Industrial research schools

A real-time evaluation of
the Swedish Knowledge Foundation's
research school programme

Ingrid Schild
Anders Hanberger

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GLOSSARY, ABBREVIATIONS AND ACRONYMS (SWEDISH)

Abbreviation/ Acronym	Swedish
CTH	Chalmers Tekniska Högskola (Göteborg)
GU	Göteborgs universitet
HHS	Handelshögskolan i Stockholm
IDA	Institutionen för datavetenskap (Linköpings universitet)
IMC AB	Industriellt mikroelektronikcentrum (Norrköping)
IOF	Institutet för Optisk Forskning AB (Stockholm)
KaU	Karlstads universitet
KI	Karolinska Institutet (Stockholm)
KIF AB	Kemiindustrins Forskarskola (Kemikontoret)
KK-Stiftelsen	Stiftelsen för Kunskaps- och Kompetensutveckling
KTH	Kungliga Tekniska Högskolan
LiU	Linköpings Universitet
LTH	Lunds Tekniska Högskola, Lunds universitet
LuTH	Luleå Tekniska Universitet
MinFo	Föreningen mineralteknisk forskning
NMK	Företagsforskarskola Naturliga material med inriktning mot Miljö- och Kulturvård (Göteborgs universitet)
NUTEK	Närings- och teknikutvecklingsverket
SIK	Institutet för Livsmedel och Bioteknik AB
SNS	Studieförbundet Näringsliv och Samhälle
SSF	Stiftelsen för Strategisk Forskning
Trätek AB	Institutet för träteknisk forskning (Stockholm/Skellefteå/Växjö)
UCER	Umeå centrum för utvärderingsforskning

GLOSSARY, ABBREVIATIONS AND ACRONYMS (ENGLISH)

Abbreviation/ Acronym	English
ACREO	Advanced Centre for Research in Electronics and Optics (Stockholm and Norrköping) (result of merger between IOF and IMC)
civilingeniör	Graduate engineer, Master of Engineering
CTH	Chalmers University of Technology
fil. kand.	First university degree (taking approx. 3 years)
fil. mag	University degree (taking approx. 4 years)
GU	Gothenburg University
HHS	Stockholm School of Economics
IDA	The Department of Computer and Information Science (Linköping University)
IMC AB	Industrial Microelectronics Center (merged with IOF to become ACREO)
IMIT	Institute for Management of Innovation and Technology, HHS and CTH
IOF	Institute of Optical Research (merged with IMC to become ACREO)
KaU	Karlstad University
KI	Karolinska Institute, Stockholm
KIF AB	Chemical Industry's Research School (Association of Swedish Chemical Industries)
KK-Stiftelsen	The Foundation for Knowledge and Competence Development
KöF-gruppen	The KK-Foundation's working committee on knowledge transfer
KTH	Royal Institute of Technology (Stockholm)
licentiat	Research degree but lower than a doctorate (usually 2 years)
LiU	Linköping University
LTH	Lund Institute of Technology, Lund University
LuTH	Luleå University of Technology
MARCHAL	Material Research School at Chalmers
MinFo	Swedish Mineral Processing Research Association
NMK	Industry Research School on Natural materials with an orientation towards environment and conservation (Gothenburg University)
NUTEK	Swedish National Board for Industrial and Technical Development
SIK	The Swedish Institute for Food and Biotechnology
SMEs	Small and medium-sized enterprises
SNS	Center for Business and Policy Studies
SSF	Swedish Foundation for Strategic Research
Trätek AB	The Swedish Institute for Wood Technology Research
UCER	Umeå Centre for Evaluation Research

PREFACE

Umeå Centre for Evaluation Research (UCER), in cooperation with the Centre for Business and Policy Studies (SNS), is responsible for a research-based evaluation of the Knowledge Foundation's (KK-Foundation) knowledge exchange programme. This programme is in a relatively early phase, and the object of evaluation is an ongoing process.

This report forms part of this ongoing evaluation. It summarizes the preliminary evaluation findings relating to the industry research school sub-programme, which constitutes the largest sub-programme in the Foundation's knowledge transfer programme. There are currently twelve such research schools, and the contract for a thirteenth is to be signed shortly. This report discusses data collected from these twelve. Note that it is not the purpose here to provide an in-depth analysis of the KK Foundation's knowledge transfer programme. The mid-term report, due at the end of the year, will seek to provide a more comprehensive account of KK's knowledge transfer programme together with conclusions and recommendations.

The Knowledge Foundation, in Swedish *Stiftelsen för Kunskaps- och Kompetensutveckling*, is referred to throughout the text as the KK-Foundation, or simply KK. Please note that the final chapter may serve as a stand alone document for readers requiring a condensed version of the report.

EXECUTIVE SUMMARY

This report forms part of the ongoing evaluation of the KK Foundation's knowledge transfer programme. The evaluation is designed as a 'stakeholder' evaluation, whereby the programme's contribution is assessed in the light of the different interests of various groups of participants. Further, in line with the explanatory approach adopted, the evaluation seeks to shed light on the nature of the knowledge transfer process.

The primary aim of this report is to document progress made in implementing the KK industrial research school programme as part of the larger knowledge transfer programme, and to communicate these findings to stakeholders. In so doing, the report achieves the secondary aim of shedding some light on the knowledge transfer process.

The report draws on three main sources of data: an electronic questionnaire sent to all research school project leaders; a second questionnaire sent to all participating research students; and a large number of semi-structured interviews conducted with a range of participants in all twelve research schools.

The process of establishing the research schools is understood in terms of the nature of the work which makes up this process. Focusing on the actual work involved reveals three overlapping stages, which broadly designate the nature of the tasks engaged in by project leaders and research school administrators. The first stage labelled *Negotiating contracts* encapsulates the tasks of shaping the form to be taken by the research school, and lasts from the point of applying to the Foundation to signing a research school contract. One research school is currently at this stage. The second stage, *Enrolling partners*, designates the range of parallel activities entailed in getting the research school up and running, and lasts roughly from the point at which a contract is finalized to reaching full student capacity. The majority of the research schools are currently at this stage. During the third stage, *Consolidating collaboration*, activity is focused on developing stable and workable forms of collaboration within the research school. The research school is working at full student capacity and forming its identity. Three research schools may be considered to have entered this stage, and a further three are on the verge of entering it.

Understanding research school establishment in terms of work reveals not only that the process is time and energy consuming, but also that the amount of work required to pass through the stages differs over time and between research schools. Research schools which drew on an existing or dormant network of firms and academic collaborators, and which already had some experience of educating industrial research students, required less work, and were thus established quicker, than those which initiated entirely new contacts and systems. For the latter, the process of enrolling sponsoring firms into the research school was particularly arduous. There may thus in practice be a trade-off between speed of research school establishment and research school success in instituting new academic-industry links; the one should not necessarily be equated with the other.

The programme aims are to enhance effective knowledge transfer between sectors, and to raise competence levels within Swedish industry. These then simultaneously constitute KK's criteria of programme success. However, at this early stage in the programme, notions of success need to be informed by participants' perceptions of the programme, and by their ambitions and experiences within it.

Participant groups' various ambitions (and thus criteria of success) within the programme, indicate that stakeholders are a heterogeneous group with very different interests, few of which coincide directly with KK's programme aims, though they may be entirely compatible with them:

- Project leaders are seeking to fulfil their particular vision for their research school; they also see the research school as a means of funding on a par with any other, and as a possible route to winning further funding in the future.
- University academics contributing to research school activities also see the research school as a funding stream. And perhaps more importantly, they hope that the opportunity of developing strong links with specific firms, offered by the research school, may enhance their chances of gaining further public and private research funding in the future. For similar reasons, they are also keen to see quality research emerge from research school activities.
- Firms are keen to derive direct or indirect economic benefit from the results of the student project. They also see the research school as a possible route to successful recruitment, and a way of strengthening links with academia. The positive image conferred by being seen to

engage in research activities and university relations is also a significant motive.

- Research students perceive success in terms of gaining a doctorate and developing a successful industrial, or industrially related career.

Participants' perceptions and experiences as identified in the report may be summarized as follows:

- Project leaders were invariably positive towards the industrial research school concept. Establishing the research schools was largely being carried out in line with their original intentions, though was proving much more time consuming and arduous than anticipated. Two particular and related factors hindering the rate of research school implementation appeared to be: the difficulty of recruiting firms; and a perceived lack of ear-marked resources for administration and overheads.

- Academic supervisors also experienced research school activities as time-consuming, though for different reasons from project leaders. Supervisors at times reported that supervising students with non-traditional backgrounds demanded more time and effort than supervising more traditional research students. Not only was effort entailed in helping such students acclimatize to the academic world, but students recruited by firms were not always regarded as ideal PhD candidates. Academic supervisors varied in the degree to which they appreciated the firm's involvement in the student's research project. Whilst some felt it compromised academic quality, others welcomed the opportunity of working with problems of an applied nature.

- Firms, like project leaders, were largely (though not exclusively) complimentary about the research school programme, though it should be borne in mind that this is a self-selected group, and that some SMEs found the required financial commitment too great. The degree to which firms chose to be involved in the student's research project varied enormously between companies, reflecting different attitudes to research and different ambitions for the project. However, not all firms felt that they were receiving sufficient feedback on the research project. The few firms which were not so positive about the programme largely had concerns over administration costsResearch students also spoke in positive terms about their participation in a research school. They were particularly enthusiastic about the opportunity of developing close links to a

company and working on applied problems. However, research schools differed in the extent to which their students perceived that the schools themselves made a difference to their working life. Such differences between research schools reflected variations between them in whether they have developed fora where students may meet each other (whether courses, seminars, or even social gatherings), and which engender a research school 'identity'. Students were generally satisfied with the supervision offered, though were more satisfied with their university-based than their firm-based supervision. Students varied in the extent to which they felt integrated into their firm, their university department, and/or their research institute, with such variations largely correlating with students' background and/or main place of work. On aggregate, students felt more integrated into their firm or research institute than into their university department. Allied to these variations in perceptions of institutional belonging, was a feeling amongst some students of being split between two or more interest groups, each claiming a stake in their work. Consequently, work loads were at times reported as heavy. Students were not optimistic that they would be able to complete their doctorate within the four years allotted.

Though the evaluation is still in a relatively early phase, it is possible to draw some tentative conclusions on the programmes's contribution to knowledge transfer. The first set of conclusions relates to the institutionalization process constituted by establishing the research schools. The research schools do offer an infrastructure which facilitates collaboration across the academic-industrial boundary. However, the extent to which research schools are building entirely new institutions and networks varies. Those schools which are primarily building up new networks invest greater time and effort to reach a particular stage of development than do schools which are mainly reactivating old networks. The former group of schools naturally has a greater potential of introducing entirely new elements into the knowledge transfer process.

On the whole, implementing the research school programme has been a relatively slow process. Most of the research schools are taking considerably longer to become established than was initially anticipated, as these are demanding projects. Research school administrations should now begin to plan for future financing.

The second set of conclusions relates to the mechanics of the knowledge transfer process within the research school programme. It is apparent that students play an important role in the knowledge transfer process through initiating and maintaining new contacts across the academic-industry boundary. Students can be said to 'embody' the knowledge transfer process, not only by providing access to new contacts across the academic-industry divide, but also by carrying knowledge and information between the two sectors.

1 INTRODUCTION

1.1 Aim of the report

This report provides feedback on the implementation of the KK-Foundation's industry research school programme. As the evaluators are still gathering data, only preliminary results are presented here. The report is not so much an end product as part of an ongoing process of attempting to understand the mechanics and dynamics of the research school programme.

The process of implementing the research school is discussed in terms of the research schools' progress towards reaching full student capacity. This process is here largely considered from the perspective of research school project leaders with reference to a heuristic model of stages of implementation. An overall aim of the evaluation is to integrate the perspectives of the various groups of stakeholders, and thus this report also records the experiences of research students, academic supervisors, and participating firms.

1.2 Sources of data

The report draws on three sources of data: an electronic questionnaire filled in by research school project leaders, recording progress and experiences as of 1. January 2000;[1] an electronic questionnaire sent to all the KK research students; and interviews conducted with participants in all the KK research schools.

Of the 99 questionnaires sent out to students (including three students who have left without completing a degree) 73 questionnaires were returned. The results of this questionnaire are discussed in chapter 3 *Strucutre of the twelve KK industry research schools*, and chapter 5 *Participants' motives and experiences of the research school programme.*

For each research school, one or more representatives of five categories of participants were interviewed: project leaders; research students; university-based supervisors; research institute-based supervisors (where applicable); and participating firms' contact persons. A total of 84

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[1] Of the twelve questionnaires sent out, eleven were returned.

interviews were conducted with 105 research school participants. Several of the interviews with research students were conducted as group interviews, whilst all the other categories of respondents were interviewed individually. These interviews were conducted during the winter and spring of 1999/2000. A list of respondents and their institutional affiliation is attached as Appendix A.

1.3 Structure of the report

The following chapter *Background: The KK-Foundation* provides a brief organizational and historical overview of the KK-Foundation and its research school programme in particular. This chapter may be read in conjunction with the document attached as Appendix B, written by the International Advisory Group linked to the evaluation. This latter document describes the KK-Foundation's role in the Swedish innovation system, and thus sets the policy and economic scene against which the KK initiatives should be understood.

Chapter 3 *Structure of the twelve KK industry research schools* and chapter 4 *Implementing the industry research school programme* are based on data gathered from research school project leaders. Chapter 3 outlines the nature and structure of each of the twelve research schools funded by the KK-Foundation. Chapter 4 analyses the implementation of the research school programme by developing a model of stages of implementation. Chapter 5 *Participants' motives and experiences of the research school programme* draws on a broader base of interview data to report how the industry research school programme is perceived by participants. The chapter records the motives and experiences of research school project leaders, research students, academic supervisors, and firms. The final chapter (chapter 6) summarizes the findings outlined in chapters 4 and 5, and ends with a number of concluding observations. It may also be read as a stand-alone document for those requiring a quicker overview of the findings.

2 BACKGROUND: THE KK-FOUNDATION

2.1 The Foundation's aims and activities

The Knowledge Foundation (KK-Foundation) was established by the Swedish Government in 1994, alongside approximately nine other research foundations, each with different profiles. These foundations were initially established as a means of investing the former wage-earner fund in a way which would benefit Sweden's economy as a whole. The new foundations were not designed to adopt the role of research councils, but rather to fund forms of R&D and allied activities which usually fall outside the remit of the existing research councils.

The KK-Foundation began its work in 1994 with a capital base of 3.6 billion Swedish *kronor* (SEK), which was invested on the stock market. By December 1998, the Foundation's total assets had risen to SEK 5.2 billion, and by the year 2000 they had reached over SEK 7 billion (Stiftelsen för kunskaps- och kompetensutveckling 2000a).

The Foundation's overall aim is to promote economic growth and strengthen Sweden's competitiveness in the global economy. This aim is pursued through three main activities: promoting the use and development of information and communication technologies; supporting profile areas of research in small and medium-sized universities and university colleges; and fostering the transfer of knowledge between universities, colleges, research institutes and industry (Stiftelsen för kunskaps- och kompetensutveckling n.d.).

An overarching policy adopted by the Foundation in order to promote economic growth, is to foster networking. The Foundation regards developing and maintaining networks as an important economic policy instrument. In particular, building new linkages and networks between academia and industry is viewed as an important means of harnessing the country's economic potential.

This emphasis on networking is entirely in line with current thinking within the economics of innovation. This literature emphasises the importance of external sources of knowledge and 'interactive learning' for maintaining a high rate of successful innovation (e.g. Freeman (ed.) 1990, Lundvall (ed.) 1992). Indeed, the recognition that networking, tacit knowledge (know-how), and learning are central to innovation

broadly explains why the innovation process is now widely conceived as systemic rather than linear (e.g. Edquist (ed.) 1997, Lundvall (ed.) 1992, Nelson (ed.) 1993). Further, in tandem with identifying the importance of generic science-based technologies (e.g. biotechnology, information and communication technologies, new materials) for sustained economic growth, the innovation literature also acknowledges the potential and actual importance of the research base for national and regional wealth creation. Whilst the economic importance of public sector research is not in question, there is however less certainty in the literature about the mechanisms underlying this contribution (see e.g. Salter and Martin 1999).

In short, the Foundation's overall aim is to foster economic growth through networking both across and within sectors. From the Foundation's perspective it is against this background that its programme areas should be understood and assessed.

The KK-Foundation's activities are divided into five programme areas: (1) Promoting the use of IT; (2) Promoting knowledge exchange between industry and academia; (3) Promoting research in new universities/university colleges; (4) Restructuring and rejuvenating the industrial research institutes; and finally (5) Promoting information dissemination and attitude change (SNS and UCER 1998, Stiftelsen för kunskaps- och kompetensutveckling 2000b). These programme areas and their respective sub-programmes are not clear-cut discrete initiatives, but rather a degree of overlap occurs between the means and goals of the various (sub)programmes. Further, programmes are developed and refined in response to experiences gained from implementation.

Between 1994 and 1998 the Foundation invested SEK 1.5 billion in various projects. The lion's share of this amount was allocated to projects in the IT programme area. Other important areas funded during this period were: the restructuring of the industrial research institutes; the promotion of research at new universities; and the promotion of knowledge exchange between universities and industry.

2.2 The knowledge exchange programme

The knowledge exchange programme constitutes the focus of the UCER/SNS evaluation. The two-fold aim of this programme is to enhance the level of expertise and competence in industry, and to

facilitate the exchange of knowledge and experience between industry and academia. The Foundation is pursuing these aims by supporting bridging and networking activities in the hope that academia and industry will derive mutual benefit from the resulting closer interaction.

The knowledge exchange programme is itself structured into seven sub-programmes as follows:
- Expert competence (tailormade short training courses largely for SMEs)
- Industrial research schools
- New forms of knowledge exchange between SMEs and universities/university colleges in networks
- Collaboration between new universities/university colleges and industry (co-financed by NUTEK)
- Developing knowledge on academic-industry relations
- Dissemination of research results (public understanding of science)
- The forestry industry programme

This report only examines the industry research school programme, which is the largest of these sub-programmes, and the one which has progressed the furthest.

2.3 Background to the industry research school programme

The following outlines the development of the industry research school programme from the perspective of the Foundation itself. It provides some insight into the background preparation work carried out by the Foundation, as well as the initial project selection process within the programme.

As part of the process of establishing its knowledge exchange programme, the KK-Foundation appears to have carried out a relatively thorough investigation of the needs of industry, and of how the university sector might contribute to meeting these needs. Over a six month period beginning in the latter half of 1995, Madeleine Caesar (who was responsible for the knowledge exchange programme) and Bjarne Kirsebom (the then CEO) organized meetings and hearings around Sweden. The aim was to identify weak links in the Swedish innovation system which the Foundation could help to remedy, either through initiating entirely new programmes, or by enhancing the

effectiveness of existing initiatives. The Foundation also conducted an investigation into industrially relevant PhD training schemes in other countries. Simultaneously, the Swedish National Board for Industrial and Technical Development (NUTEK) mapped existing industry related PhD programmes in Sweden.

On completion of this preparation work, Bjarne Kirsebom set up a working committee (the knowledge transfer, or *KöF*, group) to assist the Foundation by analysing the material gathered and suggesting appropriate programme concepts. Through sounding out the *KöF*-group, the KK-Foundation identified a demand within the Swedish economy for a PhD training scheme tailored to the needs of industry, and involving new forms of academic-industry cooperation. The decision to fund such research training emerged from the perception that many firms regarded traditional doctoral training as too theoretical and largely irrelevant to their needs. Correspondingly, it was believed that firms which did hire graduates with a doctoral training were unable to derive much benefit from the individual for a number of years. The industrial research school programme was designed in response to this perceived shortfall.

In the summer of 1996, the Foundation initiated a campaign, inviting universities, university colleges, industrial organizations and many firms to apply to the Industrial Research School Programme. To qualify for funding, applications needed to meet four relevance criteria defined by the Foundation. The funded research schools were to include a strong element of cooperation between one or more universities and firms; they were to focus on new research areas; they were to offer cross-disciplinary research training; and finally, KK-funding had to be matched by participating firms' contributions. These criteria, which applicants were encouraged to meet, were perceived to form key ingredients of a research school tailored to the needs of Swedish firms. The issue of research quality did not feature strongly in discussions at this early stage in the project selection process. However, the Foundation reportedly regarded quality of research as just as important a criterion as relevance.

The Foundation received 260 applications and notifications of interest, which reportedly varied greatly in quality. Some larger universities submitted many applications each, despite the Foundation's request that they only submit one per institution. The Foundation engaged the help of two consultants to assist in selecting amongst these applications. None of the initial applications was judged to meet the Foundation's

criteria, and thus none merited immediate funding. However, of the initial 260 applications, 90 were considered to have potential enough to warrant resubmission.

In short, this selection process was a process of negotiation between the applicants and the Foundation in their joint attempts to find ways of meeting the Foundation's funding criteria. Thus the twelve applications which eventually received funding required substantial re-working before meriting funding. Madeleine Caesar and one of the consultants were involved in this negotiation work throughout. The *KöF*-group also played an active role in this selection process, whilst the Foundation's board appears largely to have played the legitimating role of approving the selected projects.

3 STRUCTURE OF THE TWELVE KK INDUSTRY RESEARCH SCHOOLS

3.1 Introduction

This chapter describes some characteristics of the research schools. It draws on the results of electronic questionnaires filled out by research school project leaders and KK research students. Appendix C also provides at-a-glance information school by school.

