique compared to other PhDs.

The other central element in the course is "PhD" to emphasise that it is a research course at international PhD level. Not only does the project emphasise the PhD designation, the education is also affiliated with a university PhD programme.

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The Industry PhD course is continuously being adapted to meet future requirements from the surrounding environment, but in a manner where the changes do not undermine its spirit.



Industrial PhD programme results

The Industrial PhD programme is attracting increased interest among students, enterprises, and universities in Denmark and abroad.

This is not surprising considering the satisfaction evident among the central players in the Industrial PhD programme. This can leave no doubt that taking part in an Industrial PhD project is popular.

More than 90 percent of enterprises, universities and students are satisfied with the programme, and only very few have had negative experiences.

There are many indications that the framework for the Industrial PhD programme is satisfactory, and that all parties value the collaboration.

- ✓ 98 percent of Industrial PhD students are satisfied with the Industrial PhD programme.
- ✓ 94 percent of enterprise supervisors are satisfied with the Industrial PhD programme
- ✓ 98 percent of enterprises consider employing a new Industrial PhD student
- ✓ 99 percent of enterprise supervisors feel that an Industrial PhD is a good candidate for the business world.
- ✓ 94 percent of university supervisors are satisfied with the Industrial PhD programme.
- ✓ 95 percent of university supervisors are satisfied with the collaboration with the enterprises.

2.1 Broad satisfaction among the students

A general overall evaluation of the Industrial PhD programme's success rate must be based on the satisfaction ratings from the central players of the Industrial PhD programme. This section will focus on the satisfaction among the Industrial PhD candidates, both on a general level and in relation to selected sub elements.

Figure 2.1 shows the overall satisfaction ratings from Industrial PhD candidates with the project based on a questionnaire undertaken by Kvistgård Consult.

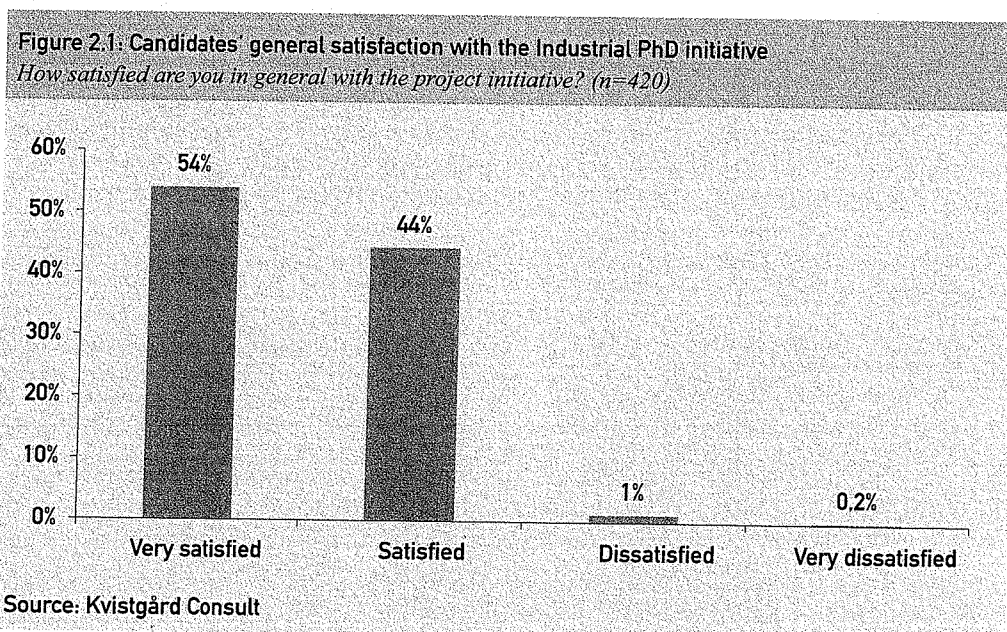


Figure 2.1 shows that 99 percent of the students are satisfied or very satisfied with the programme. A total of 54 percent state they are very satisfied with the Industrial PhD programme, while 44 percent are satisfied. Only 1.2 percent state that they are dissatisfied or very dissatisfied with the programme. In general, there is broad satisfaction with the initiative among the students.