The Foundation assumes that it costs SEK 800,000 a year to educate an industry research student in a research school. This figure is reportedly that recommended by the Ministry of Education, though it may be closer to the lower end of a range of estimated costs of educating a research student.[2] The Foundation guarantees to fund each student at SEK 400,000 over four years. The research school must find industrial sponsorship for the remaining fifty per cent. In practice, a single firm normally sponsors one or more students, paying SEK 400,000 per student to the research school (though part of this amount may be paid in kind, such as an industrial supervisor's time). The student is often (though not necessarily) formally employed by the sponsoring company for the duration of his or her PhD studies.

Research schools were expected to recruit all their students as a single cohort soon after signing the contract with the Foundation.[3] The aim is that this cohort of students will progress through the PhD training as a single group. Research schools receive funding for four years, in which time students are expected to complete their doctorates. However, owing to start up difficulties, the majority of research schools have requested that their period of funding be extended to five or six years. The Foundation has complied with these requests, though the extension does not entail any increase in the initially agreed level of funding.

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[2] It may be that the amount available from the Foundation is constrained by the stipulation that it has to be matched by industry.

[3] Though neither KK nor project leaders appeared quite clear as to whether this is in fact the case.

3.2 Basic data on the research schools

Host organizations

Table 1 provides some basic information on the twelve research schools. The abbreviations for the research schools listed in the first column of Table 1 will be used throughout the text and in subsequent tables. The table groups the research schools according to type of host organization, and indicates the schools' broad research area. Host organization refers to the organization which signed the contract with the Foundation and which has administrative responsibility for the research school. As the table shows, over half (seven) of the research schools are hosted by universities, four by industrial research institutes, and one by an industrial association of small and medium-sized chemical companies. The host organizations are dispersed throughout Sweden, from Luleå in the north to Lund in the south, though they are somewhat concentrated in the Gothenburg and Stockholm areas. Four host organizations are wholly located in the Gothenburg area, whilst three are located in the Stockholm area. One, the Institute for Management of Innovation and Technology (IMIT), is located in both Gothenburg and Stockholm.

Research areas represented by the research schools

A glance at Table 1 shows that the Foundation has succeeded in obtaining a spread of research fields amongst the research schools. Both high-tech sectors and sectors which are traditionally thought of as mid or low-tech are represented, as is a social science area.

The research schools working in high-tech areas include those based at Karolinska (biotechnology), Linköping (IT), and ACREO (electronic design and fibre optics). These represent the 'strategic' research fields which the Foundation has an explicit aim to support. A focus on some traditional sectors largely unused to conducting research or hiring research trained personnel, such as the forestry and mining industries, is also a feature of this programme.

The Foundation has stressed that there was no intention to fund particular scientific areas, and that geographic criteria played no part in the selection process. This implies that the spread of the twelve research schools over high-tech areas, primary sector industry, and management, coupled with their relatively broad geographic spread is fortuitous.

Table 1 The KK-Foundation's Industry Research Schools by host organization and research profile

Abbreviation	Host organization and its location	Research profile
Industrial research schools hosted by a university		
Karolinska (KI)	Center for Medical Innovations, Karolinska Institute, Stockholm	Biotechnology with an industrial focus
Linköping	Department of Computer Science, Linköping University	Applied IT and software engineering
Fenix	Institute for Management of Innovation and Technology (HHS, Stockholm and CTH, Gothenburg) and Chalmers University of Technology, Gothenburg	Management of industrial R&D; Executive PhD in R&D project leadership
Luleå	Luleå University of Technology	Mining and mineral processing
Lund	Lund Institute of Technology, Lund University	Building and indoor environment (air quality and acoustics)
MARCHAL	Chalmers University of Technology (Material Research School at Chalmers), Gothenburg	Materials research
NMK	Gothenburg University	Natural materials, environment and conservation
Industrial research schools hosted by an industrial research institute		
SIK	Swedish Institute for Food and Biotechnology (SIK), Gothenburg	Industry research students at SIK and orientation towards food and biotechnology SMEs
IOF/ACREO	Advanced Centre for Research in Electronics and Optics, Stockholm (formerly Institute of Optical Research)	Optics (mainly fibre optics)
Trätek	Swedish Institute for Wood Technology Research (AB Trätek), Stockholm (also Skellefteå and Växjö)	Wood processing and IT applications for effective management of the product chain
IMC/ACREO	Advanced Centre for Research in Electronics and Optics, Norrköping (formerly Industrial Microelectronics Center)	Electronic design
Industrial research school hosted by an industrial assocation (a group of firms)		
KIF	Association of Swedish Chemical Industries, (coordinated from BIM Kemi AB, Gothenburg)	The Chemical Industry's Research School (KIF AB), SMEs

Dates of establishment

Various criteria can be used to measure the starting point of the research schools. Table 2 lists the research schools by: date of KK board decision; date of contract (the last signature); and date of admission of the first student. This report equates each research schools' starting point with the date of its contract. Before this date, participants may not feel entirely sure that they will receive funding. In Table 2 the research schools are listed in descending order of age by contract date. Subsequent tables will use the same ordering.

Five contracts were signed in 1997, four in 1998, one in 1999, and the most recent was signed earlier this year.[4] A further contract for a research school is in the process of being negotiated with the newly formed industrial research institute Advanced Centre for Research in Electronics and Optics (ACREO). ACREO is the result of a merger between the Industrial Microelectronics Centre (IMC) and the Institute for Optical Research (IOF). The applicant for the new research school was IMC (hence its abbreviation IMC/ACREO). Once this research school is established, ACREO will have two KK research schools, as the former Institute for Optical Research has a small number of KK research students (abbreviated IOF/ACREO) who are now integrated into ACREO.

Column 5 of Table 2 records the number of months between a research school's contract date and the date of admitting its first student. In the majority of cases, the first student was admitted up to a year after the contract was signed (no data has been received from the Luleå/mining research school). Two research schools appear to have admitted students some months before signing their contract with the Foundation. There are several possible reasons for this apparent incongruity. Contract negotiations may have been protracted (as indeed they were in some cases); equally, the host organization's decision to admit the first student(s) may have been made independently of the availability of KK financing.

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[4] Two research schools, Fenix and SIK, strictly speaking have two contracts for industrial research students. For the sake of clarity the contracts are counted as one here, as both are in practice administered as a single research school.

Table 2 Research schools by dates of establishment: listed in descending order of date of KK contract

Research school & research profile	KK board decision	Contract date	First student admitted	Months betw. contract & 1st student admitted
Karolinska (KI) *Biotechnology*	June 1997	July 1997	July 1998	+12
Linköping *Applied IT & software engineering*	May 1997	Aug. 1997	Sept. 1997	+1
Fenix *R&D project leadership*	June 1997 & Aug. 1997	Sept. 1997	Sept. 1998	+12
SIK *Food & biotechnology SMEs*	June(?) 1997 & Sept. 1997	Nov. 1997	May 1998	+6
IOF/ACREO *Optics*	Sept. 1997	Nov. 1997	July 1998	+8
Trätek *Wood technology & forestry industry*	June (?) 1997	Jan. 1998	Sept. 1997	-4
Luleå *Mining & mineral processing*	May 1997	May 1998	?	?
Lund *Building & indoor environment*	May 1997	Aug. 1998	Nov. 1998	+4
MARCHAL *Materials research*	Oct. 1997	Oct. 1998	May 1999	+7
KIF *Chemical SMEs*	Dec. 1998	March 1999	Jan. 1999	-3
NMK *Natural materials & building conservation*	June 1999	Jan. 2000	-	-
IMC/ACREO *Electronic design*	?	2000 (?)	-	-

Student capacity and enrolment

Table 3 shows the size of the grant and the student capacity of each research school. It also indicates the number of students enrolled in January, 2000. The research schools have a collective capacity of 151 research students, and in January, 2000, 88 students had been enrolled. Two research schools (NMK and IMC/ACREO) have yet to admit students. Fenix, which has enrolled 10 students, is admitting 10 more in the autumn of 2000; and Karolinska appears to be enrolling students on a more or less continual basis. The majority of current students are enrolled in university-based research schools (53), with 28 in industrial research institute based research schools, and 10 in the single firm-based resesarch school).

Data on the number of students who have completed degrees are incomplete, though they are available for the Linköping research school. Two students have completed a doctorate in the Linköping research school, and one has completed a *licentiat*. This student has left the programme. Since this research school has only been in existence since 1997, it may be assumed that those who have already graduated were some way into their research training before the KK research school was established, and that the KK money may have been used to finance the final years of their degree. The observation that the KK funding is at times used to fund research students already in the system is substantiated in the interview data. The interview data also indicate that some students are leaving the programme with a *licentiat* degree (this has at least been the case at the Trätek, Luleå, and as mentioned above, Linköping research schools).

Data on the number of students who have interrupted their studies or left the programme without completing a degree are also incomplete, and are again only available for Linköping. Three students in the Linköping research school are taking a break from their studies. It is as yet unclear whether these will return to the programme or not. Again, interview data reveal scattered instances of students leaving the programme, but this does not seem to be a significant problem for the research schools at this stage.

Table 3 Research schools by size of grant, student capacity and student enrolment

Industrial Research school	KK grant (M Kr, to nearest 100,000)	Student capacity (as specified in contract)	No. students enrolled (1.Jan. 2000)
Karolinska (KI) *Biotechnology*	38.9	20	11
Linköping *Applied IT and software engineering*	41.0	20	19
Fenix *R&D project leadership*	64.4 (30.4 + 34.0)	20 + 37*	10
SIK *Food and biotechnology SMEs*	20.5 (4.5 + 16.0)	11 (3+8)	10
IOF/ACREO *Optics*	6.4	4	3
Trätek *Wood technology and forestry industry*	10.2	5	5
Luleå *Mining and mineral processing*	11.0	8	7
Lund *Building and indoor environment*	41.3	18	8
MARCHAL *Materials research*	16.0	10	5
KIF *Chemical SMEs*	20.7	11	10
NMK *Natural materials and building conservation*	20.8	12	-
IMC/ACREO *Electronic design*	?	12	-
Total		151	88

* **Note:** Fenix has two contracts (with different contractors) for research schools. One contractor is Chalmers University of Technology: this is for an industry research school in R&D project leadership for 20 students (34 M.SEK, 1997-2003). This is the research school referred to in this report as Fenix. The contractor of the second contract is the Institute for Management of Innovation and Technology. This is for 37 students in R&D management (30.4 M.SEK, 1997-2003). This contract is not discussed here, as it is not within the research school programme, but in the sub-programme 'New forms of knowledge exchange between SMEs and universities/university colleges'.

Table 4 Indicators of research school identity

Indicator	Yes	Not yet	Do not intend to	No response	Number responded
Own homepage	9	1	-	-	10
Own administration	7	1	2	-	10
Own logo	5	2	3	-	10
Own e-mail address	3	3	4	-	10
Own rooms on campus	2	1	7	-	10
Own research facilities/ laboratory equipment	1	-	8	1	10
Own rooms off campus	-	1	8	1	10

Indicators of organizational identity

This section focuses on whether the research schools are becoming organizational entities and developing distinctive identities (research school identity is also dealt with in the following chapter, see p.53). It draws on responses from project leaders who were asked whether they had introduced organizational features and symbols. Table 4 documents the results.

The most frequent markers of identity adopted by the ten project leaders who replied, were a homepage and an independent administration. Nine maintained homepages; indeed KK has requested that all the research schools maintain an up to date web page, which can assist the Foundation in its monitoring activities. A majority of project leaders (7 of 10) reported that their research schools had their own administration, some of which are sections of a larger administration. Linköping's KK research school is for example under an administration with

responsibility for all research training within the University's Department of Computer and Information Science.

Two research schools (Fenix and Lund/Indoor environment) occupy their own space on campus. Of the remainder, only NMK intends to obtain its own space. The research schools do not have their own research facilities or laboratory equipment, though Fenix is currently setting up a number of 'venture labs', which, it is hoped, will gather people committed to developing new business opportunities. Roughly half the research schools have a specially designed logo or intend to create one. The Karolinska research school logo features a bridge, symbolizing industry-university technology transfer.

3.3 Collaborating partners and their geographical distribution

Collaborating academic institutions

Table 5 lists each research school's collaborating universities and university departments. Of eleven research schools, only those hosted by industrial research institutes or by firms (SIK, IOF/ACREO, Trätek and KIF) are collaborating with an external academic institution. NMK is an exception to this pattern. In other words, with the exception of NMK, none of the university based research schools are collaborating with academic departments outside the host-university or universities. Of the five research schools that are collaborating with external academic partners, four are collaborating with academic partners outside the host organization's region. Thus a slight majority of research schools is only collaborating with departments within their host organization or within the host organization's region, and those that are collaborating externally tend to be based in research institutes.

The available data suggest that research schools are fostering interdisciplinarity and networking across departments either within or across organizations. Such networking tends to be concentrated to a particular geographic region. It may thus be tentatively concluded that the KK Foundation's goal of fostering networking, is - on the university side at least - being attained.

Table 5 Collaborating universities and university departments

Industrial Research School	Collaborating universities and departments
Karolinska (KI) *Biotechnology*	• **Karolinska Institutet, Stockholm** ○ Dept. of Biosciences ○ Dept. of Medical Nutrition ○ Centre for Genomics Research ○ Microbiology and Tumor Biology Centre ○ Dept. of Clinical Sciences
Linköping *Applied IT & software eng.*	• **Linköping University** ○ Dept. of Computer and Information Science
Fenix *R&D project leadership*	• **Chalmers University of Technology, Gothenburg** • **Stockholm school of Economics**
SIK *Food and biotechnology SMEs*	• **Chalmers University of Technology, Gothenburg** ○ School of Chemical Engineering (Food Science) • **Gothenburg University** ○ Dept. of Marine Ecology ○ Dept. of Respiratory Medicine and Allergology • **Lund Institute of Technology, Lund University** ○ Dept. of Chemistry (Food Engineering, Food Technology, Polymer Science & Engineering)
IOF/ACREO *Optics*	• **Royal Institute of Technology (KTH), Stockholm** ○ Dept. of Physics
Trätek *Wood technology and forestry*	• **Linköping University** ○ Dept. of Computer and Information Science ○ Dept. of Mechanical Engineering • **Luleå University of Technology** ○ Wood Technology (Skellefteå Campus) • **Royal Institute of Technology (KTH), Stockholm** ○ Dept. of Industrial Economics and Management
Luleå *Mining & minerals*	• **Luleå University of Technology** ○ Dept. of Chemical & Metallurgical Engineering (Mineral Processing) ○ Dept. of Civil & Mining Engineering (Rock Engineering and Rock Mechanics)
Lund *Building & indoor environment*	• **Lund Institute of Technology, Lund University** ○ Dept. of Chemistry (Polymer Science & Engineering) ○ Dept. of Building & Environmental Technology (Building Materials, Engineering Acoustics, Building Physics)
MARCHAL *Materials research*	• **Chalmers University of Technology, Gothenburg** ○ School of Mechanical and Vehicular Engineering (Engineering Metals, Polymeric Materials) ○ School of Chemical Engineering (Applied Surface Chemistry)
KIF *Chemical SMEs*	• **Chalmers University of Technology, Gothenburg** ○ School of Chemical Engineering (Applied Surface Chemistry, Physical Chemistry, Molecular Biotechnology) • **Gothenburg University** ○ Microbiology at the Dept. of Cell and Molecular Biology ○ Institute of Laboratory Medicine (Dept. of Pathology) • **Karlstad University** ○ Division of Chemistry (Chemical Engineering) • **Lund Institute of Technology, Lund University** ○ Dept. of Chemistry (Chemical Engineering)
NMK *Natural materials & building conservation*	• **Chalmers University of Technology, Gothenburg** • **Gothenburg University** • **Gotland University College** • **Högskolan Dalarna**

Table 6 Collaborating firms and research institutes

Research School	Large firms (>500)	Medium-sized firms (100-499)	Small firms (<99)	Research institutes
Karolinska *Biotech.*	• Pharmacia & Upjohn	• Q-Med • SBL Vaccin	• Karobio • Medivir	
Linköping *Applied IT & software eng.*	• Ericsson • FöreningsSparbanken • IKEA • Nokia • SKF • SysTeam • Telia • WM-Data		• Cepro • Devenator • Focal Point • Ida Systems • Idonex • MathCore	
Fenix *R&D project leadership*	• AstraZeneca • Ericsson • Telia • Volvo			
SIK *Food & biotech. SMEs*	• Arla Ost • Danisco Sugar • Procordia Food • Tetra Pak R&D	• AnalyCen Nordic • Kavli	• Allt-i-Fisk • Aromatic • Mentha • SydGrönt • Österlenkryddor	
IOF/ACREO *Optics*	• Ericsson Cables • Ericsson Microelectronics • Telia			• ACREO
Trätek *Wood & forestry*	• AssiDomän Timber • Brio • Casco • Graninge • Iggesund • Korsnäs • Kährs • Södra Timber • Tarkett	• Martinsons • SCC-Trätrappor • Svedbergs i Dalstorp	• KarlsonHus • Kvänum Kök • OLAB • Snickarlaget • Svenska Träbroar	• Trätek
Luleå *Mining +*	• Boliden • LKAB			
Lund *Indoor environment*	• Cementa • Dalloz Safety • Gyproc • Perstorp Flooring • Scancem Research • Skanska Teknik	• Ingemansson • Optiroc		• Swedish National Testing and Research Institute
MARCHAL *Materials*	• Höganäs • Nobel Biocare • SCA Research • Tetra Pak R&D		• Artimplant	• Swedish Ceramic Institute
KIF *Chemical SMEs*		• Bostik	• Alufluor • BIM Kemi • Bycosin • Diffchamb • Noviant • Vasco	
Total No.	41	10	25	4

Table 7 Geographical distribution of research schools' collaborating firms

Industrial Research School	Stockholm	Gothenburg	Sweden: south of Stockholm (excl. Gothenburg)	Sweden: north of Stockholm
Karolinska *Biotech.*	X			
Linköping *Applied software IT & eng.*	X	X	X	
Fenix *R&D project leadership*	X	X		
SIK *Food & biotech. SMEs*	X	X	X	
IOF/ACREO *Optics*	X			
Trätek *Wood & forestry*	X		X	X
Luleå *Mining +*	X			X
Lund *Indoor environment*		X	X	
MARCHAL *Materials*		X	X	
KIF *Chemical SMEs*		X		

Collaborating firms

Approximately 76 firms are collaborating with the ten research schools which are up and running (see Table 6) The broad distribution of these firms over a range of industrial sectors is apparent. The number of firms attached to each research school varies from 3 firms (AOF/ACREO) to 17 (Trätek).

In light of their relatively large student capacities, Karolinska and Fenix have perhaps fewer collaborating firms than might be expected (Karolinska has 5 firms and 11 enrolled students, and Fenix has 4 firms and 10 students currently on roll). The small number of firms per student at Karolinska can be explained by the fact that one firm, Karobio, currently sponsors almost half the students in the programme. Conversely, Trätek seems to have spread the cost of co-financing its five research students over many firms. This might be expected as these wood/forestry companies are unlikely to have significant R&D resources.

The firms participating in the research schools are roughly evenly distributed between our SME and large firm categories (Table 6). Thirty-five of the firms have less than 500 employees, and of these, 25 have less than 100 employees. One research school (KIF) is entirely made up of SMEs (less than 500 employees), and three (IOF/ACREO, Fenix, and Luleå[5]) collaborate exclusively with large firms (more than 500 employees). The remaining research schools have a relatively even distribution of firms by firm size.

Table 7 gives a rough indication of the geographical distribution of the collaborating firms. The majority of the collaborating firms are concentrated to the same geographical region as the host organization, suggestive of a spatial aspect to successful collaboration. Further, collaborating with local universities/firms minimizes student travel and facilitates face to face meetings. However, a majority of research schools (6 of 10) also collaborate with firms outside their region. This may reflect the concentration of certain industries to particular regions (as is the case with the forestry industry and Trätek), or it may reflect a failure on the part of the research schools to recruit local firms. The effect of the dispersed character of the research schools on research school activity is as yet unclear, and is a question which merits further consideration.

The relatively large number of small firms participating in the research schools is a striking feature of the programme, and is in line with the Foundation's aims. However, there are indications that the financial commitment required of small firms is too heavy. Project leaders

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[5] though the Luleå research school also collaborates with the Swedish Mineral Processing Research Association, funded by a number of mining and mineral companies.

commented that some firms need to renegotiate their participation annually, whilst some can only promise to support a student to the *licentiat* stage.

3.4 Students

Recruitment

Only six project leaders replied to the question of how many student applications the research school had received. Of these six, Fenix had received the most (250 student applications, all from people working in industry). A further three research schools had received between 44 and 50 applications, one had received five and the other three applications.

There are two reasons why some research schools may have received few formal applications. First, in some fields there is a lack of demand for graduate education (this is the case in mining and mineral processing for example). Second, project leaders may simply have chosen to nominate candidates they knew and whom they thought suitable. This in turn might be accounted for by a certain pressure on project leaders to enrol students quickly, given the delays caused by the difficulty of recruiting industrial partners.

Background

The following data derive from the student questionnaire; and are only valid for the 74% of students who replied. The distribution of returned questionnaires between the sexes is broadly representative of the KK student body as a whole. Of the responses received, 59% are from male students who make up approximately 60% of the KK student body.

Figure 1 shows the distribution of KK students by age and sex. The majority of the students (67%) are within the 26-35 age range. Female students are on the whole younger than the male students. Two thirds of the female students who replied are aged 30 or under, whilst a half of the male students are 30 or under.