The satisfaction can also be examined in relation to selected elements which can illustrate the specific aspects of the initiative that the students appear to be most satisfied with. The focus is on the following three sub elements that are crucial for a successful Industrial PhD process: satisfaction with the cooperation with the university supervisor, with the involved enterprise and the collaboration between these two parties. The satisfaction rating is summarised in Table 2.1:

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Table 2.1. Candidate satisfaction with select elements

How satisfied have you been with the collaboration	Extremely (1)	Somewhat (2)	Total (1+2)
With the involved university supervisor	50.0%	36.4%	86.4%
With the involved enterprise	65.4%	27.1%	92.5%
Between the supervisor and the enterprise	35.1%	38.0%	73.1%

Note: n=308
Source: Kvistgard Consult

Table 2.1 shows that the vast majority of the students are satisfied on all three counts. In general, the satisfaction is greatest with the collaboration with the enterprise (92.5 percent) and lowest with the collaboration between the university supervisor and the enterprise (73.1 percent). The same divisions apply when focusing on a high degree of satisfaction. Together this demonstrates that the students are satisfied with the collaboration between the central players.

2.2 Industrial PhD is a hit with the enterprises

The experience of the enterprises regarding the Industrial PhD programme, in addition to the students and universities, is crucial for whether the Industrial PhD programme can be deemed a success. The following focuses on enterprise satisfaction with the programme, their plans for using the programme in the future and finally their opinion of the Industrial PhD candidates as employees.

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First a study of enterprise supervisor satisfaction with the Industrial PhD programme. This proves to be very similar to the student evaluations, i.e. that the majority are satisfied with the programme. This is illustrated by Figure 2.2, where the enterprise supervisors are surveyed about enterprise satisfaction with the programme:

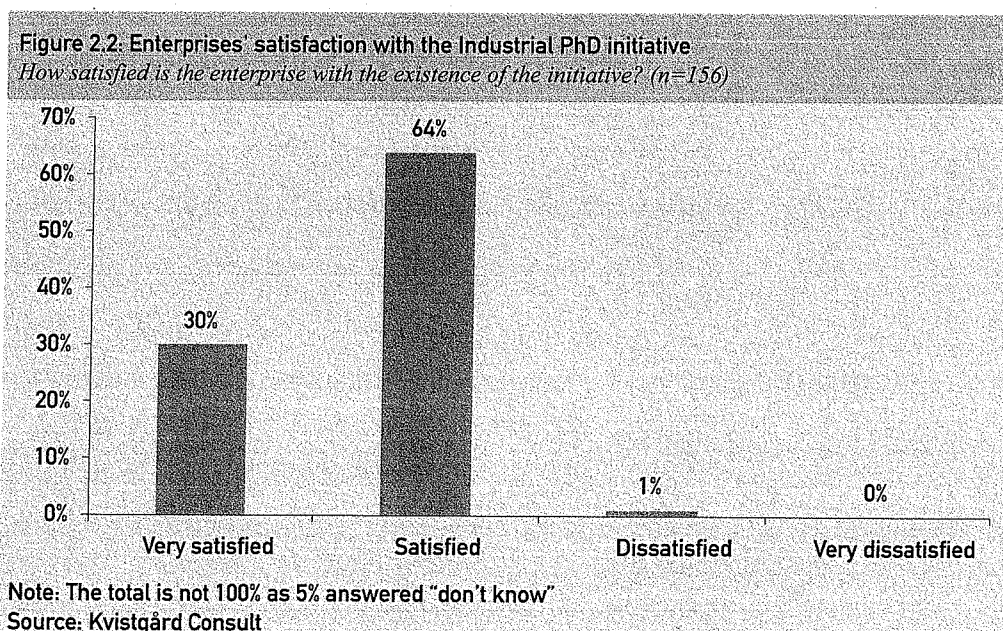
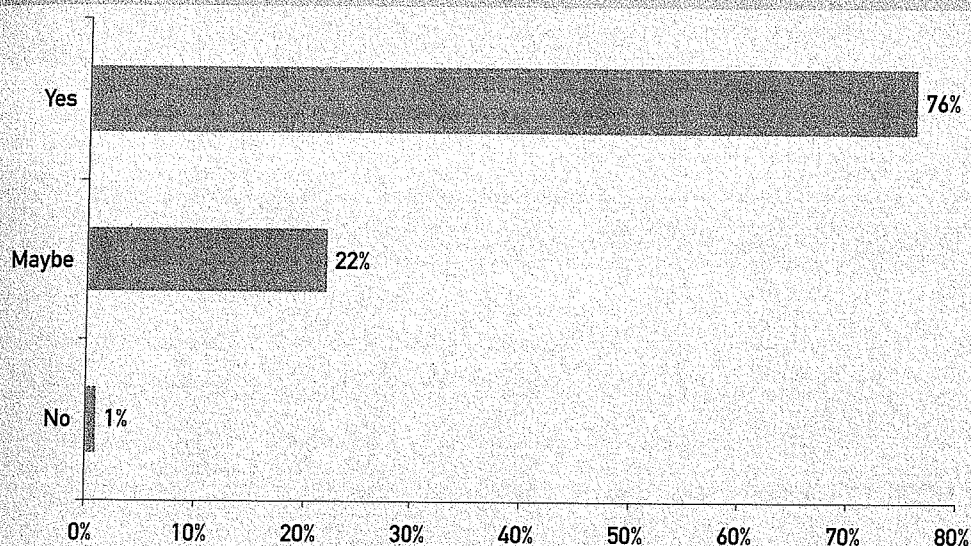