The academic qualification held by the students varies. Approximately half are *Civilingenjör*, whilst another quarter of the students are

fil.Kand/fil.mag (first degrees roughly equivalent to a bachelor's degree); a further 12% of the students have some form of *licentiat* degree.

The vast majority of the students (85%) have had at least some industrial experience before enrolling as a research student. Figure 2 shows how the students are distributed by length of industrial experience. Of those who say they have worked in industry, just over half have at least three years industrial experience, and a quarter have one year or less experience. This latter figure might include a number who have only had university placements. The year prior to enrolling in the research school, 40% of the respondents were working in the same firm as they now are linked to, and almost a quarter were studying in the same university as they are now enrolled at.

Figure 3 maps length of industrial experience by sex. Male students are slightly more likely than female students to have industrial experience; they are also slightly more likely to have longer industrial experience than their female colleagues: 50% of the male students have at least 3 years industrial experience, compared to 40% of the female students. Although the observed differences between the sexes in industrial experience are probably small enough to be stochastic, it may be conjectured that the slightly less industrial experience among the women reflects a degree of positive discrimination on application to the research school. Perhaps faced with fewer female than male applicants, and keen to recruit women, research schools were prepared to accept them with less industrial experience than their male colleagues.
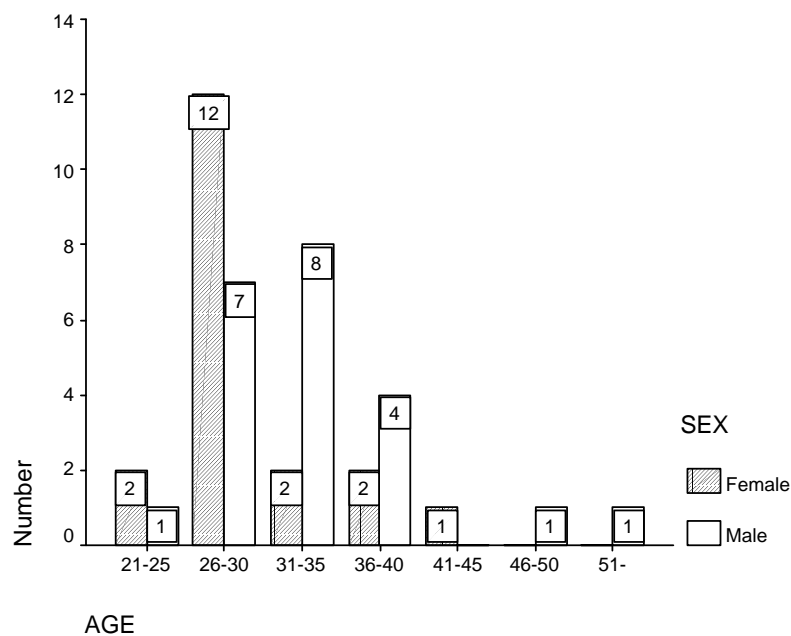
Figure 1 Number of research students by sex

Figure 2 Length of students'previous industrial experience
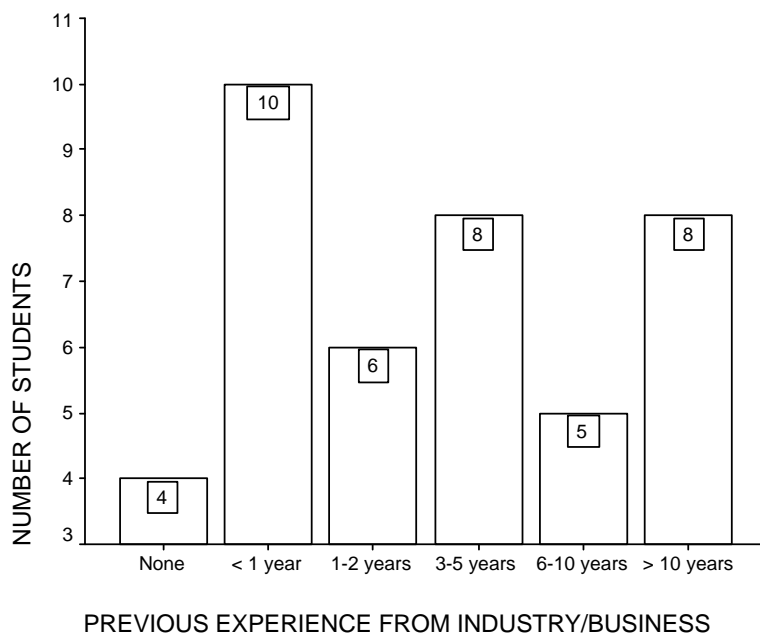
Figure 3 Length of students' previous industrial experience by sex
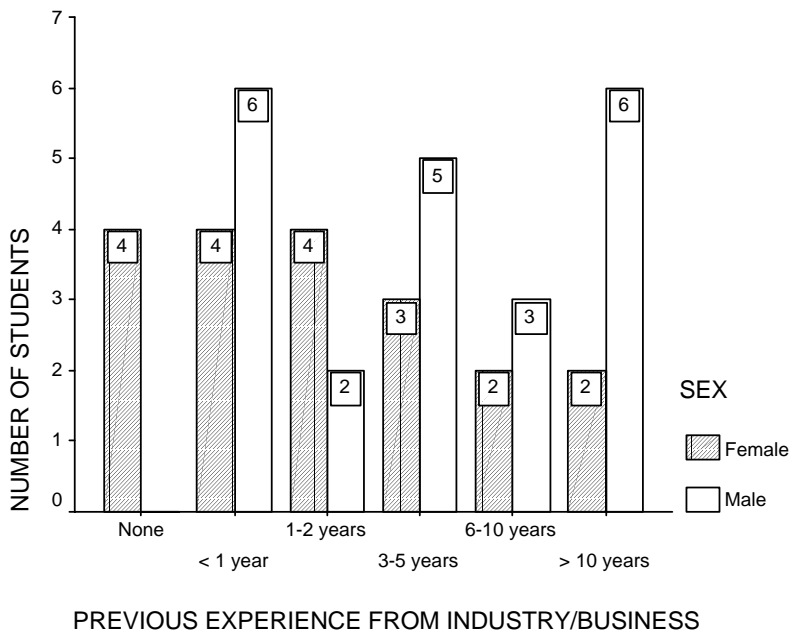
Work situation

The project leader questionnaire revealed that approximately three out of ten KK students are employed by a university (either the host organization or a cooperating university). A similar proportion is employed by firms, and a slightly smaller proportion is jointly employed by a university and a firm. The remaining 14 students are employed by industrial research institutes.

The amount of time the students spend in firms varies greatly between research schools, between students in the same research school, and over time. In all, three out of ten students spend less than 25% of their time in firms, whilst a slightly smaller proportion spends more than 75% of their time in a firm. Just over half the KK students spend 50% or less of their time in firms. The majority of research schools do not stipulate how much time students should spend in firms, which may vary considerably from year to year. Fenix however has a policy of a fifty-fifty split.

Structure of research training offered

Supervisors and supervision

Each student in a KK research school has at least one main supervisor and one industrial supervisor or secondary supervisor. Table 8 shows how all supervisors and 'main' supervisors respectively, are distributed by type of institution (university, firm, and research institute). According to the project leader questionnaire, 189 academic and industrial supervisors are currently involved in supervising students in the KK research schools.[6] Many of the supervisors are professors or assistant/associate professors. Only nine of the 189 supervisors do not hold a doctorate (and presumably these are largely firm-based supervisors).

Over 60% of all supervisors (main and secondary) are located at a university. Almost half of all supervisors are based at the host university, and a further 15% are based at a university other than the host organization. A quarter of all supervisors are based in a firm, and 12% are based in a research institute. Assuming students have one academic

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[6] This figure excludes the Luleå research school, for which data have not been received.

and one industrial supervisor, there are relatively more supervisors based in universities than one might expect. This can probably be accounted for by the likelihood that students have more than one academic supervisor (particularly since many are working in interdisciplinary fields), and by the observation that on average, each firm supervisor may be supervising more KK students than main or academic supervisors. Firms may have asked certain employees to be responsible for all or most of the KK (and other) industrial research students attached to the firm.

The 'main' supervisor has the academic responsibility of overseeing the student's education. This supervisor always has some academic affiliation, but does not necessarily work full time or even mainly in a university. Though the main supervisors in the KK programme are predominately based in universities, some are based in research institutes and firms (see Table 8 which indicates that 17% of main supervisors are in research institutes and 9% are in firms) Some main supervisors have joint appointments at a university and a firm. This is mostly evident in the more high-tech research schools, such as Linköping and Karolinska

The role of the industrial (normally secondary) supervisor is less well-defined, and differs from project to project. These supervisors have variously described their role as promoting the firm's interests in the research project, cultivating the firm's link with the university and the student, and acting as 'industrial mentor' for the student. Industry mentors normally performed the role of helping students acclimatize to firm culture.

Courses

A Swedish PhD degree programme is made up of 160 academic points or credits, a proportion of which is earned through taking a range of courses, and the remainder of which is accounted for by the thesis. Whilst some of the research schools stipulate what proportion of the degree is to be made up of courses, others do not. Research schools which have a common requirement regarding course points are generally those based in one university, such as MARCHAL. In these cases, the research school's regulations follow those of the host univeristy (perhaps with a few adaptations). Research schools which do not have a common requirement generally have students enrolled at different universities, who consequently follow their own university's rules govering course

requirements. This is the case with Trätek's students for example. Among the KK research schools, the number of points required in courses varies from 32 points to 80 points, though the majority require between 40 and 50 points in courses.

Table 8 Distribution of research schools' academic and industrial supervisors by type of organization

Institution	No. supervisors	% share	Number of main supervisors	% share	No. research schools responded
Host univ.	89	47			10
			65	74	
Univ. other than host univ.	29	15			10
Firm	48	25	8	9	10
Research institute	23	12	15	17	10
Other organization	0	-	-		10
Sum	189	100	88	100	

Comments: No distinction is made between host and other universities for main supervisors' location.

Of the nine research schools which are up and running *and* which returned the questionnaire, seven have compulsory courses in the programme. See Table 9 for a list of the compulsory courses offered by the research schools. Such courses may be compulsory for all research students in the host university, or may be specifically designed or bought for the research school itself. Some of these courses are specific to the needs of industry (Karolinska, Fenix, SIK, and KIF offer a compulsory course element in industry relevant topics), whilst others deal with the subject area or research methodology.

Four research schools (Karolinska, Fenix, KIF, and Lund) have designed or bought new courses specifically for the KK research school, and a new research school, NMK, intends to do so. Some of these courses are on industrial topics such as intellectual property rights and

entrepreneurship, whilst others are subject specific. In most cases, these courses are in theory open to university research students too, though in practice usually only KK students attend.

Comparison with traditional research training

Project leaders were asked to assess how the research training offered in their research school differed (if at all) from traditional PhD studies. Answers fell into two categories: those which stressed how the research differed, and those which stressed a difference in terms of social organization.

Answers in the first category maintained that the research projects conducted within the framework of the research school have a stronger orientation towards specific firm or industrial problems than is the case with most PhD projects (in the same field). Another salient feature mentioned was the interdisciplinary character of the research programme.

A second set of distinguishing features related to the social organization of the research activity. The link to firms was perceived to be stronger in this research programme than is usual even in technical fields. One project leader highlighted the fact that in his research school, students spend fifty per cent of their time in their firm and fifty per cent in an academic setting. The related continuous transfer of knowledge by the research student back to the company was also mentioned as a distinguishing feature.

The opportunity to work in research groups of academics and practitioners was perceived a special characteristic of this research training. Fenix's project leader mentioned the practice of working and writing together with a senior researcher as a novel element. Further, having a cohort group of students was also perceived by at least one project leader as a salient characteristic (though the degree to which research schools achieve this varies widely). One project leader encapsulated the advantages this offered thus:

> Research students admitted to different departments have a specific obligation to get together in the [research] school. This leads to an intra-university technology transfer, and the technology transfer between the university and firms is boosted by the common interest from the two parties centred around the student and the project.

Within Fenix, the advantage of the cohort model was seen in terms of the possibility of tailoring courses in sync with the students' 'research phase'.

However, the research schools vary in the degree to which they actually differ from other research training. This is largely because most Swedish science and engineering university departments are now keen to collaborate with industry. For example, the Linköping research school does not appear radically different in a university department where groups have traditionally maintained strong industrial links.

Project leaders were also asked to comment on how they believed their research school differed from other industrially-oriented research training programmes, such as that sponsored by the Foundation for Strategic Research. Whilst the majority could not answer this, two pointed out that the KK research schools are more oriented towards SMEs, an observation endorsed by the large number of collaborating SMEs listed in Table 6. As the Table shows, the KK programme is also attracting the interest of a large number of very large firms, which is perhaps necessary in order to attract the small firms. Appendix C documents project leaders' perceptions of the advantages of the KK research school programme.

Table 9 Compulsory research school courses

Research school	Titles of compulsory research school courses / Comments supplied by project leaders
Karolinska (KI) *Biotechnology*	• Good Laboratory Practice • From discovery to patent • Drug discovery and innovation knowledge • Science based entrepreneurship • Economic reasoning and accounting • Project administration and management
Linköping *Applied IT +*	There may be obligatory subject specific courses, depending on subject student is registered in.
Fenix *R&D project leadership*	• Methodology (30 credits) • Management and leadership (20 credits) • Business Development (15 credits)
SIK *Food and biotechnology SMEs*	Each research student must include industry relevant components. These vary depending on students' prior experience. There is connection with the research school LiFT (SSF), in accordance with our contract with the KK.
Lund *Building and indoor environment*	The research school has two parts Indoor Air Quality & Acoustics and Stability. For the 'Indoor Air Quality' an individual study plan is written for each student. Some courses e.g. "Indoor Air Quality" will in practice be taken by all students, but are not compulsory, as students are working in different subject areas. For "Acoustics and Stability," which contains much dedicated mathematics, there is a curriculum of c. 7 courses that all students will follow
MARCHAL *Materials research*	2 of the following 5 are obligatory for all Chalmers research students • English technical writing • Information retrieval • Pedagogy for research students • German for research students • Theory of science The research students also have obligatory courses according to their discipline, which varies.
KIF *Chemical SMEs*	Compulsory faculty courses: • Information literacy (2 credits) • Technical Reporting in English (2 credits) Compulsory courses at Research School: • Experimental Design (4 credits) • Entrepreneurship and Business Development 6 credits Business Economics (3 credits) • Contract Law, Intellectual Property and Trade Mark (3 credits) • Leadership and Project Management (4 credits)
NMK *Natural materials +*	Not yet decided, but to obtain the interdisciplinary focus, each research student will take certain courses

N/A: IMC/ACREO; Luleå; Trätek; IOF/ACREO

4 IMPLEMENTING THE INDUSTRY RESEARCH SCHOOL PROGRAMME

4.1 Introduction

This chapter describes the process of implementing the research school programme from the perspective of the research schools as entities. Implementation here refers to the processes involved in building up the research school to full student capacity. At this relatively early stage in the research school programme, progress in implementation may be considered one indicator of the programme's success. Implementation is analysed here in terms of three stages and the factors affecting each stage. Important themes are collaboration and resources.

4.2 Identifying and mapping stages of implementation

On the basis of empirical material gathered mainly from project leaders, three broadly chronological yet overlapping stages of establishing the research schools have been identified. These stages are labelled: *Negotiating contracts* (stage 1); *Enrolling partners* (stage 2); and finally, *Consolidating collaboration* (stage 3). It is important to note that though broadly chronological, these stages are not meant to represent a linear process. Rather, they serve the heuristic purpose of simplifying and structuring a description of the implementation process.

Stage 1 (*Negotiating contracts*) begins with the iterative processes of applying to KK and ends with signing a research school contract. During this stage, project leaders and other initiators begin to shape the form taken by the research school. Activities include courting the interest of industrial partners, and negotiating a contract with the Foundation. One research school (IMC/ACREO) is currently at this stage.[7]

Stage 2, *Enrolling Partners*, begins when the contract with the Foundation has been signed and includes the range of parallel activities entailed in getting the research school up and running to more or less full student

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[7] A further KK research school in bioinformatics, to be coordinated by the Centre for Medical Innovations at KI, was in an embryonic form at the time of writing, and is not included in this survey.

capacity. The majority of the research schools are currently at this stage. The activities involved during this stage are diverse, and encapsulated by the twin generic terms *enrolment* and *articulation*. Enrolment refers to the process of enlisting research school participants, such as the board, industrial sponsors, students and supervisors. Articulation refers to the iterative and collective process of linking these various actors with appropriate roles within the research school, and to the related process of distributing the available material resources accordingly. Attempting to interest and enrol possible industrial partners, and negotiating and finalizing contracts with partner firms are perhaps the most challenging tasks at this stage. During stage 2 a more heterogeneous and geographically dispersed group of actors becomes involved in steering developments than is the case during stage 1. The end of stage 2 roughly coincides with the point in time at which the research school is more or less running at full student capacity.

During stage 3, *Consolidating collaboration*, the research schools are working more or less at full capacity. They are beginning to stabilize as identifiable, though heterogeneous (and often geographically dispersed) collectives. Activity is focused on finding workable ways of collaborating within the research school, and across the academic/industry divide. Three research schools can be considered to have entered stage 3 (Karolinska, Fenix, and Linköping).

Figure 4 below shows how far each research school has come in relation to these implementation stages using student enrolment as its key criterion. The Figure lists the research schools in descending order of age according to contract date (see Table 2) It is important to note that this Figure is stylized, and that the length of the arrows does not reflect an exact measurement, but a rough approximation of implementation in relation to the three stages, which themselves are merely conceptual. The diagram serves to illustrate how far each research school has come in the process of building up to full capacity. It does not provide a basis for comparing the 'progress' made by the various research schools, as they began at different points in time. Nor does it give any indication of the time taken by the research schools to reach the various stages.

It might naturally be expected that those research schools which were first granted funding (at the top of the diagram) are also those which have come furthest in implementation. In cases where research schools diverge from this expected pattern it is relevant to discuss why they appear to be developing either slower or quicker than might be expected.

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Figure 4 Development of research school in relation to phases of implementation

Phases of implementation
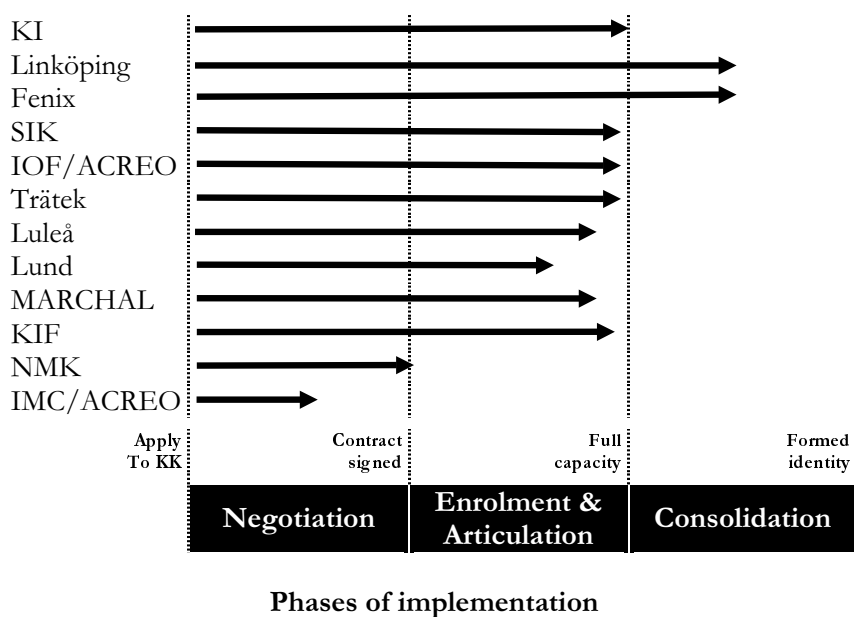
Mapping the twelve research schools in relation to these three stages shows that as expected the earlier research schools have by and large come the furthest. The Figure does however suggest some minor departures from the expected pattern. For example, KIF (the chemical industry's research school) has progressed further than expected in relation to length of time since the contract date. This observed quicker than expected progress can largely be explained by successful networking and institutionalization, led by the research school's director and coordinator. This appears to counter the expected pattern that research schools in mid and low-tech areas will have greater problems collaborating across the academic-industry boundary than those working in high-tech areas.

The Lund research school in building and indoor environment might be expected to have developed further than it appears to have done. A possible explanation for its slower than expected development is that one of the two parts of this research school, the section dealing with air quality, has encountered problems in recruiting firms. Building companies are unwilling to risk their own resources identifying problems which they regard as public health issues. This hesitancy is compounded by the building sector's lack of tradition of supporting R&D.

When considering the rate of implementation, it should be borne in mind that the research schools began from different starting points. Thus the research schools which were up and running fairly quickly were largely, though not exclusively, those which already had a system for training industry research students, as was the case with Linköping and SIK. Linköping's relatively rapid progress can be partially explained by the observation that the process of institutionalization did not begin from scratch. This research school appears to have slotted into a pre-established organizational structure at the University's Department of Computer Science (IDA). Launching the research school served to integrate and structure other existing industrial research student projects and programmes, without requiring the establishment of new forms of working and networking on the university side. In the case of SIK, and fully in accordance with SIK's contract with the KK Foundation, the KK research students join courses running under the umbrella of another research school at SIK funded by The Foundation for Strategic Research (SSF).

4.3 Negotiating contracts

Stage 1 *Negotiating contracts* entailed applying to the Foundation, negotiating the contract and establishing the board. The arduous task of contracting partner firms also begins at this stage and continues into the next. As pointed out in chapter 2, none of the initial applicants fulfilled all the Foundation's funding criteria, presumably owing to unfamiliarity with this particular industry research school concept[8] The process of applying to the Foundation for a research school was thus a process of negotiation. Applicants made a series of revisions as the Foundation

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[8] KK's funding criteria are listed on p.17 above. Research schools were preferably to be industrially relevant, interdisciplinary, of scientific merit, and have the potential to initiate new patterns of collaboration between industry and academia.

attempted to communicate its idea of the research school concept to promising applicants.

The new research school in natural materials (NMK), hosted by Gothenburg University, provides an example of this negotiating process. In 1996, the University's Department of Inorganic Chemistry submitted an application for research funding to the Foundation (this was not an application for a research school). Roughly simultaneously, the University's Department of Geology together with a humanities department also submitted an application to the Foundation. In response, the Foundation suggested that the two applications (inorganic chemistry and geology/cultural heritage) be merged and reformulated to fit the industry research school concept. The current project leaders appear to be satisfied with this outcome.

Several project leaders reported that once funding for a research school had been granted, contract negotiations with the Foundation tended to drag on longer than anticipated. In some cases, this was due to hesitant university lawyers, in other cases delay was attributed to changes among the KK administrators responsible for the programme.

4.4 Enrolling partners

During stage 2, activity is focused on attempting to interest and enrol possible partners. Negotiating with firms and signing contracts with them continues from stage 1; students and supervisors are recruited largely during this stage. Establishing an education programme and possibly developing courses is another important task during this stage. Many of the factors affecting implementation at this stage relate to the process of mobilizing resources.

Enrolling firms

During both stages 1 and 2, attempting to interest possible industrial partners and negotiating contracts with partner firms are perhaps the most challenging tasks. Recruiting firms with which a research school has had no previous cooperation, is often arduous. Research schools reported expending considerable time and effort convincing such firms of the benefits of participating in the programme, and building their trust.

There are several explanations for this difficulty. First, firms which showed an interest initially, at times subsequently felt unable to invest in the school, either because they were unable to spare staff time, or because the individual who initially showed an interest changed roles within the firm, or left the firm. Second, the pool of potentially interested firms was often somewhat small, and there is some evidence of competition between research schools over enrolling the same firms.

Third, some firms (especially small firms) regarded the financial commitment as too heavy. Spending SEK 1,600,000 on a research student is a major investment for an SME, especially since part of that amount will go towards research school administrative costs. The KI biotechnology research school would have ideally preferred to have included more start-ups, of between 10 and 30 employees, in the research school. However, the project leader and coordinator at KI reported that these companies could not afford to join and would only be able to participate if they received some subsidy on the 50% contribution.

A further reason why it may be difficult for research schools to recruit firms is because firms may not perceive the scientific or technological focus of the school as sufficiently relevant to their most important business areas. Two research schools which have experienced this problem are Lund (indoor environment) and IOF/ACREO (fibre optics). The Lund research school has been hampered because of difficulties in marketing the 'air quality' section of the research school to firms and academia. For building companies, the idea of supporting research which may reveal shortcomings in their own products and processes is too sensitive. And on the academic side, the interface between human sciences and building research does not fit easily into the research trajectories of either medical or physical science university departments. The other section of this research school (acoustics) has flourished quicker, though seems to be revitalizing existing industry links to support the students, rather than forming new ones. The acoustics section has a more clearly defined theme than the air quality section, and acoustics is of course less controversial for the building industry than air quality. Air quality is harder to package and market, and is also the most sensitive for industry.

The project leader of IOF/ACREO's research school has experienced difficultly enrolling firms for similar reasons. Although companies were positive towards the idea of supporting a research student within this

research school, they would not commit themselves. Optics, the research area in this case, is a generic/enabling technology, and whilst many companies depend on this technology, it is not often part of their core competence. In view of this, the research institute itself should perhaps be able to contribute the industrial component of the costs, especially since this research school was created as part of KK's restructuring programme for research institutes.

Recruiting students

Student recruitment is known to be difficult in some fields, though only the Luleå research school seemed to be hampered by lack of student demand. In this case, difficulty in student recruitment may be a function of the small numbers of students graduating in the subject area (mineral processing and rock engineering). Other research schools did however mention instances in which firms decided at the last moment that they were unable to release staff for the doctoral programme.

Establishing courses and enrolling supervisors

Research schools appeared to differ in their ability to afford joint research school activities, such as courses. This difference seemed partly related to the type of host organization (university, institute or firms), but may also be because research areas vary widely in their resource requirements, and such differences do not appear to be recognized in the programme's funding structure. Those areas requiring extensive lab space have high rental costs, other areas require expensive experimental equipment. Data suggest that research schools which were able to offer their students tailored course packages, could afford to do so either by virtue of working in a relatively low cost research area (with lower overheads), or by using existing course packages funded by other means.

Fenix, in a (low cost) social science area, is able to offer its students a specially designed programme of courses. The 80 academic points which constitute the course component are delivered in a package tailor-made for the cohort of executive PhD candidates. Organizing the programme in this structured way is in fact a necessity, owing to time constraints; students work half time for their respective firms, and are still expected to complete the doctoral degree within five years.

SIK is also able to offer special industry-relevant courses, though as mentioned above, the KK research students join courses funded by another research school at SIK funded by SSF. Because of this, SIK students interviewed felt more part of the SSF research school than the KK research school, which had no real meaning to them, save as a source of funding.

Other research schools found it difficult to offer specific industry-relevant courses. KIF for example had planned to offer a package of courses on commercial topics, making this a selling point to potential students. The research school had ordered a specially designed package of courses from Chalmers, only to find that it could not afford to buy the package. The current (cheaper) plan is to offer a slimmed-down set of courses assembled from existing university courses. Consequently, the number of points to be taken in commercial topics has been reduced. As a firm-based research school, KIF lacks ready access to university courses, which it has to buy on the open market. Some schools suggested the possibility of sharing the costs of such industrially-relevant courses between them, and more than one mentioned the possibility of drawing on Fenix's expertise in providing such courses.

University supervision was at times mentioned as being in short supply. At least one research school would prefer a staggered start of students for this reason. In another case, a university-based supervisor reported that it is difficult to take on research students without additional financial provision for supervision, pointing out that university staff are increasingly dependent on external funding for their salaries. He had resorted to taking money from another (non-KK) project to support the supervision of his KK students.

4.5 Consolidating collaboration

During stage 3 *Consolidating collaboration*, research schools are working at full student capacity. Activity is focused on consolidating the research school as a heterogeneous and geographically distributed entity by developing workable forms of collaboration. Problems relating to collaboration thus come to the fore. Research schools may begin to develop a distinctive profile based on a particular vision of academic-industry collaboration.

Teething problems in collaboration

In general, the link between the industrial and academic side of the research schools' activity was often relatively weak, with little coordination between firms/research institutes and universities. This was evident in the way that students and their projects tended to gravitate either to the academic side or to the industrial side; few students seemed truly comfortable straddling the two, though the majority of students interviewed reported enjoying good relations with their firm.

Further, not all the research schools were addressing the question of how feed-back was being provided to the companies, and whether companies were able to absorb the knowledge. KIF is an example of a research school in which this link was being consciously fostered by participants. Its experience illustrates that effort is required on both sides for the link to function. Perhaps ironically, given its research profile, the firm contact aspect of Fenix's activity appeared to be somewhat underdeveloped. The 'reverse-mentoring' scheme by which executive PhD candidates in theory provide academic feed-back to their company colleagues, did not always work as intended. Fenix students reported that the appropriate target group for their reverse-mentoring was not always apparent. And from the firm perspective, one company found the feedback too theoretical.

Collaborative dynamics

The dynamics and ease of collaborative partnerships within the research schools varied according to the identity and interests of the partners involved, and the longevity of the collaboration. Thus university-firm collaborative partnerships differed from intra-academic collaborations; university-firm partnerships also differed from each other in line with differences between firms. Further, established collaborations differed from new relationships.

Research schools appeared to experience the task of collaborating with industrial partners as more arduous than enrolling and collaborating with academic partners. Research schools' attempts to find workable forms of interaction and collaboration with firms were at times hampered by firms' unpredictability and instability. Firms are subject to mergers, failure, changing business strategies, rapid staff turnover, and other

changes which affect collaboration with a research school. Further, the short time horizon within which firms must operate affected planning within research schools. In some cases, firms reviewed their contribution to the research school year by year, leaving the research school with no guarantee of continued participation.

Research school collaboration with academic partners appeared to be more straightforward, as might be expected given that the stakes are lower for academic partners. Further, the majority of research school host organizations are themselves academic departments used to collaborating within academia. However, in two observed instances of a cross-departmental link in the same university, the link did not seem to function in line with research school objectives. In the Lund research school there was little flow of activity between the 'air quality' and 'acoustics' sections of the research school, though a joint course is planned for later this year. The two sections appeared to function almost as separate entities, one of which is an integrated part of the acoustics department. The Luleå research school (minerals and mining) involves three departments in the same university, yet students in different departments were not aware of the other students in the research school. Again, there seemed to be minimal joint activities among these departments, the respective professors having little contact with one another in the context of research school activities. If anything there appeared to be a degree of competition between the departments over student recruitment.

Broad differences between industrial and academic culture affected collaborative relationships, but so too did firm-specific characteristics. Small mid and low-tech companies in particular were often unused to being involved in research, and this naturally affected the dynamics of collaboration within the research school. This was evident in KIF, whose membership is made up of a number of chemical SMEs. There was sometimes a mismatch between the firm's idea of what the research project should entail and the academic supervisor's idea of what the student should concentrate on. Some firm contact persons appeared to require help to understand the nature of the research process.

There are examples in the interview data of small mid and low-tech companies attempting to control a student's project perhaps a little too strongly. In one instance, there was no person in the company who could help the student scientifically, but the sister company was attempting to keep a tight rein on the project, even though it was not co-

funding it. This sister company was pressurizing the student to produce results prematurely and to publish earlier than she felt able to. In this and similar instances, the importance of a mediator between the two sides of the project was clear. In KIF for example, the school's coordinator at times played the role of mediator between the (small) firm on the one hand and the student and his or her university supervisor on the other. Thus the coordinator regularly attended project meetings at which the student, academic supervisor(s) and firm contact person(s) discussed the student project. The presence of the coordinator clearly made a difference. This was evident in another project in which the academic supervisor reported that the company in question was attempting to control the project in a way which was detrimental to its scientific quality. According to the supervisor, the company did not act in this way in meetings when the research school coordinator was present, as it would have been unacceptable to the latter. Rather, the company communicated its strong views by phone between meetings.

The supervision or mentorship offered by firms or research institutes was not always reported by students to be adequate. This difficulty was perhaps most apparent with small mid or low-tech firms, but was not restricted to this category of firms. Some small firms visited acknowledged that it was difficult to find industrial supervisor capacity.

The problems of collaboration evidenced by the SMEs above were not observed in the cases of small high-tech companies, such as those participating in the KI research school. These firms appeared to be more in tune with the demands and nature of university research.

The longevity of a collaborative relationship appeared to make a difference to its quality. Collaborations with a history stretching back before the existence of the research school, and which were reactivated in the context of the research school, appeared easier to get off the ground and make effective than entirely new collaborations.

Working towards a vision

Some of the research schools appear to have developed a clearer profile and sense of what they want to achieve than others. Examples are KIF, Fenix, Karolinska, and Lund, which seem to harbour particular ambitions beyond merely surviving. For KIF it is the small firm emphasis, and raising awareness in the chemicals sector of the

importance of research for competitiveness. For Fenix it is the concept of 'ping-pong research' (Adler 1999), a style of research akin to action management research: promoting research-based project management in firms and firm-inspired management research in academia. The Karolinska biotechnology research school has a vision of supporting start-up companies, and is trying to develop in line with this. The Lund research school has a vision of promoting a new interdisciplinary field at the intersection of health sciences and building research. Working towards these vision appears to be a long-term project for them. Each of these research schools has a visible coordinator or leadership, who can also play the important role of mediator between academic and industrial spheres, which in turn plays a strong role in fostering the identity of the research school.

Summary

The length of time taken by the research schools to reach key stages in the implementation process has varied. In particular, the time and effort needed to enrol firms into the research school has been underestimated. Further, research schools begin from different bases. Those which already had a system for training industry research students, and those which can draw on existing networks or re-activate old ones, appear to be able to proceed at a faster rate than those which have to build entirely new networks. Whilst some research schools have reached relatively far with relatively little effort, others have invested much effort without advancing as far as they had hoped.

5 PARTICIPANTS' MOTIVES AND EXPERIENCES OF THE RESEARCH SCHOOL PROGRAMME

5.1 Introduction

Whilst the previous chapter discussed implementation from the perspective of research schools as a whole, this chapter does so from the perspectives of groups of participants in research schools. This is done by focusing on the various motives and experiences of: project leaders; academic supervisors; firms; and research students.   The extent of participants' experience varies, and many are relatively new to the programme. Four research schools began during the second half 1997, five began during 1998, one in 1999 and two this year. The order in which the four groups of actors are dealt with below has no bearing on their relative importance

5.2 Project leaders

Motives

Project leaders' motives for applying for research school funding and becoming inovolved in research school activities tended to differ according to whether they were university or research institute-based. University-based project leaders' motives for applying generally reflected their need to generate external forms of income.   Universities are increasingly dependent on external funding, even for salaries, and several viewed the KK grant as a means of adding volume to existing activities, on a par with any other source of research funding.

As well as viewing the KK grant as a direct source of funding, university-based project leaders also saw it as a means of strengthening their chances of gaining future research funding. Funding agencies such as the EU and NUTEK are more likely to fund projects if there is industrial participation from an early stage. Using the KK research school to develop new firm linkages and consolidate old ones, will in turn help these project leaders compete successfully for research funding from these other agencies in the future.

Research institutes are facing greater competition and cannot afford to be complacent about maintaining a central role in their respective

industrial sectors. Thus research institute-based project leaders were generally motivated by a need to maintain and improve the level of their institute's scientific and technical expertise and skills, both in the short and long term. Employing doctoral students was seen both as a means of swelling the number of research staff, and a means of enhancing the institute's skills level. For most of the research institutes (Trätek, IOF/ACREO, SIK), the research school programme is a part of the process of institute restructuring and renewal, in which the KK Foundation is playing a key role.

Experiences

With the exception of the extensive delays they reported, project leaders' observations and experiences generally dovetail well with KK's aims. Most project leaders felt that their research school was being implemented in line with the original intentions, though the majority has experienced a delay of between six months and two years. Generally, project leaders felt that the research training in their research school was of greater industrial relevance than traditional research training, and that participating firms showed greater interest in the projects than is often the case in other industry research programmes.

However, project leaders had greatly underestimated the difficulty of recruiting firms as co-funders. They found that small firms at times found it difficult to participate in the programme on grounds of cost. Difficulty in recruiting firms in turn delayed the recruitment of students. For some project leaders, the most problematic aspect of the KK grant was a perceived lack of resources for administration and overheads, which at least one was covering through unpaid overtime and money from other projects. Another research school coordinator mentioned that the Foundation might communicate their reporting requirements in a clearer way.

5.3 Academic supervisors

Motives

Academic supervisors, like project leaders, saw the research school programme as a funding source similar to any other. And again like project leaders, they also saw their participation in the research school in

strategic terms. It provided a means to develop new firm contacts and to consolidate existing ones, strengthening the chance of winning future research funding from other agencies.

Beyond this general motive, academic supervisors fell into two broad groups according to the main benefits they hoped to derive from supervising the student project. Differences between these two groups' motives are reproduced in their different experiences.

The first group saw the supervision task mainly in terms of the project's potential contribution to scienctific knoweldge, and were thus primarily concerned with the academic quality of the student's work. Supervisors in this group may have had extensive interaction with industry, but had not normally worked with the student's firm before. They often had little awareness of the student's life at the company.

Supervisors in the second group were more interested in and in tune with the industrial application of the student's project. Many supervisors in this group had themselves an ongoing collaboration with the student's firm, were aware of the firm's culture and problems, and thus had better insight than the first group into the student's activities at the firm.

Experiences

Supervisors in the first group above, felt more work went into supervising these students than 'ordinary' university research students, normally because the KK students had different backgrounds from the students they were used to. In one case, a supervisor reported putting much time and effort into supervising a research student who had been recruited by the small company co-sponsoring the project. The supervisor felt the company had not chosen the person best equipped to carry out quality research, but had rather emphasized social intelligence when recruiting.

This group also attempted to shield their activities and the student project from unacceptable firm intrusion. In one case a student's consultancy work for his firm regularly spilled over into supervision time. In response, the academic supervisor imposed a strict limit on the amount of time he was available to help with consultancy questions, which were banned outside this time-slot. In another case, a supervisor maintained that the partner firm's desire to control the student's research

was compromising its quality. He sought to protect the project from such pressures by negotiating with the firm contact person.

Supervisors in the second group showed more interest in the industrial application of the student's project. They were on the whole more tolerant of firm involvement and were more ready to collaborate with the student's company over the direction of the project.

Common to both groups of academic supervisors was the need to help students become socialized into the academic world and way of thinking. This was of course largely in cases where students had previously been pursuing careers in research institutes or firms. A supervisor attached to Fenix suggested that only in their second year did the research students begin to feel like colleagues. The socialization process was a long one, as several of the research students are engineers metamorphosing into social scientists.

5.4 Firm representatives

Motives

Firms pointed to increased competition, especially within the EU, an associated faster rate of innovation, and increasing technological and business complexity, as factors which now highlight the significance of the firm's knowledge capacity for maintaining and increasing its market share. By fostering relations with universities, firms can gain access to university knowledge; research equipment and facilities; scientifically and technically trained people; and credibility. Having a 'foot in the door' to a university department can play a strong role increaing a firm's competetiveness, and participating in a research school offers an entry point.

A closer scrutiny of why firms participate in the research school programme, beyond a general desire to foster university links, reveals that some emphasize the importance of access to a specific expertise; for others, recruitment is paramount; and for yet others, the research school offers a way of training their own staff; image also plays an important role for some.

These different emphases among firms' motives are evident in differences between firms in how they manage their programme

participation. 'Participation' management issues indicative of a firm's motives include: involvement (or not) in student recruitment; method of student recruitment; employment (or not) of the student during his or her doctoral studies; involvement in defining the student's research topic; and degree of involvment in the student's project.

Access to expert knowledge

Firms which were primarily interested in the university knowledge itself, gave examples of areas in they wished to apply that knowledge, in the bid to enhance competetiveness. These included: understanding and improving production processes; understanding and meeting customer needs; managing complexity.

Several participant firms were motivated by a desire to improve their production processes through gaining a theoretical understanding of how their process worked. These were especially chemical companies which had built up their production processes through years of experience. It was hoped that a scientific approach would replace trail and error when solving process and production failures; in the long run making for a more effective process.

Firms also stressed the importance of research to help meet customers' ever more specific demands. By gaining research expertise in customers' products and processes, a firm is in a better position to tailor its production to those needs.

The increasing complexity of products and projects poses a management challenge, which a research-inspired approach to management can help to meet. This was stressed by a representative from Ericsson, who recounted that his firm had attempted to manage product development at ever greater levels of detail, but that this had not worked. A more analytical approach to project management was required.

In some cases, firms which were primarily sponsoring the research student because they were interested in the project results themselves, attempted to maintain tight control over the student's research project. University supervisors at times felt this was detrimental to the quality of the research.

Firms primarily participating in the programme because they are interested in concrete applications of specific university knowledge, would probably have carried out the project even if the KK opportunity had not arisen, in which case they may well have organized it differently. For example, they might have contracted the research out to a university research group with which they already had links (this is especially likely in biotechnology and biomedicine), or they might have carried out the project internally. Few firms however said they would have carried out the project without some kind of subsidy.

The above is illustrated by comments made by firm supervisors participating in KI's research school. They brought up two features of the research school which they felt were not entirely compatible with their motives for participating. They felt that the administration was too expensive, and that there were too many courses. They indicated that courses interrupted students' experimental work in the lab, and perhaps felt that time spent on courses was time away from the projects they were paying for. One of these supervisors suggested that the students did not have enough opportunity of working independently, which was perceived as important for a future career in industry. The courses and administration meant that supporting a research student in the research school was no cheaper than contracting the project out to a university research group, which was indeed perceived as a more straightforward means of interacting with academia. It needs to be noted here that the latter way of sponsoring university research is the way biomedical/pharmaceutical companies are used to operating, and supporting the research school is an experiment for them. Note that these do not reflect company views, but were expressed by individual supervisors.

Access to scientifically and technically trained people

Firms which primarily participated in the programme as part of their recruitment policy, saw the benefits of the programme both in terms of the possibility of recruiting the student they had sponsored, and as an indirect means of attracting more well-qualified recruits in the longer-term. Having PhD qualified employees, and being seem as a firm which invests in doctoral training for its staff are both likely to attract highly-qualified recruits.

Some of these companies preferred their research students to be based in the company for a significant proportion of their doctoral studies; this was partly to introduce students to the firm culture, and thus increase the chances that the student would want to stay on after completing his or her degree. Thus a company in Kiruna preferred their research students to live and work in Kiruna, in the hope that they would choose to continue living there after graduating. Another company in Karlstad made a point of inviting its student to all the firm's social events, even though the student lived and worked in Gothenburg. Because of this, the student felt very welcome and part of the company.