Figure 2.2 shows that a total of 94 percent of the enterprises say they are satisfied with the programme. The programme can thus be deemed a great success among the enterprises.

Enterprise satisfaction, as previously noted, is their experience of how well they feel the programme is functioning. Another way to illustrate this is to include enterprise plans to participate in an Industrial PhD project in the future.

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Figure 2.3: Enterprises' expectation of using the initiative again
Does the enterprise expect to use the initiative in the future? (n=156)



Note: The total is not 100% as 0.6% indicate "don't know"
Source: Kvistgård Consult

Figure 2.3 shows that three out of four enterprises plan to use the programme again in the future, which must be viewed as a very positive result. This is supported by that fact that only 1 percent decidedly refuse to participate again. This must be regarded as a reflection that the enterprises feel that their experience with the projects has been that they benefit a great deal from participating. The result also supports the initial impression that the enterprises are satisfied with the programme, as the desire to participate again is a clear acknowledgement of this.

The Industrial PhD programme is not only directed towards the successful completion of the projects in the enterprises, but also towards making the candidates who have successfully completed the programme an attractive resource for the enterprises. Thus it is interesting how the enterprise supervisors, from their business perspective, evaluate the skills of the Industrial PhD candidates who have successfully completed the programme. This is shown in Table 2.2.

Table 2.2: Enterprises' view on the Industrial PhD candidates after completing their education

Company supervisors	Agree completely	Agree some-what	Disagree completely
An Industrial PhD candidate is business minded and thus a good candidate for the business world after completing the education?	72.7%	26.6%	0.6%

Note: n=154

Source: Kvistgard Consult

Table 2.2 shows that the enterprises view the Industrial PhDs who have successfully completed the programme as a good resources. Thus, not only do the enterprises view the programme as advantageous for the duration of the project, but also as a good recruitment base afterwards.

2.3 The universities are pleased with the Industrial PhD programme

The universities are the third central player, and it is important to include their experience of the Industrial PhD programme as well. Here the focus is on their general satisfaction with the initiative and the collaboration with the enterprises. Table 2.3 shows university supervisor satisfaction with the Industrial PhD programme and the enterprises involved respectively.

Table 2.3: University satisfaction with the Industrial PhD programme.