Firms envisaged PhDs fulfilling many kinds of roles in the company. Some firms reported that qualified PhDs would not only or even mainly have purely research roles in the company. One role would be to monitor external research. Another would be to provide access to a university network, and develop that network further. At least two firms had created entirely new job categories for PhD qualified staff. Further, in certain competitor countries (the USA, Germany), a doctoral degree is held in high respect amongst the business community. Employing PhDs at senior levels can thus lend credibility to the organization.

Despite these apparently convincing reasons given by some firms for hiring qualified PhDs, others admitted that it was not always necessary to have a PhD to fulfil them. A *Licentiat* or a Master's were sometimes said to be adequate, or even preferable. Thus in the context of Fenix's research school, a firm representative acknowledged that the firm could probably organize the required training just as well themselves, but that the seal of quality which accompanied a university degree was important.

Firm image

The positive image conferred by being seen to be a firm which supports research training (whether of its own employees or otherwise), and has an enlightened view on the importance of research, was a factor for several companies, though for only one did this appear to be the primary motivation.

Showing customers and suppliers that the company takes research seriously can enger their trust. Alt-i-Fisk, a fish wholesaler, supported a doctoral student partly in a bid to redress the tarnished image of the fishing industry. The student's project was to be on an environmental

topic. Beyond this however, the focus of the project was less important to the company than that it was seen to be spending money on environmental research. As one of the biggest fishing wholesalers in Sweden, Alt-i-Fisk seemed almost to see itself as a representative for the whole fishing industry.

5.5 Research students

Motives

Almost half of the students who responded to the questionnaire (73 responses of 99 sent out) applied to the research school on their own initiative. The remainder were encouraged to apply either by their research institute (21%), university (14%), or firm (11%). Students became aware of the existence of the research school through a number of channels. These included: seeing an advertisement in a newspaper; through personal connections; or through their company's intranet.

Approximately 20% of the students applied to other doctoral training programmes at the same time. When asked whether the KK research school was their first choice, almost half of the students replied that it was; the majority of the remainder (36%) were unsure. Thus at least approximately half the students may be assumed to have actively sought out the research school. Students had a range of different reasons for choosing this research school. Reasons include: it provided secure funding for four years of doctoral studies; they were attracted by the research topic; and they were attracted by the possibility of having close links with a firm. Theses reasons are represented among the citations below taken from the student questionnaire:

> The reason for choosing the KK-Research school was mainly because this meant that I could continue my work with my colleagues at the institute where I did my masters thesis. To be honest, I was at first quite skeptical to studies in an industrial program since my interests are rather theoretical in nature.

> I did not consider the financing source as the important thing, rather the research topic.

> My supervisor told me about this programme, and I thought it was terrific. But I did not compare it with other programmes because it was what I wanted to do.

> I did not really compare programs. This was an opportunity that suited me - to do doctoral studies while at the same time having an established relation to the industry (50% studies, 50% work at my old firm).

When asked about their career plans, over half the respondents (55%) mainly had an industrial career in mind when they applied to the research school. A third of the students were interested in some kind of combined industrial/academic career. Ten per cent of students did not have any explicit plans, and only one student said they wanted to pursue an academic career, though 'with as much contact with my present firm as possible'.

Figure 5 shows students' career plans by sex of student. It indicates that whilst both male and female students are first and foremost interested in an industrial career, female students are relatively less clear than their male colleagues about their future plans.

Figure 6 indicates where the students say they would like to start their careers. The majority of students (48%) hope to start their industrial career in the firm they are linked to today; 21% hope to start their industrial career in another firm in Sweden; and a further 4% students hope to do so in a firm outside Sweden. Figure 7 shows preferred first career destination by sex. It indicates that male and female students do not differ in where they would prefer to start their industrial career. The three students who hope to go abroad for their first career destination are all men.

Not all students felt able to or wanted to stay on in their current firm afterwards. Students made the following comments about their career plans:

> I believe the company I am linked to is too small to employ a full-time consultant, but I would be happy to work for them in projects.

> As for now, I do not have any big plans for the future, but I will probably want to remain on the academic/research side of the industry, i.e. at a research institute.

Interviews confirmed this impression that the majority of students are intent on industrial careers. They also suggested that the majority of students are keen to stay on at the firm they are now attached to as doctoral students. Fenix students felt a strong obligation towards their current firms, which are making a substantial investment in them, to continue working there at least for a few years after finishing their doctorates. However, one said that if she finds she is unable to use her

newly acquired expertise in her current company after she has finished her doctorate, she will seek a job elsewhere.

All except two students who answered the questionnaire said they are aiming for a doctorate degree (one at Trätek and one at Luleå said they are aiming for a *licentiat* degree). However, as indicated in chapter 3, and as interview data confirmed, some students have taken a break in their studies or left the programme completely before taking a degree. Others have left after taking a *licentiat* degree. The exact number who have left, and whether they intend to return or not, is currently unknown.

Experiences

Supervision, courses and research topic

Students in these research schools have at least two supervisors, and often more than two (see p.38 for a description of their roles). Usually at least one supervisor is university-based and the second is firm or research institute based.
Table 10 indicates student satisfaction with supervision. It shows that the majority of students are generally satisfied with the supervision, and that they are slightly more satisfied with the university-based supervision than the firm-based supervision. Fifteen per cent of students are not very satisfied or not at all satisfied with the university-based supervision, whilst 30% of students are to some extent dissatisfied with their firm-based supervision. Ten per cent are dissatisfied with their research institute-based supervision.

When asked to comment on courses, the most common problem reported was that there were too many interesting courses to choose among. KI students interviewed were very positive about the special research school courses they had taken, which included one on drug discoveries, and one on intellectual property. Likewise, interview respondents at Fenix were positive about the course programme, which for effectiveness is mostly group-based, and run very tightly as a package. However, students did mention that they would have preferred more individual monitoring, especially as part of the stated aim of the programme is leadership development.

Figure 5 Students' career plans by sex
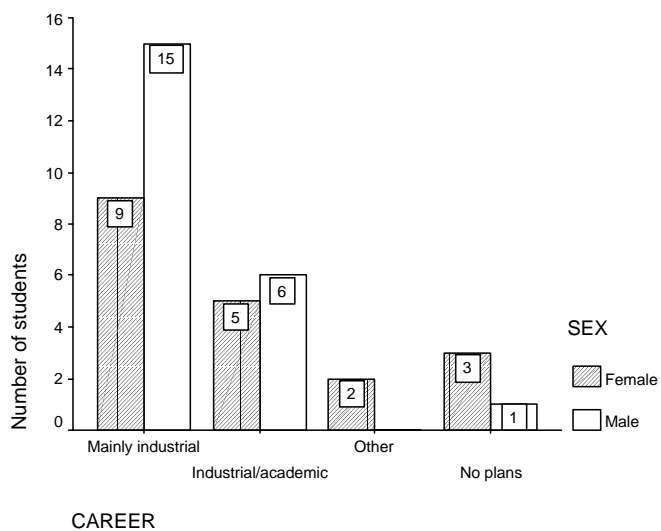
Figure 6 Students' preferred first career destination
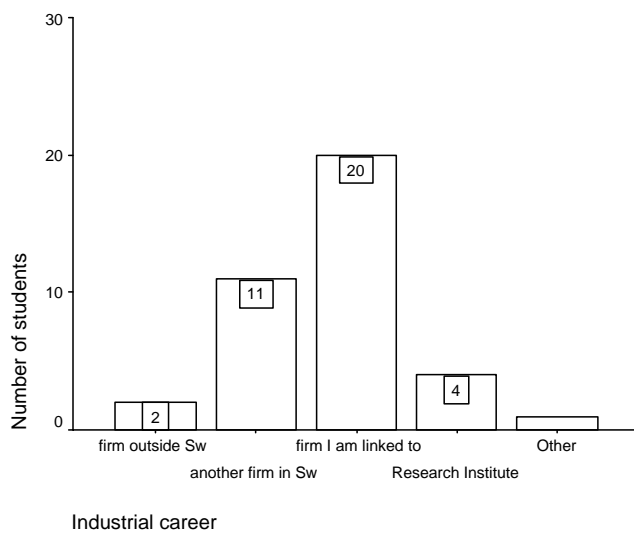
Figure 7 Students' preferred first career destination by sex
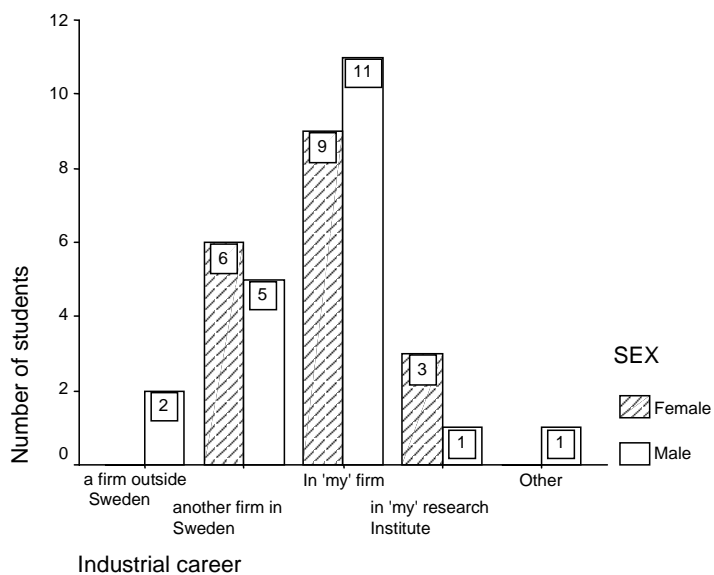
Most students replying to the questionnaire have decided their research topic. Table 11 indicates who has participated in deciding the students' research problem. Most students had wholly or partly decided their research topic themselves (78%). Supervisors had also been involved in this process to varying degrees. Firms were involved 'to a great extent' in the process of deciding the research topic in 33% of cases. In 16% of cases, a firm had not been involved at all. Firms were at least to some extent involved in defining the topic in 63% of the students' projects. The remainder includes a number of students who are not linked to a particular firm. This would apply to many of the students based in research institutes.

Table 10 Student satisfaction with supervision

Are you satisfied with the:	University-based supervision	Firm-based supervision	Research institute-based supervision
Very satisfied	19	14	11
Satisfied	37	27	28
Not very satisfied	9	16	7
Not at all satisfied	2	6	-
Unsure	5	1	2
Not relevant/No answer	1	9	25
Total	73	73	73

Table 11 *Various actors' involvement in deciding the student research topics*

To what extent were the following involved in deciding your research topic:	To a great extent	To some extent	Not so much	Not at all	Unsure	Not relevant	Not answered
My self	39	18	10	3	-	1	2
My university-based supervisor	23	20	14	6	2	6	2
My research institute-based supervisor	20	13	9	2	4	15	10
The firm	24	22	7	12	1	4	3
The Research School board	2	3	8	24	16	12	8
Other	-	-	2	4	7	27	33

Table 12 *Student perception of integration into different institutions*

To what extent do you feel integrated into the:	To a great extent	To some extent	Not so much	Not at all	Unsure	Not relevant / Not answered
University/university college	26	22	19	2	1	3
Research institute	24	14	3	1	4	27
Cooperating firm	29	26	8	4	1	5

Unlike most 'ordinary' research students, the intention is that these research school students will have a foot in each of the two worlds of industry and academia. The survey showed that at present the research students feel slightly more integrated into their cooperating firm than their university. As Table 12 shows, 21 (of 73) students do not feel very integrated into their university department, whilst 12 (of 73) students do not feel very integrated into their cooperating firm. Fifty percent of the students conduct their research primarily in the context of a research team or group, leaving half who presumably work on their own with their project.

Interviews suggested that students experienced working in two very different environments simultaneously in different ways. Where the collaboration worked, students on the whole saw only benefits; whilst for others, the requirement to straddle work environments is hampering progress in their research.

In general, firms were perceived by students to have very different monitoring systems and quality assessment criteria from academic supervisors. There are clear examples where the student felt caught in the tension between product development and autonomous research work. In one case, a further layer to this conflict was added when a dispute arose between the firm and the university supervisor over access to intellectual property, forcing the student to take sides. There were other instances of firms attempting to control the project to the extent that the student was unhappy with the situation. In one case, a company felt the student was not producing enough results, even though the student had only been active for a few months. In this case, the student felt split between three organizations: her university department, her firm, and her firm's sister company.

Another example of the split existence of the doctoral students, is that it is at times hard for them to impose limits on the amount of time they work for firms/research institutes; there is a danger that they spend too long working on company or research institute projects. However, many firm supervisors were sensitive to the difficult balancing act which the research students have to perform. Thus some protected the student from being burdened with too much company work. An Ericsson representative recounted that the company tries to minimize the 'split

existence' of the student by trying to ensure that the tasks the student has in the work place dovetail with the student's research topic.

A general perception among these students is that they have a heavier work load and greater responsibility than 'ordinary' research students. They are expected to contribute to the activity of the firm, assist in knowledge transfer, and conduct academic work of the same standard as an ordinary research student. At Fenix the heavy work load was particularly apparent. Fenix students work 50% in their companies on normal company work, whilst at the same time following a rigorous academic programme. They are expected to complete their doctorates in five years, working half time. They feel obliged to follow the programme through to the end because not completing at this stage would be worse for their careers than never having started. Fenix is unique among the research schools in the highly structured nature of the programme. In general, because of the requirement to spend time in firms and sometimes work on firm or research institute projects, some students reported it took longer for them to get started with their PhD work than ordinary PhD students.

A lack of coherence in the students' programme of study/research, suggests that these students might take longer to complete their doctorates than university research students. In some cases, students' firms and academic departments are in different parts of the country; travel and organization become more complicated and time consuming. There may also be a lack of dialogue between academic supervisors and industry mentors, and there are also instances of quite fundamental disagreements between the university supervisor and the firm over the direction to be taken by the student's work.

The KK research schools are less concentrated around a specific research problem or area than some other research school models. This has implications for the cohesion of the research school, and thus the student's feeling of belonging. Students in any one school may be pursuing projects on quite different topics (though within the same broad area). Thus it may not always be immediately apparent what they might gain from interacting with one another, aside from forming network links, which many mentioned would be important for them in their future careers.

For all these reasons, there is a risk (as indeed there is in any doctoral programme) that some students may drop out before taking a degree. It

is too early to monitor the drop out rate amongst KK students, though there are individual instances of students dropping out.

Knowledge transfer

A slight majority of students replying to the questionnaire responded that their 'industrial affiliation and network' have contributed to the university in different ways. And the same number responded that their 'academic affiliation and network' have contributed to the collaborating firm and/or industry. This is the most important direction of knowledge transfer in commercializing university generated knowledge. What have the students experienced in this context so far?

Students cited a number of ways in which they both contributed to knowledge transfer into the university, and made a positive contribution to the university because of their industrial link. One for example, said that he had himself brought university and firm employees together, whilst another said she was able to impart information on how firms think and plan their work to her academic colleagues. Yet another suggested that maybe her university colleagues now have

> a more varied image of organization and decision making at a small firm and how the commercial aspect influences the work

Other ways in which students benefited their academic environment included facilitating student visits and placements at their firms. One commented

> This is a new way of working which has received a lot of interest from researchers and students at the institution

Thus there are different ways in which the student's industrial link can bring benefits to the academic environment. Some of the examples given suggest the communication of tacit knowledge, which the literature has identified as a major problem in the process of knowledge exchange.

In what terms then did students describe their ability to contribute to their firms by virtue of their academic affiliation? Reproduced below are some of the ways in which they felt knowledge transfer was taking place:

> I know what problems are relevant for my firm and can thereby formulate research questions that are more interesting for the company.

> We have arranged several seminars and 'think tanks' to create knowledge exchange to the firm.

> As my firm is research-intensive but with few people with an academic degree the direct contact with the university is of great importance.

> The firm has received research results which they can use in product marketing, as well as in conferences and other events.

> We are able to use university equipment

> Several research projects are carried out in cooperation with Ericsson. Reflections and research results are brought to Ericsson in a simple way

As these citations indicate, some of these forms of knowledge transfer to the firm are straightforward, others subtler. Interviews with research students suggested that they themselves embodied the link between the university and industry. In other words knowledge exchange is channeled through them as individuals. When asked about this in the electronic questionnaire, a majority of the students who have replied agreed with this observation. In support of this they described how they saw this mechanism working in their own case:

> This is the start. Then the research group is the channel and the network within the firm. It's always easier for me to take new contacts and be the first bridge, but then it is the whole group. It is too big a burden to carry otherwise.

> There is a great amount of information about the processes in a firm that would never see the light of day if no one brought them out and analyzed them. I have seen that working with these issues has put me in the position to connect people working at a firm and the university respectively and directing them to the people with the needed information.

> Often a lot of information is locked either at the firm or at the university, but since a research student knows both sides the information can find its way to the correct destination. The research student can often be the one to read the 'map' for both industry and the university.

> We are presently addressing this problem in Telia and are building a more complete network that will form a non person-dependant bridge between the company and academia.

Not all students agreed however:

> Telia has not yet shaped a receiving function/network and it is not easy to make industry come to our activities.

As suggested here, in order for knowledge transfer into the company to function well, it has to be facilitated in the company. Whilst some companies actively make it easier for the student to contribute to the company with their newly acquired knowledge by giving them an appropriate and well-defined roll, others were more passive on this score.

Those students who do feel that they somehow embody the knowledge transfer mechanism, largely perceive themselves as the initial link. The students' citations above also indicate that students themselves play a key role in the process of network building.

6 SUMMARY AND CONCLUSIONS

6.1 Introduction

This report has documented preliminary findings relating to the implementation of KK's industry research school programme. This final chapter provides summaries of chapters 4 and 5 of the report and draws some conclusions based on the report's findings. Chapters 4 and 5 are summarized under the three headings: *The implementation process* (section 6.2); *Participants' criteria of success* (section 6.3); and *participants' experiences* (section 6.4). Section 6.5 highlights aspects of academic-industry collaboration and interdisciplinarity emerging from the research school data. Section 6.6 focuses on observations and concerns relating to the funding structure and criteria stipulated by the Foundation. The final section (6.7) draws conclusions based on the report's findings. This chapter may serve as a stand-alone document for readers requiring a quicker overview of the report's contents.

6.2 The implementation process

The KK-Foundation, along with a number of other Foundations created in the early 1990s, may be conceived as a new type of actor in the Swedish innovation system. On behalf of the government, it has begun to take initiatives to foster economic growth by introducing new structures and networks into the Swedish innovation system. The process of implementing the KK research school programme constitutes part of that process of developing new networks and institutions. Both individually and collectively, the industrial research schools comprise groups of formal and informal networks, operating both within and across academic and industrial institutional boundaries.

Based on empirical material gathered mainly from research school project leaders, chapter 4 identified three broad and overlapping stages in the implementation process. These more or less discrete stages of establishing the research schools are: *Negotiating contracts* (stage 1); *Enrolling partners* (stage 2); and finally, *Consolidating collaboration* (stage 3). It is important to note that though broadly chronological, these stages are not meant to represent a linear process. Rather, they serve the heuristic purpose of simplifying and structuring a description of the implementation process.

The *Negotiation* stage (stage 1) begins with the iterative processes of applying to the KK Foundation and ends with signing a research school contract with the Foundation. During this stage, project leaders and other initiators begin to shape the form taken by the research school. Activities include courting the interest of industrial partners, and negotiating a contract with the Foundation. One research school (IMC/ACREO) is currently at this stage.

Stage 2, *Enrolling partners*, begins when the contract with the Foundation has been signed, and includes the range of parallel activities entailed in getting the research school up and running to more or less full capacity. The majority of the research schools are currently at this stage. The activities involved during this stage are diverse, but may be encapsulated by the twin generic terms enrolment and articulation. Enrolment refers to the process of enlisting research school participants, such as the board, industrial sponsors, students and supervisors. Articulation refers to the iterative and collective process of linking these various actors (board members, industrial partners, students, supervisors, and project leader) with appropriate roles within the research school, and to the related process of distributing the available material resources accordingly. The end of stage 2 roughly coincides with the point in time at which the research school is more or less running at full student capacity.

During stage 3, *Consolidating collaboration*, the research schools are working more or less at full capacity. During this stage, research schools are beginning to stabilize as identifiable, though heterogeneous (and often geographically dispersed) collectives. Activity is focused on developing stable and workable forms of collaboration. Three research schools can be considered to have entered stage 3 (Karolinska, FENIX, and Linköping), and a further three (SIK, Trätek, and KIF) may be considered on the verge of entering this stage.

A note is in order here on conceptualizing the starting point of the research schools. Various criteria can be used to measure this point: e.g. the submission of an application; the funding decision by KK's board; signing the research school contract; or enrolling the research school's first student. This report equates the research schools' starting point with the date at which each school's contract with the KK Foundation was signed. An important reason for applying the date of contract

signing is that before this date, participants cannot be entirely sure they will receive funding from the Foundation.

Mapping the twelve research schools in relation to the three stages outlined above, shows that they have reached different points of development, which is of course to be expected since they started at different points in time (see Figure 4 p.45). They largely, though not invariably, follow the expected pattern whereby the earlier research schools have progressed the furthest.

The research schools do however differ in the amount of time taken to proceed through the various stages, reflecting differences in the factors affecting implementation, and the kinds of obstacles faced. For example, in relation to research schools with contracts signed at a similar time, the Lund 'indoor environment' research school might be expected to have progressed further than it appears to have done. An important explanation is that one of the two parts of this research school, the section dealing with air quality, has encountered problems recruiting firms. Building companies are unwilling to risk their own resources identifying problems which they regard as public health issues. This hesitancy is compounded by the building sector's relative lack of tradition of supporting R&D.