University supervisors		Very satisfied	Satisfied	Dis-satisfied	Very dis-satisfied
Satisfied with the initiative	How satisfied were you with the Industrial PhD programme	47.4%	46.5%	2.9%	0.6%
University supervisors		A great deal	Some-what	Slightly	Not at all
The collaboration with enterprises	How satisfied were you with the collaboration with the enterprises involved?	64.5%	30.8%	2.3%	2.3%

Note: n=171

Source: Kvistgard Consult

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Table 2.3 shows that the universities are generally very satisfied or satisfied with the Industrial PhD programme, which applies to a little over 94 percent of the responding university supervisors. An almost identical number (95.3 percent) state that they are very or somewhat satisfied with the enterprise collaboration.

The universities' positive assesment of the programme is entirely consistent with both the candidate and the enterprise evaluations. For all three parties there was a high degree of satisfaction with the programme in general, and there was also satisfaction with the respective collaborators.

Industrial PhD profiles



This chapter examines the profiles of students, enterprises and universities that use the PhD programme.

The analysis shows that Industrial PhD students are among the best students based on grades from the Danish system and often show mobility when switching universities for the Industrial PhD project. It also demonstrates that they often have a technical/natural sciences background, but the percentage of students from other subject areas is growing, and more women have started choosing the Industrial PhD programme.

The geographical analyses show that there are still many Industrial PhD projects in and around Copenhagen, and a number of large enterprises make frequent use of the programme. Yet there are still many smaller, often research-intensive, enterprises from a broader range of trades which are becoming a growing part of Industrial PhD projects, so the profile is definitely not uniform.

- ✓ 26 percent of the students received the highest grade for their Ma Thesis
- ✓ A little over 40 percent had a grade point average above 10
- ✓ The number of female PhDs has doubled in 10 years
- ✓ The spread in specialisation has increased dramatically in the last five years
- ✓ 70 percent of the Industrial PhDs are in the Greater Copenhagen area
- ✓ The Technical University of Denmark and Copenhagen Business School are the most frequent users of the Industrial PhD programme
- ✓ 35 percent switched university when starting their Industrial PhD project.

3.1 Who are typical Industrial PhDs?

All candidates who meet the formal requirements may collaborate with a host enterprise for an Industrial PhD project. But certain specialist areas and profiles have historically dominated the group of applicants.

The following describes Industrial PhDs in regards to their academic areas at the university, mobility measured by the number who transferred universities between their Masters and their PhD, grade level indicated by their thesis grade and weighted average of MA and BA grades, gender and age.

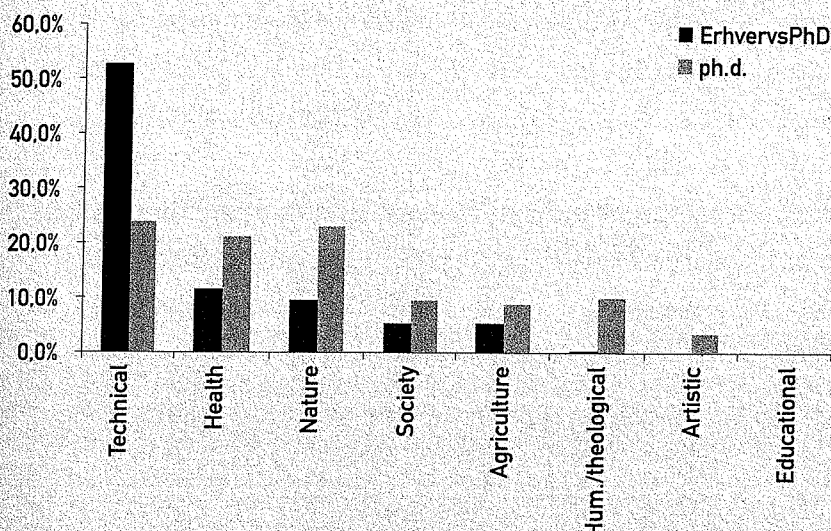
The Industrial PhD programme is particularly used by people with a technical education.

The Industrial PhD programme has been frequently used by students with technical, or natural sciences backgrounds. This is shown in historical statistics for the segmentation among the approved Industrial PhD applications. But a deeper understanding of the trade segmentation within the Industrial PhD programme requires a comparison with the regular PhDs, where the natural sciences, technical and medical science areas also have a large share of the total number of PhDs

Figure 3.1. examines the division of Industrial PhDs among the areas of specialisation compared to other PhDs:.