KIF, the chemical industry's research school, appears on the other hand, to have progressed further than others in relation to length of time lapsed since its contract was signed. This observed quicker than expected progress can largely be explained by successful networking and institutionalization, led by the research school's director and coordinator. It would appear that this provides a counter-example to the expected pattern that research schools in mid and low-tech areas will have greater problems collaborating across the academic-industry boundary than those working in more obviously high-tech areas.

More generally, we have identified several factors affecting the time needed to proceed through the different stages. During stage 1 *Negotiating contracts*, research schools which can draw on existing networks, or re-activate old ones, appear to be able to proceed at a faster rate than those which have to build entirely new networks. This factor is closely associated with whether the host organization has a tradition of working across the academic-industry divide.

During both stages 1 (*Negotiating contracts*) and 2 (*Enrolling partners*), attempting to interest and enrol possible industrial partners, and negotiating contracts with partner firms are perhaps the most challenging tasks. Thus an important factor affecting the implementation of most of the research schools is the difficulty of engaging firms and convincing them of the value of investing in a research student. There are many reasons why it may prove difficult to attract firms. First, firms which have shown initial interest may subsequently feel unable to invest in the school, either because they find they are unable to spare staff time for PhD training, or because the individual in the firm who initially showed interest in the programme has changed roles in the firm, or indeed left the firm. A further reason why it may be hard for research schools to recruit firms is because firms may not perceive the scientific or technological focus of the school as sufficiently relevant to the firm's business areas. Research schools at times encountered difficulty matching their profile with the specific interests of individual firms. There is also some evidence of competition between research schools over enrolling firms. Further, investing SEK 1,600,000 on a research student is a relatively major commitment, especially for an SME. It is highly likely that many smaller firms which could potentially benefit from such a programme feel unable to afford this. In short, the task of recruiting firms with which the research school has had no previous cooperation, is often arduous. Research schools often expend much time and effort convincing such firms of the benefit of participating in the programme, and building their trust.

During stage 2, student recruitment is difficult in some fields. This may be partly related to the observation that firms at the last moment find they are unable to release staff for doctoral training. The Minerals and Mining research school in Luleå in particular has experienced difficulty in recruiting students.

During the later stages of implementation – towards the end of stage 2 and during stage 3 (*Consolidating collaboration*) - problems relating to collaboration come to the fore. Research schools' attempts to find workable forms of interaction and collaboration are sometimes hampered by the unpredictability of firms. Firms are subject to mergers, failure, changing business strategies and other changes which may affect collaboration with the research school. Aside from such unexpected events, effort is required on both sides for the collaboration to function smoothly. Small mid and low-tech firms in particular may not be used to

being involved in research, and may need some help to understand the nature of the research process.

It is clear by this later stage that small high-tech companies are more natural collaborators with academia than small mid or low-tech companies. The high-tech/low-tech distinction appears to make more of a difference to collaboration than whether the firm is large or small. Further, collaborations with a history stretching back before the existence of the research school, and which were reactivated in the context of the research school, appeared easier to get off the ground and make effective than entirely new collaborations. This may explain why the latter appear to be fewer in number in the research school programme as a whole.

Research schools appeared to experience the tasks of enrolling and collaborating with *academic* partners, as less arduous than appeared to be the case with industrial partners. Two reasons suggest themselves. First, the stakes are much lower for academic partners since they are not required to co-finance a student. Second, the majority of research school host organizations are themselves academic institutions, used to collaborating within academia. However, in at least two observed instances of collaboration between departments in the same university, the cross-departmental link did not appear to function in line with research school objectives.

A general observation to be made is that whilst some research schools have reached relatively far with relatively little effort, others have put in a lot of hard work without advancing as far as they had hoped. Some of the factors identified here serve to explain why this is so.

6.3 Participants' criteria of success

In accordance with the 'stakeholder' approach to evaluation adopted here, this report seeks to appraise the research school programme from the perspectives of a range of groups of participants (see chapter 5 and section 6.4 below). Since these various groups of participants are engaged in different professional activities, and thus participate in the research school for different reasons, and with different ambitions, they are naturally likely to have different perspectives on what might constitute a successful programme. In order to assess the relative benefit

of the programme for different participants, it is necessary to identify these criteria of success.

Chapter 5 identified various groups of participants' motives for participating in the programme. These motives are translated into participants' criteria of successful outcomes of the programme. These are summarized below for each stakeholder group.

Criteria of successful programme outcomes for each stakeholder group

The KK Foundation*
- Effective knowledge transfer between sectors
- Raised levels of competence within Swedish industry

Project Leaders
- Fulfilled vision for the research school
- Win research funding

Academics
- Win research funding
- Developed links with firms
- Develop quality research

Firms
- Benefit from project results
- Successful recruitment
- Strengthened firm image
- Strengthened links with academia

Research students
- Gaining a doctorate
- Develop successful industrial or combined industrial/academic career

* **Note:** The KK continuously apply various instrumental criteria of success, such as successful implementation of the funding criteria, and progress in implementing the programme. However, these do not directly concern programme outcomes, and are thus not listed above.

6.4 Participants' experiences

This section summarizes experiences recounted by the various groups of research school participants. The aim is not to give a complete account of participants' experiences, but to highlight some opinions and

experiences relevant to the evaluation. Naturally, individuals' experiences will be partly determined by the length of time participants have been involved in a research school. It should thus be borne in mind that many participants interviewed (especially students and firms) joined a research school relatively recently. Note that the order in which categories of participants are listed in this section has no bearing on their relative importance.

Project leaders

Research school project leaders were invariably positive about the research school concept. Most project leaders felt that their research school was being implemented in line with the original intentions, though the majority had experienced a delay of a half to two years. They now realize that they greatly underestimated the difficulty of recruiting firms as co-funders. For example, small firms have not always been able to make the financial commitment required. The difficulty of recruiting firms has in turn delayed student recruitment.

Generally, project leaders felt that the research training offered in their research school differed from traditional research training. This was both because the research school enabled students to have close relations with individual companies, and because students' projects were directly relevant to the needs of cooperating firms or industry in general. Thus a further feature reported to differentiate these research schools was the continuous transfer of knowledge by the research student back to the company. The cross-disciplinary character of research schools was also regarded as differentiating the education offered from traditional research training. Except for the extensive delays reported, project leaders' observations and experiences would appear to dovetail well with KK's aims.

However, at least four project leaders expressed some degree of disatisfation with either the amount or the structure of the KK grant. At least two of these experienced the lack of earmarked resources for administration and overheads as problematic. And at least one project leader reported that administration and overheads were being partly covered by unpaid overtime and money from other projects.

Academic supervisors

Academic supervisors fell into two broad groups: those who were primarily concerned about the academic quality of the student's work, and those more in tune with, or more interested in the industrial dimension of the student's project. Supervisors in the first group may have had extensive interaction with industry, but had not normally worked with the student's firm before. Many in this group had little awareness of the student's 'other life' at the company. Many supervisors in the second group, on the other hand, had themselves an ongoing collaboration with the student's firm, were thus well aware of the firm's culture and problems, and had better insight than the first group into their student's activities at the firm.

In a small number of instances, supervisors in the first group above, suggested that students recruited to the research school by sponsoring firms were not necessarily the best qualified to carry out research training. Such supervisors felt that they needed to put more time and effort into supervising these students than 'ordinary' research students. This group also reacted negatively to any perceived compromise in the quality of the student's research rooted in pressure from the partner firm.

Supervisors in the second group above, took more interest in the industrial side of the student's project, and were on the whole more tolerant of industrial application and involvement. Thus supervisors in this group were perhaps more likely to engage with the student's company over the direction of the project. Supervisors in both groups however, reported that it could take a relatively long time for KK students to decide on their research problem, because the research topic needed to be negotiated with the firm.

Common to both groups of academic supervisors was the need to help the student become acclimatized or socialized into the academic world and way of thinking. This was of course largely in cases where students had previously been pursuing careers in research institutes or firms.

Firms

Interviews with firms suggest that they can be categorized into three groups according to their motives for participating: a) firms which are primarily interested in the results of the research project, and have no

specific intention of recruiting the student afterwards (this can be thought of as subsidized R&D); b) firms which are primarily interested in supporting a research student to conduct a specific project of key importance to the firm, and which also intend to recruit the student after they have gained their degree (combination of subsidized R&D and enhancing the long-term competence of the firm); and c) firms which are primarily interested in the effect that supporting a research student will have on their image (marketing motives).

Those firms supporting the student mainly because they are interested in the project results (groups (a) and (b) above), may well have carried out the project even if the KK opportunity had not arisen, though they would probably have organized it differently. However, few firms said they would have carried out the project without some kind of subsidy. Firms in groups (a) and (b) tended to exert a degree of direction on the student's research project, which was perceived by one group of academic supervisors to have a detrimental effect on the quality of the research. In general, firms in these two groups were keen to socialize the student into the firm culture.

Firms in group (c) were primarily interested in being *seen* as a company with an enlightened view on the importance of research and a highly qualified work force. Promoting such an image might enhance a firm's credibility in the eyes of (potential) customers and suppliers.

Firms generally reported very positive experiences from having a research student. Some small firms were unable to offer their student much if any supervision, though students in these cases did not appear to expect such supervision either. As with academic supervisors assisting students acclimatize to the academic setting, some industry mentors found themselves helping research students who were recent graduates acclimatize to firm culture.

Research students

The questionnaires received so far from students (73 of 99 sent out), suggest that the majority of students have an industrial background. Of the 73 responses received, eleven students have no previous experience of working in industry. During the year prior to enrolling in the research school, 40% of the questionnaire respondents worked in the same firm as they are now linked to. On the whole, male students had longer industrial experience than female students.

The vast majority of students replying to the questionnaire said that they were aiming for a doctoral degree; only two students (one at Trätek and one at Luleå) said they were aiming for a *licentiat* degree. (A small number of students have however already left the programme with a *licentiat* or without completing a degree.)

Students' reported career plans are largely in line with the KK-Foundation's aims. Thus a small majority of students returning the questionnaire reported that they hoped to pursue an industrial career on completing their research degree. Of these, the majority hoped to begin this career in the firm or research institute to which they are currently linked, whilst others believed their current company to be too small to employ a full-time Ph.D. A third of the students responding were primarily interested in a combined industrial/academic career after their studies.

Students were more satisfied with their university-based than their firm-based supervision (11 of 73 said they were at least to some extent dissatisfied with their university-based supervision, and 22 of 73 said they were at least to some extent dissatisfied with their firm-based supervision). No real significance should be attached to these figures before they have been compared with a control group.

Most students reported that they had decided their research topic, and that they were involved in this decision themselves. University-based or research institute-based supervisors were also involved in this process. The responses suggest that just under two-thirds of the firms were also actively involved in the process of defining the student's research topic. Almost half the students responding carried out their research primarily in the context of a research team or group; many students are thus working on their own.

On the question of institutional belonging, students were slightly more likely to feel integrated into their cooperating firm than their university. This pattern of responses should doubtless be understood in the light of their predominantly industrial backgrounds. Correspondingly, a majority of the students felt that their industrial affiliation and network had contributed to the university in a number of different ways, for example in terms of tacit knowledge exchange. An equal number also felt that their academic affiliation and network had contributed to the collaborating firm and/or industry. Indeed, two-thirds of the

responding students viewed themselves as the link between the university and industry; that is to say they felt the knowledge exchange was channeled through them as individuals. Whilst some saw their role as an 'initial link', others saw it as a more permanent link. It would thus appear that several of these students have already initiated a process of network building. At the level of knowledge exchange then, the collaborative link as embodied by the student, would appear to be functioning as intended.

A general observation relating to the PhD training offered within these research schools is that these students appeared to have a heavier work load than traditional PhD students. They are expected to spend time at the firm, facilitate the transfer of knowledge to the firm, and perform as well academically as an ordinary research student.

Interviews revealed that students experienced working in two very different environments simultaneously, in different ways. Where the collaboration worked smoothly, students saw only benefits. However, some felt that belonging to two very different places of work resulted in a lack of coherence in their programme of study/research, and that this had a negative impact on the progress of their work.

Not unexpectedly, perhaps, some students (and their supervisors) reported that because of the time spent in firms, they took longer than their purely university-based colleagues to familiarize themselves with their academic subject area. Lack of coherence was particularly apparent in cases where students' firms and academic departments were in different parts of the country, such that travel and organization becomes more complicated and time consuming. More seriously, in some cases there was a lack of dialogue between academic supervisors and industry mentors. Instances of quite fundamental disagreements between the university supervisor and the firm over the direction to be taken by the student's work were apparent. There were cases in the interview data of students feeling caught in the tension between product development and autonomous research work. In one case, a further layer to this tension was added when a dispute arose between the firm and the university supervisor over access to intellectual property, forcing the student to take sides.

In short, this lack of coherence in students' work situation finds a number of expressions which collectively suggest that these students may need more time to complete their doctorates than university research

students; they also highlight the central importance for these students of well organized and effective supervision. A small number of students have already dropped out of the programme before taking a degree. It may be conjectured that such instances are at least partly related to the difficulties associated with being affiliated with two (or more) work places with quite different agendas.

The students' work conditions merits discussion. Some of the above observations suggest that these students may need more time to complete a doctorate than students without affiliation to a firm. Certainly supervision must be effective if they are to complete their degrees in the alloted time. Perhaps it would be appropriate to offer them an optional extra semester.

6.5 Academic-industry collaboration and interdisciplinarity

There are many dimensions to successful collaboration. Collaborative partners may differ in their perceptions of which aspects of a collaboration are functioning well, and which not so well. A student may feel happy with his or her firm, feel welcome there, and feel that they are contributing to the firm's activities, but the academic supervisor may feel less than enthusiastic over the firm's influence on the direction taken by the student's project.

An observation to be made from the data is that small firms unused to research activity at times have difficulty reconciling their plans for the research project with the academic supervisor's vision for the project. This is for example evident in KIF, the chemical industry research school, where all firm participants are SMEs. In one case, the collaborating firm was unable to offer any scientific supervision, but its sister company, interested in the results, continuously chased the student up, wanting her to publish and produce results prematurely. In the university supervisor's eyes, such intense and premature interest in the results was inappropriate. In this case, both university supervisors intervened in an attempt to shield the student from strong firm influences.

A further observation relating to academic-industry collaboration is that firms are not always stable partners, partly owing to relatively rapid staff turnover. The importance of firm stability for successful collaboration in turn raises the question of how small is too small. Very small firms may

be too unstable to be partly responsible for a doctoral student. For example, a small start-up firm participating in the SIK research school met problems which meant it was not longer able to support the student. SIK and the firm in question are now together trying to find a new company interested in taking over the project.

As observed on p.78 above, the data largely suggest that small high-tech companies are more natural collaborators with academia than small mid or low-tech companies. Indeed, as mentioned earlier, the high-tech/low-tech distinction seems to make more of a difference to collaboration than whether the firm is large or small (though this needs to be investigated systematically). The distinction between re-activated and entirely new collaborations also appears significant for accounting for the perceived success or otherwise of the collaboration. Indeed, the majority of collaborations initiated by the research schools appear to be reactivated rather than entirely new, perhaps indicating the difficulty of gaining the interest of and working with new industrial partners.

The research schools appear to be fostering interdisciplinarity, the economic relevance of which is as yet unclear. However, in at least two research schools which straddle departments in the same university, the cross-departmental link does not seem to function in line with KK's aims for the research schools (though no conclusions should be drawn from this yet). In the indoor environment research school, for example, there is little flow of activity between the air quality and acoustics parts of the research school, which seem almost to function as separate entities (although a joint course is planned for later this year). Similarly, in the minerals and mining research school, which involves three departments at Luleå University, students in different departments were not always aware of the existence of each other. Again, there appears to be minimal cross-over activities between the departments; if anything, a degree of competition between these departments is evident.

6.6 KK Funding and criteria

The following concerns relating to the funding structure and criteria stipulated by the Foundation were either raised directly by research school participants, or have been identified by the authors of the report.

An aspect of the KK funding policy which requires some clarification is the status of industrial research institutes in relation to co-funding. It is

not clear whether research institutes are primarily treated as firms or as academic institutions. Whilst at least two university-based research schools (MARCHAL and Lund) list research institutes as collaborating organizations (see Table 6), the Foundation maintains that research institutes are not eligible to co-sponsor a student. The Foundation appears to have changed policy on this question, for initially at least, research institutes appear to have been legitimate co-funders of students, as witnessed by the IOF/ACREO research school.

There are currently no special conditions for small firms within the programme. On the whole, small firms (apart from the very successful) can barely afford to support university research even if it is subsidized. Thus perhaps consideration should be given to more favourable funding conditions for these firms.

A concern raised in some form by at least three project leaders, and one which is rooted in the stipulation of matched industry funding, relates to administrative and other overhead costs. These project leaders felt the money allocated was not adequate to build the research school up as an organizational entity. Because there is no ear-marked sum for administration, the costs of administration are necessarily partly convered by participating firms, which are thus investing in a research school rather than in individual students. And this is often too large a commitment for them. Likewise, some project leaders reported that they felt they were subsidizing the research school. As one project leader explained, universities are increasingly dependent on external funding, even for researchers' salaries; such funding thus needs to recognize a broad range of costs such as administration and supervision. Further, science fields and thus university departments, differ widely in their costs. For example, those requiring extensive lab space (e.g. building technology) need to meet high rental costs, whilst others require very expensive experimental equipment. Such 'extra' costs faced by some science fields might not be immediately visible to a funding agency.

The research schools which voiced this concern were in natural science fields (relatively expensive) and were trying to build up an identity as a research school according to a particular vision (Karolinska, Lund, KIF/Chemical). KIF for example was unable to afford a course package designed for them by Chalmers, a disappointment which has subsequently caused a great deal of extra work for the coordinator of KIF. (A number of schools have suggested the possibility of sharing the costs of industrially-relevant courses between them.) These research

schools appeared to manage by 'making do' and by staff working overtime. Project leaders and supervisors should not be *expected* to work overtime or cover supervision costs from another project; as one of them pointed out, 'it's not *that* fun.'[9]   Herein lies a paradox: those research schools which – in line with KK's aims – are attempting to achieve a clear identity, vision and visibility, are also those which depend most strongly on central coordination and administration at the heart of the research school. And it was the very lack of ear-marked resources for central research school activities that these research schools felt was perhaps the most problematic aspect of the KK grant. Readjusting this situation might imply reconsidering the stringency with which the criterion of matching industrial funding is implemented.

A significant observation in this context is that some of the research schools which were up and running fairly quickly were also those which already had some kind of system for training industry research students (e.g. Linköping and SIK). In such cases, the KK money can become just another funding stream supporting existing activities.

A further concern, again raised by a minority of research schools, related to a perceived expectation that research schools should be running at more or less full capacity soon after the grant had been received. Most research schools have required a period of one or two years to get started, and have consequently negotiated up to two years' extension of the grant period. Exceptions to this general pattern are again cases where the research school is integrated into pre-existing arrangements for industry research students, as is to some extent the case with SIK and Linköping. One project leader suggested it might perhaps be more appropriate to stagger student enrolment over time in order to allow for a gradual start. However, this would make it more difficult to run the research school as an entity, as is presumably to be desired.

There are a number of reasons why several project leaders have experienced difficulty in getting started. University supervision may be in short supply. Securing the interest of firms is time and energy consuming, as to a lesser extent is recruiting students. Two project leaders related firm and student recruitment problems to a catch-22 situation rooted in the need to match firm with student: whilst firms may be unwilling to commit funding before they know who they are funding,

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[9] In Swedish 'så roligt är det inte'.

research schools may find it difficult to recruit a student before they know which firm and project they are recruiting for.

As was implied earlier in this chapter (p.84), some students appear to becoming anxious that they will not be able to complete their doctorates within the four year period allocated. Few were confident that four years would be sufficient to complete their doctorate. Whilst some were pragmatically hoping to at least gain a *licentiat* degree within the four years, others believed that funding would somehow sort itself out should the KK money run out. However, students based in firms or who were particularly closely connected to their firm, seemed to have greater resolve to complete in the allotted time..

Getting used to two very different work environments, having to communicate with up to three supervisors, and at times having to travel significant distances between their firm and their academic institution all suggest that these students are likely to take longer than 'ordinary' research students to complete their doctorates. It is thus worth considering whether the four year limit is appropriate for these research students. Perhaps students who need to take a little longer than four years should have the option to do so.

Four years' funding is not only quite short for individual doctoral students, but also for the research schools as a whole, some of which are taking at least two years to get going. This relatively short period of KK funding, combined with the considerable length of time taken to get started, has implications for the research schools' future prospects.

Research schools' current preoccupation with building up to full capacty leaves little room for consolidation and looking to the future. Few project leaders seemed to be devoting much time to planning how to continue activities after the end of the funding period. Exceptions are pehaps the three earliest research schools, which are also those which have come the furthest in implementation (KI, Fenix, Linköping). These were certainly thinking forward, even if they had not yet taken concrete steps to secure further funding. In this light it is not unreasonable to suspect there may be a risk of some research schools' activities petering out after the first five to six years' funding.

6.7 Conclusions

The aim of this report has been to track progress in implementing the programme and to report the findings back to the various stakeholders. The mid-term report, due in November this year, will seek to provide a more comprehensive account of the programme together with conclusions and recommendations.

Though the evaluation is still in a relatively early phase, it is already possible to draw some tentative conclusions on the programmes's contribution to the knowledge transfer process. The first set of conclusions relates to the institutionalization process as constituted by the establishment of the research schools. The second set of conclusions relates to the mechanics of the knowledge transfer process itself.

In terms of the institutionalization process, it is clear that the KK Foundation has managed to realize the idea of a new type of research school in Sweden: the *industrial* research school. This type of research school can be thought of as constituting an infrastructure of new or partially new institutions and networks bridging the worlds of academia and industry.

A central aim of the programme is to foster collaboration across the academic-industrial boundary. Whilst the research schools do offer an infrastructure to facilitate such interaction, implementing the research school programme has been a relatively slow process. Most of the research schools are taking considerably longer to build up than was initially anticipated; they are challenging projects to get up and running.

However, the extent to which research schools are building entirely new institutions and networks varies, as is evident in differences between research schools in the amount of effort required to reach their current point of development. Those schools which are primarily building up new networks invest greater time and effort to reach the same stage of development as schools which are mainly reactivating old networks. However, the former group of schools naturally have a greater potential of contributing something entirely new to the knowledge transfer process.

Concerning the mechanics of the knowledge transfer process itself, the findings suggest that the research students themselves, through initiating

and maintaining new contacts, constitute a key link in the knowledge transfer process. Thus some students have created new, formal or informal networks both within academia and spanning the academic-industry boundary. It may be conjectured that the research students are thereby adding some new element to the knowledge transfer process. The evaluation will seek to trace the substance of this added value, and how it is perceived by research school participants.

A related observation is that students can be said to 'embody' the knowledge transfer process. Not only do students initiate, stimulate and provide access to new contacts across the academic-industry divide, but there is evidence that they also carry and transmit significant knowledge and information between the two sectors. A majority of students perceived themselves as 'embodying' knowledge transfer, an observation which was further confirmed by some supervisors.

Other participants, such as supervisors and project leaders, naturally contribute to the knowledge transfer process too. The data do not suggest that this contribution can be described as added value, since these participants often draw on existing or dormant networks and channels. However, in cases where a supervisor has not had much previous contact with the student's firm, students may again play a catalytic role in introducing supervisors to the firm and its network. This might in turn result in more intensive or extensive collaboration and thus knowledge transfer at a later stage.

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APPENDIX A INTERVIEW RESPONDENTS

Research School	Project leader	University supervisors	Research Institute supervisors	Firm contact	Students
ACREO Kista/ Norrköping	Magnus Breidne Shaofang Gong	Ari Friberg, Prof. Optics KTH/Klaus Biedermann, Prof. Optics KTH	Walter Margulius; Raoul Stubbe ACREO	Ingemar Peterman ACREO/KTH Optics	Ingemar Peterman ACREO/KTH Optics
FENIX	Sven Kylén, Fenix	Bengt Stymne, Prof. Business Administration HHS Flemming Norrgren, Programchef, Fenix	N/A	Lillemor Holm, Volvo PV Arne Philipsson, Ericsson Kerstin Kylberg-Hanssen, Astra-Zeneca	Golaleh Ebrahimpur, Volvo/Fenix Jan Wickenberg, Astra-Zeneca/Fenix; Cassandra Marxhall, Telia/Fenix; Robert Sandberg, Telia/Fenix
KIF	Enn Päärt, BIM Kemi AB	Hans Elwing, Prof. Surface Biotechnology, GU David Wilson, Electrical Engineering, KaU Ulf Germgård, Prof. Chemical Pulp, KaU Magnus Nydén, Applied Surface Chemistry, Chalmers	N/A	Mariana Björklund, Research Manager, BIM Kemi AB; Anders Andersson, R&D Manager, Noviant; Gunnar Ljungberg, CEO, Noviant; Geoff Richards, Bycosin; Håkan Byström, CEO, Bycosin AB	Veronica Stigsson, Noviant/Chemical Engineering, KaU Jenny-Ann Östlund, Bycosin/Applied Surface Chemistry, Chalmers Helena Wassenius, BIM/Applied Surface Chemistry, Chalmers
KI	Agnete Mode John Skår	Lennart Nilsson, Prof. KI Britta Wahren, Prof. Smittskyddsinstitutet Mats Wahlgren, Prof. KI	N/A	Bo Öberg, Medivir Nils Carlin, SBL Vaccin Stefan Nilsson, KaroBio	Anne Kjerrstrom, KI/SBL Vaccin; Bartek Zuber, KI/Medivir; Tomas Barkhem, Peter Carlsson, Marcus Ruda, Lars-Göran Bladh, Erik Flöistrup (all 5 KI/KaroBio)
Linköping IDA	Sture Hägglund, Prof. IDA Lillemor Wallgren	Bertil Lyberg, adj.prof. Telia/IDA Kristian Sandahl, adj.prof. Ericsson/IDA Miriam Kamkar, IDA	N/A	Malin ? personal sjef Ida Systems AB (for Bengt Sandlund Ida Systems)	Pär Carlshamre, IDA, LiU/Ericsson Karl Gäre, IDA, LiU/System Data Konsult; Aseel Ibrahim IDA, LiU/Nokia; Lena ? tjl.IDA, LiU/IDASystems

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Luleå	Eric Forssberg, Prof. Mineral Engineering LuTH	Yanmin Wang, Mineralteknik LuTH; Erling Nordlund, Bergmekanik LuTH; Kou Shaoquan Division of Mining Engineering, LuTH (for Per-Arne Lindqvist, Prof. Bergteknik)	N/A	Torbjörn Narttijarvi LKAB Per-Olof Samskog, LKAB	N/A	Ann-Catrine Johansson, Mineralteknik, LuTH; Daniel Sandström, Bergmekanik, LuTH; Magnus Granljung, Bergmekanik, LuTH; Roger Hahne, LuTH; Fredrik Selin Bergteknik, LuTH
Lund	Kyösti Tuutti, R&D Manager Skanska Teknik AB & adj.prof. byggnadsmaterial LTH; Göran Fagerlund, Prof. and head of division of building materials, LTH	Erling Nilson, Acoustics LTH; Lars Wadsö, Byggnadsmaterial LTH; Per Hammer, Acoustics LTH	N/A	Håkan Wernesson, Perstorp Flooring	N/A	Jonas Brunskog, Acoustics, LTH/Skanska Teknik; Tina Hjellström, Building Materials LTH; Ulrika Hammargren, Building Materials LTH/Skanska Teknik
MARCHAL	Nils-Hermann Schöön, Prof.emeritus, Chalmers	Bertil Helgee, Chalmers; Mikael Rigdahl, Chalmers	N/A	Thomas Thunborg, Volvo Per Flodin, Artimplant	N/A	Nils Toft; Mikael Eriksson; Katrin Gisselfält
NMK	Helene Bergsten, Miljökoordinator, Chalmers/GU	N/A	N/A	N/A	N/A	N/A
SIK	Hans Lingnert		Anders Leufvén Ulf Rönner	Annerita Olofsson-Jansson, Allt i fisk Sandra Flodström, AnalyCen Nordic AB Jörgen Andersson Danisco Sugar		Annika Hansson, SIK Gisela Richardson, SIK Frederike Ziegler, SIK
Trätek	Birgit Östman	Claes Gustafsson, Prof. KTH; Göran Goldkuhl Prof. CMTO, LiU; Stig-Inge Gustafsson, LiU Anders Grönlund, LuTH	Bo Källsner Martin Gustafsson I Johansson	Hans Brännström, R&D Manager, Kährs		Fredrik Markgren, Trätek/KTH Henrik Berglind, Trätek/LuTH Anna Pousette, Trätek/LuTH

APPENDIX B THE INDUSTRIAL RESEARCH SCHOOLS

1.Biotechnology with an industrial focus
http://info.ki.se/education/researchtraining/researchschools/ffb/index_en.html

Research field: Biotechnology, molecular and cell biology, biochemistry, genetics and DNA technology are the core areas of this programme.

Host organization: Karolinska institutet, Stockholm

Project leader: John Skår

Contract signed: July 1997

First student admitted: July 1998

Student capacity: 20

Research students enrolled 1, Jan 2000: 11

Collaborating universities, departments and research institutes: Karolinska institutet (Dept. of Biosciences, Dep. of medical nutrition, centre of genomics, microbiology and Tumor Biology Centre) Huddinge University Hospital (Dept. of Clinical Sciences)

Collaborating firms: Large firms (>500): Pharmacia & Upjohn; Medium firms (100-499) Q-med; Small firms (< 99): SBL Vaccin AB, Karobio AB, Medivir AB.

KK grant (million Swedish crowns): 38,9

Objectives:
- develop a high-quality business/industrial oriented PhD-training programme, of international quality
- promote an individualized research training with extensive supervision, strenthen collaboration with firms, develop PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least twenty research students with the aim of completing lic- or doctorate within 3 or 5 years respectively.

2. Applied IT & software engineering
http://www.ida.liu.se/kk-ffs/

Research field: Software engineering and other related areas of applied engineering. The research school focuses on the engineering aspects of construction, development, production and maintenance of software for industrial processes together with the supportive tools of these processes.

Host organization: Linköping University

Project leader: Sture Hägglund

Contract signed: August 1997

First student admitted: September 1997

Student capacity: 20

Research students enrolled 1, Jan 2000: 19

Collaborating universities, departments and research institutes: Department of Computer and Information Sciences at Linköping University.

Collaborating firms: Large firms (>500) Ericsson, FöreningsSparbanken, IKEA, Nokia, SKF, SysTeam, Telia, WM-data; Small firms (<99), Cepro, Devenator, Focal Point, Ida Systems, Idonex, MathCore

KK grant (million Swedish crowns): 41

Objectives:
- develop a high-quality business/industrial oriented PhD-training programme
- promote an individualized research training with extensive supervision, strenthen collaboration with firms, foster PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least twenty research students with the aim of completing a lic- or doctorate within 3 or 5 years respectively.

3. Fenix R&D project leadership
http://www.fenix.chalmers.se/fenix/

Research field: Project leadership, management, organization, knowledge transfer and reflective learning.

Host organization: Chalmers University of Technology, Gothenburg and Stockholm's school of Economics

Project leader: Sven Kylén

Contract signed: September 1997

First student admitted: September 1998

Student capacity: 20

Research students enrolled 1, Jan 2000: 10

Collaborating universities, departments and research institutes: Chalmers University of Technology, Gothenburg and Stockholm's school of Economics

Collaborating firms: Large firms(>500); AstraZeneca, Ericsson, Telia, Volvo

Total budget (million Swedish crowns): 34 (+ 30)

Objectives:
- develop a high-quality business/industrial oriented PhD-training of international quality
- promote an individualized research training with extensive supervision, strenthen collaboration with firms, develop PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least twenty research students with the aim of completing a lic- or doctorate within 3 or 5 years respectively.
- Produce a new type of PhD who is particularly suited to a leadership role, and managing change.

4. SIK Food and biotechnology SMEs
http://www.sik.se/kks/index.html

Research field: Food and biotechnology

Host organization: The Swedish Institute for Food and Biotechnology

Project leader: Hans Lingnert

Contract signed: November 1997

First student admitted: May 1998

Student capacity: 11 (3+8)

Research students enrolled 1, Jan 2000: 10

Collaborating universities, departments and research institutes: Chalmers University of Technology (School of Chemical Engineering (Food Science) Gothenburg University (Dept. of Marine Ecology, dept. of Respiratory medicine and Allergology) Lunds Institute of Technology (Dept. of Chemistry)

Collaborating firms: Large firms (>500); Arla Ost, Danisco Sugar, Procordia Food, Tetra Pak R&D; Medium firms (100-499) AnalyCen Nordic, Kavli; Small firms (<99) Allt-i-fisk, Aromatic, Mentha, SydGrönt, Österlenkryddor

KK grant (million Swedish crowns): 20,5 (16 + 4,5)

Objectives:
- develop a high-quality business/industrial oriented PhD-training, of international quality
- promote an individualized research training programme with extensive supervision, strenthen collaboration with firms, develop PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least eight research students simultaneously with the aim of completing a lic- or doctorate within 3 or 5 years respectively
- aim that at least 80 % of those who have completed the Ph.D. shall obtain employment in industry

5. IOF/ACREO Optics
http://www.iof.optics.kth.se/KK-projekt.htm

Research field: Optics

Host organization: AB Institutet för optisk forskning

Project leader: Magnus Breidne

Contract signed: November 1997

First student admitted: July 1998

Student capacity: 4

Research students enrolled 1, Jan 2000: 3

Collaborating universities, departments and research institutes: Royal Institute of Technology (KTH), Stockholm (Dept. of Physics)

Collaborating firms and research institutes: Large firms (>500); Ericsson Cables, ericsson Microelectronics, Telia; Research institute; ACREO

KK grant (million Swedish crowns): 6,4

Objectives:
- develop a high-quality business/industrial oriented PhD-training of international quality
- promote an individualized research training programme with extensive supervision, strenthen collaboration with firms, develop PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least four research students with the aim of completing a lic- or doctorate within 3 or 5 years respectively.
- be of university academic standard

- **6. Trätek Wood technology and forestry industry**
http://www.tratek.se/forskskola/index.htm

Research field: Wood technology and forestry industry

Host organization: AB Trätek, Institutet för träteknisk forskning

Project leader: Birgit Östman (coordinator)

Contract signed: January 1998

First student admitted: September 1997

Student capacity: 5

Research students enrolled 1, Jan 2000: 5

Collaborating universities, departments and research institutes: Linköping University (dept. of Computer and Information Science, dept.of Mechanical Engineering), Luleå university of Technology (Wood Technology in Skellefteå), Royal Institute of Technology, KTH, (Dept. of Industrial Economics and Management)

Collaborating firms and research institutes: Large firms (>500); AssiDomain Timber, Brio, Casco, Graninge, Iggesund, Korsnäs, Kährs, Södra Timber, tarkett); Medium firms(100-499); Martinssons, SCC-Trätrappor, Svedbergs i Dalstorp, Small firms (<99); KarlsonHus, Kvänum Kök, OLAB, Snickarlaget, Svenska Träbroar, Research institute; Trätek

KK grant (million Swedish crowns): 10,2

Objectives:
- develop a high-quality business/industrial oriented PhD-training of international quality
- promote an individualized research training programme with extensive supervision, strenthen collaboration with firms, develop PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least five research students with the aim of completing lic- or doctorate within 3 or 5 years respectively.
- reach university academic standard

7.Mining and Mineral processing, Luleå
http://www.km.luth.se/kmm/KKS/KKS-fosk.htm

Research field: Mining and Mineral processing, Mineral extraction and processing, physical-chemical analytical methods for separation and product adjustment.

Host organization: Luleå university of Technology

Project leader: Eric Forssberg

Contract signed: May 1998

First student admitted: ?

Student capacity: 8

Research students enrolled 1, Jan 2000: 7

Collaborating universities, departments and research institutes: Luleå university of Technology (Dept. of Chemical & Metallurgical Engineering (Mineral processing), dept. of Civil & Mining Engineering (Rock Engineering and Rock Mechanics)

Collaborating firms: Large firms (>500); Boliden, LKAB

KK grant (million Swedish crowns): 11

Objectives:
- develop a high-quality business/industrial oriented PhD-training of international quality
- promote an individualized research training with extensive supervision, strenthen collaboration with firms, develop PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least eight research students with the aim of completing lic- or doctorate within 3 or 5 years respectively.

8. Building and indoor environment, Lund
http://www.indoorenvironment.lth.se/

Research field: Building and indoor environment

Host organization: Lund University

Project leader: Kyösti Tuutti

Contract signed: August 1998

First student admitted: November 1998

Student capacity: 18

Research students enrolled 1, Jan 2000: 8

Collaborating universities, departments and research institutes: Lund Institute of Technology, Lund University (Dept. of Chemistry (Polymer Science & Engineering), Dept. of Building & Environmental Technology (Building Materials, Engineering Acoustics, Building Physics)

Collaborating firms and Research institutes: Large firms (>500); Cementa, Dalloz Safety, Gyproc, Perstorp Flooring, Scancem Research, Skanska Teknik; Medium firms(100-499) Ingemansson, Optiroc, Research institute; Swedish National Testing and Research Institute.

KK grant (million Swedish crowns): 41,3

Objectives:
- develop a high-quality business/industrial oriented PhD-training of international quality
- promote an individualized research training with extensive supervision, strenthen collaboration with firms, develop PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least eighteen research students with the aim of completing lic- or doctorate within 3 or 5 years respectively.
- Improve knowledge on indoor environment in the building industry, to help overcome the problems of bad indoor environment

9. Material research, Marchal
http://www.chalmers.se/MARCHAL/MARCHAL.HTML

Research field: Material research

Host organization: Chalmers University of Technology

Project leader: Nils-Herman-Schöön

Contract signed: October 1998

First student admitted: May 1999

Student capacity: 10

Research students enrolled 1, Jan 2000: 5

Collaborating universities, departments and research institutes: Chalmers University of Technology(School of Mechanical and Vehicular Engineering (Engineering Metals, Polymeric materials), School of Chemical Engineering (Applied Surface Chemistry)

Collaborating firms and Research institutes: Large firms (>500); Höganäs, Nobel Biocare, SCA Research, Tetra Pak R&D, Small firms (<99); Artimplant, Research institute; Swedish Ceramic Institute

KK grant (million Swedish crowns): 16

Objectives:
- develop a high-quality business/industrial oriented PhD-training of international quality
- promote an individualized research training with extensive supervision, strenthen collaboration with firms, develop PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least ten research students with the aim of completing lic- or doctorate within 3 or 5 years respectively.

10. Chemical SMEs
http://www.chemind.se/KIF/

Research field: Chemical products

Host organization: Kemikontoret, Stockholm

Project leader: Enn Päärt

Contract signed: March 1999

First student admitted: January 1999

Student capacity: 11

Research students enrolled 1, Jan 2000: 10

Collaborating universities, departments and research institutes: Chalmers University of Technology (School of Chemical Engineering (Applied Surface Chemistry, Physical Chemistry, Molecular Biotechnology), Gothenburg University (Microbiology at the Dept. of Cell and Molecular Biology, Institute of Laboratory medicine (dept. of Pathology)), Karlstad University (division of Chemistry (Chemical Engineering), Lund Institute of Technology, Lund University (dept. of Chemistry (Chemical Engineering)

Collaborating firms: Medium firms (100-499); Bostik, Small firms (<99);Alufluor, BIM Kemi, Bycosin, Diffchamb, Noviant, Vasco

KK grant (million Swedish crowns): 20,7

Objectives:
- develop a high-quality business/industrial oriented PhD-training of international quality
- promote an individualized research training with extensive supervision, strenthen collaboration with firms, develop PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least eleven research students with the aim of completing lic- or doctorate within 3 or 5 years respectively.

11. Natural materials and building conservation, NMK
http://www.nmk.miljo.gu.se

Research field: natural material and building conservation

Host organization: Gothenburg University

Project leader: Oliver Lindqvist

Contract signed: January 2000

First student admitted: -

Student capacity: 12

Research students enrolled 1, Jan 2000: 0

Collaborating universities, departments and research institutes: Chalmers University of Technology, Gothenburg University, Gotland University College, Högskolan i Dalarna

Collaborating firms: -

KK grant (million Swedish crowns): 20,8

Objectives:
- develop a high-quality business/industrial oriented PhD-training of international quality
- promote an individualized research training with extensive supervision, strenthen collaboration with firms, develop PhD qualified researchers for industry
- develop an effective administration, with the goal of facilitating an industrial career for doctorates
- train at least twelve research students with the aim of completing lic- or doctorate within 3 or 5 years respectively.

APPENDIX C ADVANTAGES OF THE INDUSTRIAL RESEARCH SCHOOL

(as listed by research school project leaders)

Leadtimes can be shortened
Research can more easily produce actionable knowledge to firms during the academic work
Academia and industry can strengthen cooperation through joint research ventures and bridge building
Researchers get to know early about hot industry relevant research questions
Doctoral students don't have to leave firms which could harm their career
Cohorts make it easier to establish a learning community where the students become the central people and can thrive on industry-academia challenges
The school helps in revitalizing industry-academia relationships as well as a format for running a doctoral programme.

It focuses on an industrial sector with almost no tradition or contact with research.

The SMEs get a unique input of knowledge and a qualified PhD who is familiar with SMEs. This will help the company in its product/process innovation, and also contributes a new worldwide network to knowledge partners. For many companies, their first graduate will be trained to PhD level. The company then gains the opportunity of being at the international research front for new product development.

The distance between academic research and commercialization in firms is diminishing. Patenting and commercializing research results is the basis for research funding. A good knowledge about these aspects and the possibility/necessity to act in both academia and in firms is essential. The school fosters/educates in both worlds. That is an advantage over traditional academic education.

It offers: industrially relevant coordinated research training; the opportunity of new ways of working and an emphasis on interdisciplinarity; the establishment of networks with firms and research institutes; the opportunity to concentrate on important research areas in an effective way.

It fosters the creation of links between firms – research institutes – universities. It prepares research students for their continued industrial career.

The large size of the research school makes it possible for us to develop new courses and for the students to get to know each other. This is very good. However, many of our projects concern indoor air quality problems and other problematic issues. Studies of such problems should maybe be publicly funded rather than industrially funded.

It can create an exchange between universities and firms, particularly SMEs which would otherwise not have had the opportunity to carry out their own research.

Students collaborate closely with industry and gain a better understanding of the way industry thinks and acts.