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Figure 3.1: The distribution of Industrial PhDs and other PhDs on main areas
Completed Industrial PhDs (n=505) and PhDs (n=9467) 1993-2003



Note: The total is not 100% as the figure does not show the category 'Not indicated' which for the Industrial PhDs makes up 14.3%. It is not clear from the figure that education comprises 0.2% for PhDs and the humanities/theology comprises 1% for Industrial PhDs.

Source: Danmarks Statistik

Figure 3.1 shows that there are differences between the Industrial PhDs and all other PhDs. There is a clear dominance of Industrial PhDs in technical education, to which approximately 53 percent are related. For the other PhDs, there is a more even distribution between the main areas, where the technical, natural sciences and medical science areas each constitute approximately 20 percent of the total number of PhDs.

Other PhDs are thus distributed a little more broadly in the academic areas.

This difference can most likely be attributed to the different circumstances under which the two types of PhD education are presented. Relatively few enterprises conduct art, humanities or educational research compared to enterprises in health sciences and technology, for example. This may be reflected in a lower number of applications to the Industrial PhD programme from students with humanities, theological, arts or educational backgrounds. The point is, the requisite partnership between the students and the enterprise may be easier to establish in the technical and medical science areas where there is a larger selection of enterprises with research capacities.

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Despite this, there has been an increase in the spread of specialisation if only the period 2002-2005 is included. The Ministry of Science, Technology and Innovation¹ initiated a number of marketing measures during this period that may be part of the explanation that candidates from new specialist areas have been attracted to the Industrial PhD programme.

This is based on such things as the increase in Industrial PhD projects initiated within the humanities, social sciences and mercantile specialist areas, as shown in Table 3.1:

Table 3.1: Industrial PhD projects divided by specialist areas 2002-2005				
Number of different projects	2002	2003	2004	2005
Health sciences	31	28	20	22
Technical/natural sciences	11	11	30	37
Agriculture and food	3	11	2	5
Social Sciences/Mercantile	4	10	11	13
Humanities	1	4	7	6
Total number of projects	50	64	70	83
Source: Industrial PhD Sekretariat, Council on Research and Innovation				

Table 3.1 shows that the share of Industrial PhD projects within the humanities, social sciences and mercantile academic disciplines tripled from 2002 to 2005. In 2002 there were 5 Industrial PhD projects within these areas which rose to 18 in 2005. The technical/natural sciences also experienced growth, their share doubled during the period. Measured for this brief period, the number of health science Industrial PhD projects actually dropped in numbers and percentage wise. But viewed in relation to their share of approximately 11 percent in Figure 3.1, which includes the period 1993 to 2003, the trend was for their share to increase. In 2005 they were approximately 26 percent.

Due to the progress of certain academic areas, it can be expected that the Industrial PhD programme will be increasingly directed towards smaller, research-intensive enterprises. This is due to the humanities, social science and mercantile projects often

¹ Fra 2002 til maj 2006 blev ErhvervsPhD-initiativet administreret af ErhvervsPhD-sekretariatet i Ministeriet for Videnskab Teknologi og Udvikling. I maj 2006 blev Forsknings- og Innovationsstyrelsen etableret, og ErhvervsPhD-initiativet administration blev sammen med RTI's øvrige innovationsordninger flyttet til denne styrelse. Før 2002 blev ErhvervsPhD-initiativet administreret af Akademiet for de Tekniske Videnskaber for Erhvervsfremme Styrelsen under Erhvervsministeriet. Ordningen hed indtil 2002 Erhvervsforskerordningen.

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being initiated within the private businesses in the service sector. i.e., among enterprises that have a great deal of specialised knowledge in their working field but have traditionally had less to invest in research or experience in establishing research networks with universities.