It fosters the double flow of knowledge and experience between universities and industry

APPENDIX D AN INTERNATIONAL PERSPECTIVE ON THE KNOWLEDGE COMPETENCY (KK) FOUNDATION'S ROLE IN SWEDISH INNOVATION

Henry Etzkowitz, Luke Georghiou, Luigi Orsenigo

Introduction:

Sweden has recently undergone a revolution in its research funding system that, to a greater or lesser degree, can be seen in many other countries. There has been a shift in emphasis from funding research as an end in itself, or for military or other specific purposes, to encouraging institutional spheres to work more closely together to promote innovation. A group of Foundations were founded in the early 1990's to focus on filling gaps in the country's innovation system.

Combining public and private functions, these new quasi-governmental organizations operate as not-for profit entities. One of their main objectives is to encourage internal academic reform as well as assist universities to move out of the governmental sphere, engage more closely with industry and become more involved in their regions. As each institutional sphere "takes the role of the other" the stage is set for a new series of closer interactions and collaborations. The Foundations thus play a key role in facilitating and incentivizing university-industry collaborations, accelerating a process underway for other reasons.

The re-structuring of the university is also driven by changes in knowledge production and utilization as new forms of knowledge are created through the intersection of academic, industrial and government interests. A new set of scientific disciplines has recently been created that simultaneously exhibit both theoretical and practical implications, rather than the latter emerging after a long time delay. Thus, the growth of molecular biology, computer science and materials science more closely relate theoretical advance to technological innovation and vice versa.

In the United States, government-industry relations assumed increased significance in the 1990s even as university-industry ties came to the forefront of attention in the 1980s. In much of the European Community these two sets of bilateral relations developed in reverse sequence with academic-industry connections following upon the development of government-industry relations.

Regardless of the sequence of events, the common result is that the internal structure of these three institutional spheres are being transformed as their relations with each other intensify, presaging a new tripartite configuration. Structures and functions are no longer matched on a one to one basis as in the classic sociological structural-functional model. Instead, emergent structures such as the entrepreneurial university encompass multiple functions that overlap each other. Hybridization is becoming widespread, moving across various institutional spheres, changing the shape of society.

The formation of tri-lateral networks and hybrid organizations represent the pre-conditions for creating a dynamic trajectory of knowledge-based economic growth, as opposed to the construction of a Science Park, road, bridge, tunnel or even a campus. These latter tactics are secondary and only become actualized as regional innovation forces when they are embedded in networks. In the network mode of innovation, new sources of economic growth arise from those interactions. The transformation of the university into a matrix organization with teaching, research and business capacities is a key element in a new economic growth model.

In the "network society" organizations are no longer separate and distinct entities but rather exist along a continuum, embodying various elements that were formerly specialized in single units. Thus, even as universities have incorporated some of the functions of business firms; some business firms have taken on some of the characteristics of universities, especially in collaborating and sharing knowledge among each other. Government agencies have also taken on aspects of the private sector in their mode of operation.

The premise of governmental activism is that the conditions for high-tech economic growth are not spontaneous creations; rather they can be identified and put in place by explicit measures. As regions formulate knowledge-based innovation strategies the constellations of actors, and their relative importance in the local political economy is transformed. With knowledge assuming increased significance as a factor of production, in both high-technology and older manufacturing industries, the traditional elements of land, labor and capital reduce in importance with various political consequences including the inclusion in regional growth coalitions of knowledge producing institutions such as universities.

In the three sections that follow we will consider the role of the Foundations at the micro, meso and macro levels as public venture capital, new elements in the national innovation system and at the meta-level of evaluation. Some of

the basic questions discussed include: should institutional spheres operate with distinct and separate purposes, with linkages or mediating organizations between them, or should even closer collaborations be encouraged in which institutional spheres overlap and carry out tasks not classically within their purview, such as universities founding companies. The role of government, industry and university, heretofore more or less taken for granted, is now being debated at the most fundamental level of institutional purpose and design.

I. The Role of Public Venture Capital

By their very existence, the Foundations relativized the traditional research funding system. Heretofore, most Research Councils were oriented to the older universities and traditional academic disciplines. An industrially oriented Research Council was focused on the country's traditional mid-tech industries and a limited range of higher-tech fields. The Foundations opened up a rigid innovation system both by making available alternative sources of funds and by their willingness to seek out new research providers. Beyond creating a diversity of funding sources in a research funding system that had become out of phase with the country's innovation needs, the Foundations typically take a more proactive role in R&D management as "public venture capitalists."

Despite its origins on the center-right of the political spectrum, the missions of the various Foundations reflected the entire range of Swedish political and social interests. Whereas the Strategic Foundation has focused on reforming the traditional academic "ivory towers", the KK or "competency foundation" has concentrated its efforts on introducing research into sectors of Swedish industry that have traditionally done little research such as the wood products industry.

The KK is not a Research Council. Most of its funds are directed at building interactive capacities between institutional spheres such as university and industry, enhancing the knowledge capabilities of schools, firms and university colleges as well as through attention to infrastructural issues such as upgrading educational technology. The KK has also funded the newly emerging regional colleges and universities to expand their research efforts, especially in new disciplinary and interdisciplinary fields with commercial relevance such as software. Its remit includes orienting universities to industry, upgrading competencies in traditional low-tech industries and raising the qualification levels of industrial researchers.

The Strategic Foundation, on the other hand, has taken on the project of introducing flexibility into graduate education in the biological science as one if its major missions. Working from inside and outside of the universities, the Strategic Foundation has attempted to introduce a competitive element into a static academic environment. It has done this requiring schools to compete for fellowship funds with innovative research programs and by allowing Ph.D. students to have a greater say in deciding which lab they will eventually take their degree.

The new Foundations play a strong role in deciding where their money goes and how it is used. In now traditional peer review procedures, much authority is left to the research community itself in deciding the distribution of funds according to largely disciplinary criteria. By articulating criteria for funding such as collaboration among firms and universities and specific areas for the disbursement of funds whether to encourage upgrading of traditional wood industries or to develop new areas of software at regional colleges. In general, the foundations promote closer ties of academia to industry and fund interdisciplinary fields, often at newer universities hospitable to their development.

Although significant amounts of these funds went to universities, their distribution was often predicated on cooperation with industry and/or with academics in cross-disciplinary research and training schemes beyond the bounds of the older universities and their professoriat. The Foundations also served as an alternative source of university funding to the Research Councils, supporting the development of research at new universities and supporting academic reform at the older schools.

From the Endless Frontier to the Endless Transition

The Swedish innovation dilemma is one in which even success can lead to loss. Sweden's economy had become too narrowly based on a limited set of large, typically mid-tech, companies who are strongly motivated to extend, and sometimes move, their operations abroad in order to increase their access to markets. On the other hand, new firms are often limited in their growth by their limited focus on the relatively small national market.

The gap in the Swedish innovation system is two-fold: (1) means to upgrade low tech industry to make it more competitive before it disappears in the face of low-cost international competition and (2) a strategy to identify and encourage new high tech candidates for growth. The KK Foundation has taken some steps to address both of these issues, the former, for example,

through the research schools program and the latter by building up new R&D areas, such as in IT, at the regional colleges.

The Endless Frontier of basic research funded as an end in itself with only long term practical results expected is being replaced by an "Endless Transition" model in which basic research is linked to utilization through a series of intermediate processes, often stimulated by government. In the US these include the SBIR, STTR, IUCRC and Engineering Research Centers at NSF that bring faculty into closer relationships with firms. In Sweden, the beginnings of a movement in this direction has occasioned a debate similar to the one in the US.

The debate over the appropriate role of the university in technology and knowledge transfer, and the alternatives posed, are not peculiar to Sweden. They are echoed in the critique of academic technology transfer in the US by several economists (e.g. Mowery, Nelson) who argue that academic technology transfer mechanisms create unnecessary transaction costs by encapsulating knowledge in patents that would, they argue, otherwise flow freely to industry. But would the knowledge be efficiently transferred to industry without the series of mechanisms for identification and enhancing the applicability of research findings by carrying the development process further, through special grants for that purpose or in new firms formed for that purpose in university incubator facilities?

In the Research 2000 debate some Swedish academics argue that the two worlds of industry and academia should be kept apart. As one put it, "The, academy should be the academy, carry out basic research, open up understanding between worlds rather than changing. The alternative perspective is that academic research should change dramatically, open up to business." Academic differences are often "academic" until an economic crisis occurs and a decision is made to upgrade from a mid-tech economy to one more closely based on knowledge and academic research. This transition has led to a reevaluation of the role of the university in society.

As traditional sources of research funding have been reduced, the foundations are a "wild card" in the Swedish innovation system, with the resources to pursue new directions. The logic of politics has provided Sweden with a "war chest" to assist its transition to a new innovation regime. One question is what direction to take: whether to emphasize forming local interdisciplinary "critical masses" of researchers, whether academic, governmental or industrial, as virtual Institutes, versus geographically decentralized networks of sectoral

R&D activity. Of course, various combination of strategies resulting in a four-fold matrix are also possible.

The Foundations were intended to be temporary mechanisms, with a remit to spend their capital within a decade and then go out of business in 2005. However, a boom in the stock market meant that the capital of some foundations increased faster than they could disburse funds. Indeed, the capital of the Knowledge Competency (KK) Foundation has been increasing. Thus, the idea now is not to end operations in 2005. Perhaps the Foundations, having provide their utility in upgrading Sweden's low tech industry and encouraging new high tech research and industrial development, will become a permanent element of Sweden's innovation environment?

II. Implications for Sweden's National System of Innovation

In recent years, the debate on the structure of the national systems of innovation (NSI) - i.e. the set of public and private agents that contribute to the innovative activities of any one country – has become a priority issue in many European countries as well as in the
USA and Japan.

There are many different - and sometimes conflicting - reasons for this renewed interest. First, in general, a growing recognition of the role of innovation for economic growth and welfare, coupled - however - with stringent budgetary constraints and a generalized dissatisfaction with the conventional mechanisms for supporting research (e.g. subsidies to R&D to large firms). In particular, the potential for economic growth offered by the diffusion of new technologies and innovative capabilities within small firms and by the creation of new technology-based companies has attracted the attention of policy-makers and analysts. Second, a shift in emphasis from large "mission-oriented" programs – like military research - to smaller, decentralized projects based on collaborative research between firms, universities and other public and private agents (with some exception, like the human genome project). Third, the perception that the "traditional" articulation of the research process (as stylized in the so- called linear model) is not adequate any longer both as a conceptualization of the research process itself and as an organizational structure of the research system. Rather, it is increasingly recognized that the research process involves continuous feedbacks, interactions and collaboration between different stages and among different agents, disciplines, etc. Increasingly, for example, large firms invest directly in what used to be called "basic research" and increasingly universities are involved in the commercial exploitation of academic research.

In Europe, this debate has taken a somewhat different direction as compared to the USA. Whereas in North America the discussion focuses on possible excesses towards a "privatization" of science, in Europe there is a widespread perception that the overall quality of scientific research and above all the ability to transform it into technological innovation are significantly lagging behind the USA, especially in new key technologies and industries.

All this has led in the past decade to a mushrooming of initiatives all across Europe aiming at establishing stronger links between industry and universities and to encourage a more entrepreneurial attitude by universities and - more generally - to reform the academic systems and the National Systems of Innovation.

This process is proceeding at a very different pace across the European countries and results are mixed, if not unimpressive. It has to be recognized, however, that the problem of designing an efficient structure of national systems of innovation is tremendously difficult, especially for economists, as it confronts analysts with all sorts of imperfections, market failures, trade-offs. Thus, (economic) theory does not offer a lot in providing policy recommendations on how to design a research system, although in recent years some significant progress has been achieved in beginning to provide the basic building blocks of an analytical framework for dealing with these issues.

The debate on National Systems of Innovation had the great merit - among other things – to stress the inherent complexity and evolutionary nature of the structure of research systems across countries, as an adaptive response to some unavoidable trade-offs that emerge whenever one is dealing with innovation. Just to mention the most basic ones, the trade-off between the public and private nature of knowledge, the trade-off between exploration and exploitation of alternative routes of research, the trade-off between centralization vs. decentralization and coordination vs. division of labour in innovative activities.

Moreover, the debate on National Systems of Innovation emphasized the complementarities existing between different agents/institutions and the role of history in shaping the evolution of the research systems. For all these reasons, National Systems of Innovation are never completely coherent, but reflect different (often piecemeal) responses to specific instantiations of the above mentioned trade-offs in particular periods of time, sometimes resulting as unintended consequences of decisions taken for totally different reasons in different domains.

Against this background, the National Innovation Systems debate, however, did not develop detailed and precise taxonomies of research systems around the world. In very general terms, it was recognized that National Systems always include a set of common elements, although their specific weight within the system and their specific modus operandi might drastically vary across countries: a) the system of academic research b) the R&D system in the private sector c) non-profit organizations like charities, etc. d) bridging institutions between a) and b).

Simplifying drastically, each of these elements was supposed to act following different logics. For example, universities perform the basic functions of training and producing public knowledge, whilst companies invest resources in R&D projects motivated by the expectation of profits. In many countries, specific public organizations entirely devoted to research (rather than to teaching) have been created to support and enhance the research efforts in particular fields and/or for particular goals (National Laboratories, CNRS, Max Planck Society, etc..). In the academic world, peer review constitutes the basic mechanism of resource allocation, whereas in the commercial world resources are (imperfectly) allocated on the basis of expected profits. Bridging institutions and non-profit organizations mediate between the two spheres in various ways. Furthermore, another rough distinction between "diffusion-oriented" and "mission-oriented" systems has been proposed to analyze research systems.

Within this excessively simplified representation, the Swedish Foundations (and the KK Foundation in particular) appear as a rather new and different type of institution. They are not pure bridging institutions, nor are they simple funding agencies for academic or corporate research. They are not simply in the business of technology transfer; nor are they either pure public or private institutions. They do not operate solely through the principle of peer review, but they are not obviously for profit agents. Moreover, it has to be recognized that the Foundations differ greatly among themselves, in terms of goals, modus operandi, etc.. What is even more interesting is that the Foundations are not even simply "hybrid" agents, they are a totally new breed of institutions.

At the present stage, the role that the Foundations seem to have taken is that of an additional and alternative source of funding for supporting research, which operates through different resource allocation principles and for different aims as compared to both conventional research councils or industrial R&D funding agencies and even as compared to traditional non-

profit institutions. In general terms, their "mission" seems to be the creation of loci and opportunities of integration (rather than simply the bridging) of the academic and industrial sphere, through a variety of initiatives ranging from the research schools, to the programmes of the Strategic Foundation to break the traditional disciplinary bases within universities and introducing flexibility in curricula and a problem-oriented attitude in research.

In this sense, the Foundations represent a "maverick" and a "shock" within the traditional articulation of the Swedish research system. First of all, they constitute now a highly significant source of funding, in addition (and not substitute) of other traditional sources. If only for this reason, they are now major players and provide a significant impulse to Swedish innovative activities in quantitative terms.

Second, they certainly witness the perception that the boundaries between academic and industrial research have become blurred and new types of networks have to be created to support innovative activities in Sweden. Thus, they target rather unconventional goals and allocate funds following different procedures and principles. Again, as such, this is an important development, at least as it is recognized that pluralism in the sources of funding and in the allocative principles may enhance variety, diversity of efforts, emergence of new types of a What their role (and their success) will turn out to be in the future remains obviously to be seen. However, if only for the reasons mentioned so far, the case of the Swedish Foundations is rather unique and an extremely interesting "natural experiment" in the evolution of National Systems of Innovation.

III. The System Level: Evaluation of Foundations

The introduction of this new cohort of funding bodies to the Swedish innovation system has provided an impetus for change, the full consequences of which are probably only just beginning to be manifested. While the Foundations were originally set to complete their missions by 2005, it is desirable that evaluation of their impact should begin much sooner, firstly to enable mid-course corrections and secondly to consider the needs of the Swedish research and innovation system beyond that date, particularly in view of their likely extension. While evaluations and evaluation systems are already in place to look at the specific activities of the Foundations, consideration also needs to be given to their collective effect within the context of the Swedish system and to the consequences of these interactions for the strategy of individual Foundations, in this case the KK. Effects may be considered in several layered categories, depending upon their timing and scope. A simple

taxonomy could be to classify them according to their place in the sequence Funding - Activity - Consequences. Let us consider what the range of possibilities could be within this framework.

Taking first the financial stimulus created by the establishment of the Foundations, a series of evaluation issues are raised. Some are, at least on the surface, factual, for example the level of increase in the total resources available to the Swedish research community. Even here, there may be complexity as new activities by the Foundations may not necessarily involve direct support for research and hence not be amenable to categorization for longitudinal analysis. Furthermore, there could well have been reactions by pre-existing funding agencies to the presence of new actors, including potentially both imitations of successful policies on the one hand and the cutting of activities that are seen to be duplicated on the other. This effect may take place both at macro-level in terms of the resources available to pre-existing agencies and at the micro- level through the allocative policies of those agencies. Beyond the issue of the global resources available there are distributional issues such as whether there has been a reallocation of resources between fields or institutions as a result of new criteria for funding, the broadening of the base from which those allocating resources are drawn and the greater plurality of funding agencies in the system.

As well as the reactions of existing players, the Foundations too may have been responsive to the actions of to other agents and each other's policies, as above comprising both imitation and avoidance of duplication. A core KK activity, the promotion of Research Schools, is an example of an activity in an area which engages most funding agencies and where some clarity is needed as to whether support is sufficiently differentiated and/or complementary to serve best the needs of the Swedish system.

Moving from funding inputs to the activities which they induce, a second wave of effects is likely to be manifested as the policies of the Foundations are implemented. Human resources account for one group, whereby there are increases in the number of active researchers as a result of support for training and the availability of funding to a broader set of actors. Evaluation of the increase in the volume of research activity will have to take account of supply side issues, notably the degree to which quality is maintained as the system is expanded. In the short-term an increase could be expected to support progressively those who fell outside the previous cut-off point. In the longer-term, however, previous levels of competitiveness and quality at the margin could be regained or exceeded as the new supply of new entrants increases and moves up the learning curve. Negative effects could result for those fields

or groups excluded from the stimulation offered by the Foundations since, even if their funding remains constant, they may be less able to compete with better resourced areas for research students and staff.

Changes in the infrastructure which exists to promote transfer between research and innovation actors comprise a second group of new induced activities and are of particular relevance in the case of KK. One way in which these could be explored is to catalogue changes in managerial practice and support systems which have emerged to accommodate KK's initiatives. For example, new or expanded industrial liaison or commercialization offices at universities would be one manifestation of such a change. Slightly less tangible would be the emergence of new semi-formalised networks which span traditional boundaries. A full analysis of the system may also reveal lacunae in the range of institutions available - for example, given Sweden's small institute sector, there may be certain long-term missions which do not flourish in university or industry environments and hence which are missing from the Swedish system.

From the perspective of an evaluation, while the impacts listed above are of interest, they are all fundamentally inputs to the system and do not necessarily reflect the magnitude or direction of change in the system which the Foundations could induce. The general experience of the evaluation of innovation policies has shown that the most desirable effects are those which are persistent after the initiative is completed. It follows naturally that persistence is most likely when the policy has induced a behavioural change in its target community. Policies likely to result in behavioural changes normally have a strong learning element incorporated in their design. At its simplest the learning may result from inducing an organization or individual to undertake an activity in the expectation that the experience will demonstrate the benefits sufficiently that the organization will in the future undertake the same activity using its own resources. One variant on this theme is that the demonstration is diffused to third parties, who then may be persuaded to adopt the activity in question. It may be that realisation of benefits can only be achieved after the organization has moved up the learning curve - acquired new capabilities or infrastructure necessary to sustain the activity.

Ultimately, the test of the addition of the Foundations will lie in the effect they have on the Swedish innovation system as a whole. Measurement is problematic at this level of aggregation given the wide range of other influences which are at play. Macro-indicators such as the level of industrial R&D spending are likely to respond as much to the business cycle as to new infrastructure. Nonetheless, if the Foundations are doing their job, there

should be discernable change at system level with the cycle as a whole operating at a higher level and with a greater evident receptivity to new technology. For existing firms indicators such as the proportion of research staff employed, rate of introduction of new products and processes and linkages to the scientific community provide important information. For the university sector, the degree of linkage is critical. It is fashionable to measure this in terms of the emergence of spin-off firms but the process should go much further in recognition of the full range of relationships which exist between science and industry: transfer of people (students and staff) in both directions, provision of problem-solving advice to existing firms, adding a longer term, higher technological dimension within the context of collaborative research, and development of new techniques and equipment are all activities which should be given equal weight. While all of these require cultural change if their level is to increase, none should divert universities from their basic missions of teaching and providing high quality basic research.

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Industrial research schools

A new type of research school, the industrial research school, has been introduced with support from the KK-Foundation. These research schools can be thought of as constituting an infrastructure of new or partially new institutions and networks bridging the worlds of academia and industry.

Implementing the research school programme has been a relatively slow process. Establishing the research schools has in most cases taken considerably longer than was initially anticipated. Those schools which are building up new organizations and networks invest greater time and effort to reach a particular stage of development than do schools which are mainly reactivating old networks. However, the former group of schools has a greater potential to contribute a new dimension to the knowledge transfer process.

Concerning the mechanics of the knowledge transfer process itself, the findings suggest that the research students themselves, through initiating and maintaining new contacts, constitute a key link in knowledge transfer. Thus some students have created new, formal or informal networks both within academia and spanning the academic-industry boundary. A majority of students perceived themselves as 'embodying' knowledge transfer, an observation which was further confirmed by some supervisors.

Umeå Centre for Evaluation research has been commissioned to carry out a real-time evaluation of the KK-Foundation's knowledge exchange programme. This report deals with an early stage of the implementation process.

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Evaluation - a critical activity