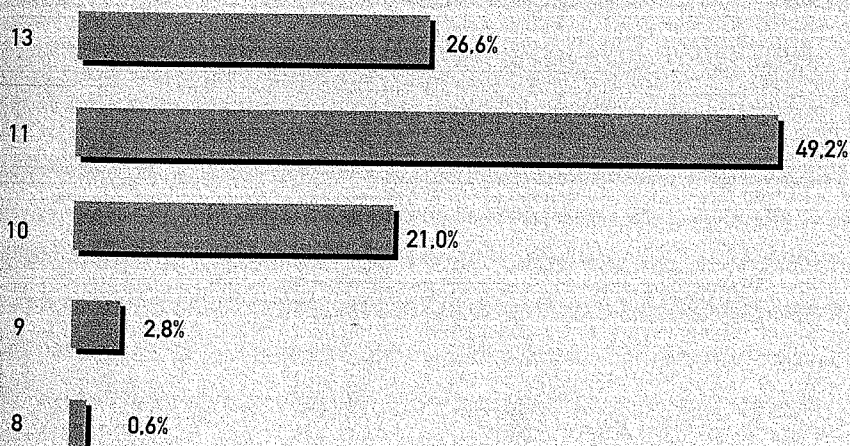
High marks among the candidates.

The Danish Council for Research and Innovation has set a number of goals for the Industrial PhD programme with the main focus on the high academic quality of the education. This is reflected in, among other things, that there are special requirements for the applicant's grade point average and scientific production where relevant. The minimum requirements for the Industrial PhD candidate are:

- Masters level education
- The weighted grade point average for the entire Masters education (including both the Bachelor and Masters programmes) must be a minimum of 9.
- They must have achieved a grade of 10 for their thesis.

A review of the grades for the Industrial PhD candidates shows that they have very high grades, which in a large number of cases well exceed the minimum requirements. This applies to their thesis grade as well as to their weighted grade point average. This is depicted in Figure 3.2, which shows the percentage division of thesis grades for Industrial PhD students from 2002 to 2005:

Figure 3.2: Thesis mark for all Industrial PhD students 2002-2005
Percentage distribution of thesis mark (n=181)



Source: FIST: Statistics of candidate marks

The figure above shows that more than one out of every four Industrial PhD students from 2002 to 2005 achieved a thesis grade of 13.

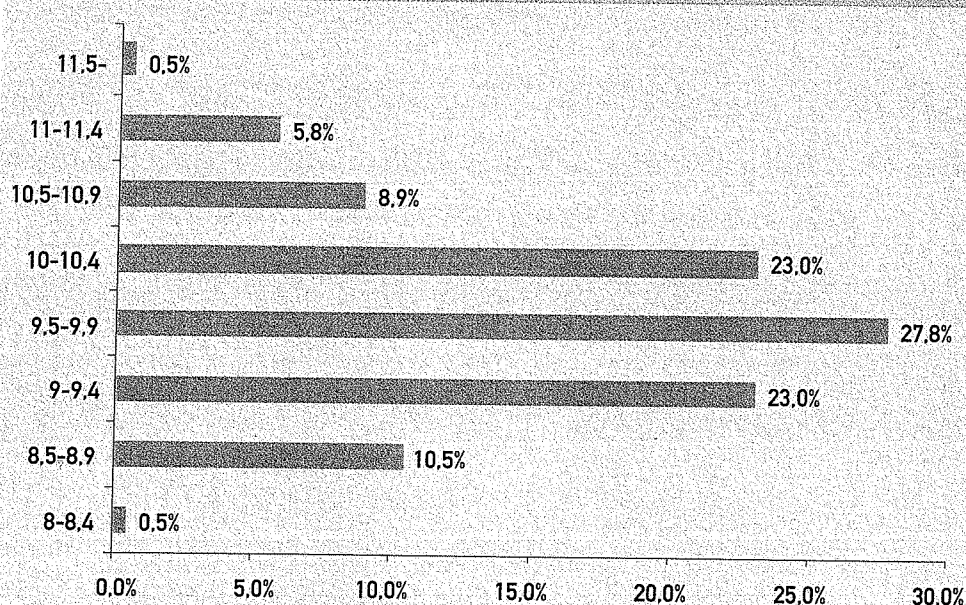
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A total of 46 percent achieved a grade of 11, and consequently a total of 68 percent of the students achieved a grade for a thesis that is at the very top of the scale.

Of the remaining approved applicants, 18 percent achieved a 10 for their thesis, equal to the minimum requirement, while only 3 percent did not meet this requirement. Some special cases with lower grades were accepted if the candidate could document they were qualified to do research, for example through a considerable number of published articles in scientific journals or other research activities².

If the focus is turned to the weighted grade point average the Industrial PhD students have for their entire Masters education (excluding thesis), it shows that many have high grades here as well. Figure 3.3 shows this division:

Figure 3.3: Weighted average mark for all Industrial PhD students 2002-2005
Percentage distribution of weighted average mark (n=191)



Source: FIST: Statistics of candidate marks

Figure 3.3 shows that 89 percent of Industrial PhD students met the minimum requirements for a weighted grade point average of 9 for their entire Masters education. Of these, 38 percent achieved a minimum of 10, while more than 6 percent of the Industrial PhD students had a grade average above 11. Compensation is made for a failure to achieve a grade point average among 11 percent of the accepted applications which have an average between 8 and 9 and thus do not satisfy the formal requirement. However, many applicants are close to the grade requirement to which their additional research specialisation experience is added.

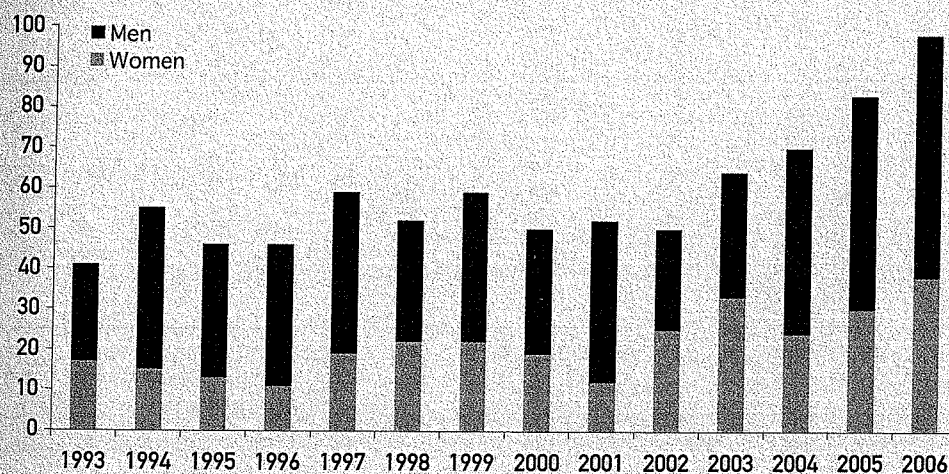
² Vejledning for ErhvervsPhD-initiativet, maj 2006

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More female students are choosing Industrial PhD projects

As noted, approximately half of the Industrial PhD students have a background with a technical Masters education. There is generally a higher number of male students in this education, which could also be expected to be reflected in the gender division among Industrial PhD students. This was examined for the years 1993 to 2006, as shown in Figure 3.4:

Figure 3.4: Industrial PhD student distribution by sex 1993-2006
Approved Industrial PhD students in absolute numbers (n=776)



Note: The figures are projected for 2006 on the basis of data for the first six months by doubling numbers.

Source: FIST: Sex and university from 1993 to 2006

The Industrial PhD programme has been generally dominated by men, although the average for the period 1993-2006 was 64 percent men and 36 percent women. That masks relatively large fluctuations, where for example, there were 33 men versus 13 women in 1995, while in 2003 the women dominated with 33 approved applications compared to 31 from men. Thus, there is no clear trend in the division between men and women, which makes it difficult to produce a uniform profile.

Yet if one only looks at the actual number of women that are taking an Industrial PhD education, there is a clear increase over a ten-year period. In the 1990s an average of 17 women had their PhD application approved, while the average for 2000-2006 was 26 women (see Table 3.1). So in terms of absolute numbers, there is a steady progression in the number of female Industrial PhD students.

3.2 Which enterprises typically use the Industrial PhD programme?

This section presents participating enterprises based on indicators such as the enterprise size, geographical location, research readiness, trade, background for participation in the project and the likelihood that they will participate in more than one Industrial PhD project.