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THINKING ACROSS DISCIPLINES - INTERDISCIPLINARITY IN RESEARCH AND EDUCATION

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FOREWORD

We are becoming fewer to produce the foundation for Europe's welfare and prosperity. That is why we need to think in an alternative and new way to exploit our academic competences in the best and broadest way possible. We need to be wiser, when other countries and regions are cheaper.

Therefore, it is also important that we are capable of thinking across disciplines in research and educations. The frame interdisciplinarity enjoys massive attention and is to a great extent being used in the debate on research and education policy as a buzzword and with a very large diversity of meanings. With this publication we wish to contribute to a more qualified agenda about the value and the extent of working across the different disciplines within research and education. This study is the most comprehensive in Denmark of today, and we hope that we can initiate a discussion on the large possibilities that interdisciplinarity provides. Policy action is particularly important in relation to the challenges and possibilities of working more across disciplines. By focusing on the interdisciplinary path, we can create some good conditions for the research and education institutions to launch new initiatives.

We are not dealing with changes where the individual researcher or student need to learn, know or experience a little of everything. Interdisciplinarity needs to build on top of the strong academic environments, where the researcher, the teacher or the student combines several different subject areas in new and productive ways, so that it solves complex societal challenges to which diverse knowledge and competence indeed is needed.

It is simply about realising the logic rationale about the fact that it is in the encounter with the unknown that we create the new realisations and insights.

Have a good reading!

Lars Nørby Johansen
Chairman of DEA

Peter Højland
Chairman of FBE

OBJECTIVES AND RESULTS

The Danish Business Research Academy (DEA/Danmarks ErhvervsforskningsAkademi) and the Danish Forum for Business Education (FBE) work to make research and educational programs relevant for the Danish business sector and to enhance the interaction between the business community and the social science and humanities research institutions.

On this background, DEA and FBE have asked the analytical and consulting firm of DAMVAD, assisted by the Danish Centre for Studies in Research and Research Policy (CFA) and The Danish Evaluation Institute (EVA), to conduct a study of approaches to interdisciplinarity within Danish research and higher educations.

Interdisciplinarity is about creating something new by crossing boundaries, and thinking across them. Today we face several tremendous social challenges, such as climate and environmental changes, demographic changes, demands for more and better welfare and health benefits and increased globalization. We do not yet have solutions to these many challenges. However, the solutions can be found by thinking across the boundaries of economics, technology, cultural understanding, natural sciences, design, branding, medical science, IT, language and innovation. In other words, by thinking across fields and disciplines within research and education.

An interdisciplinary approach is also about the financial bottom line. Interdisciplinarity can become a new parameter of competition for Denmark, if we resolutely provide support for it. Through increased interdisciplinarity, we can get more out of the investments in knowledge and education that we are currently pursuing, among others as a part of globalization strategy.

At the same time, we can strengthen the interaction between research, education and business, so that firms can develop unique products which combine the most advanced knowledge within the humanities disciplines, social sciences, technology, health sciences and the natural sciences.

Thus, increased interdisciplinarity in research and education is not a goal in itself,

"We are not students of some subject matter, but students of problems. And problems may cut right across the borders of any subject matter or discipline."
Carl Popper

but a means for creating new knowledge and competencies at a world class level. It will strengthen Denmark in the competition with other countries and regions.

In an international context as well, interdisciplinary thinking has moved up on the agenda. In both the OECD and the EU as well as in many advanced knowledge nations, there is a political will to make an effort in this area. In Denmark, focus is now being directed toward the value of thinking across disciplines in research and education. There are many good visions and objectives at the policy level, but measured in practice, and in relation to the best interdisciplinary environments, at elite universities such as Stanford, Oxford and MIT, we in Denmark still have much to do to truly promote interdisciplinary approaches.

The DEA and FBE seek to elucidate how far there really is from the political visions to concrete initiatives and actions. This is important for the way in which researchers, students and firms cooperate across traditional and established areas, especially in the linkage between traditional natural and technical sciences and areas within the humanities and the social sciences.

The goal is to become far better than we now are at creating genuine and optimal frameworks for students, researchers and the business community, to be able to think and work in interdisciplinary fashion and breach the traditional disciplinary boundaries. If we do not set a clear focus on promoting cross-disciplinary thinking within research and higher education, we risk losing out on the necessary new knowledge and the skilled workers, who are the ultimate guarantee for our welfare. Here it is not always a case of legislation and regulations, but also about creating strong incentives and greater cultural openness for being able to think across disciplinary boundaries. Interdisciplinary research and education must not be seen as a substitute for monodisciplinary research and education. It is, rather, a supplement. It is not a case of 'either...or' but of 'both...and'. In many cases, strong monodisciplinary knowledge is the precondition for new cross-cutting knowledge. And conversely, interdisciplinary knowledge can contribute to creating the necessary dynamic within the individual fields.

MAIN FINDINGS REGARDING INTERDISCIPLINARITY

The studies conducted by DEA and FBE show that there are good grounds to emphasize interdisciplinary approaches within research and higher education in Denmark. The challenge, however, is that we have not yet reached the point where there is sufficient political will, nor have we come far enough compared with the best practices abroad, those with which we should be comparing ourselves.

MAIN FINDING 1 INTERDISCIPLINARITY CREATES RESULTS, BUT WE PUT TOO FEW RESOURCES INTO IT

• **Interdisciplinary communities contribute most to knowledge sharing.**
The most interdisciplinary research communities, i.e., the radical interdisciplinary communities which cooperate across 'distantly related' research areas -- such as when so-called 'soft' fields like the humanities cooperate with the 'hard fields' such as technical sciences -- have a significantly greater

interaction with external partners about their research than do communities that work solely within their own fields.

The study shows that among the most interdisciplinary research communities 93% have research cooperation with external partners, e.g., firms or other research communities, whereas this is true of only 71% of the monodisciplinary communities. These findings say something about the high relevance of interdisciplinary research, as well as about the knowledge diffusion of such research to the rest of society.

• Interdisciplinary communities attract the most outside funding.
The group of highly interdisciplinary communities have a significantly greater amount of outside funding than do other communities. On average, interdisciplinary communities have double the outside funding as do monodisciplinary communities. The most interdisciplinary communities attract an average of DKK 430,000 per researcher/year (one research position working full-time for a year), versus DKK 274,000 per researcher/year in the monodisciplinary communities. The results say something about the quality of the interdisciplinary research and about the fact that interdisciplinary research communities are attractive communities for investment.

• Interdisciplinary communities bring international knowledge home to Denmark.
The most interdisciplinary communities have more cooperation with foreign knowledge communities than do monodisciplinary communities. Importing international knowledge is crucial for a small country such as Denmark, as we produce only a very small portion of the world's total knowledge production and therefore cannot ourselves produce all the knowledge we need.
Nearly 80% of the 'radical interdisciplinary' communities have cooperation with foreign knowledge communities, while this is true to only 40% of the monodisciplinary communities.

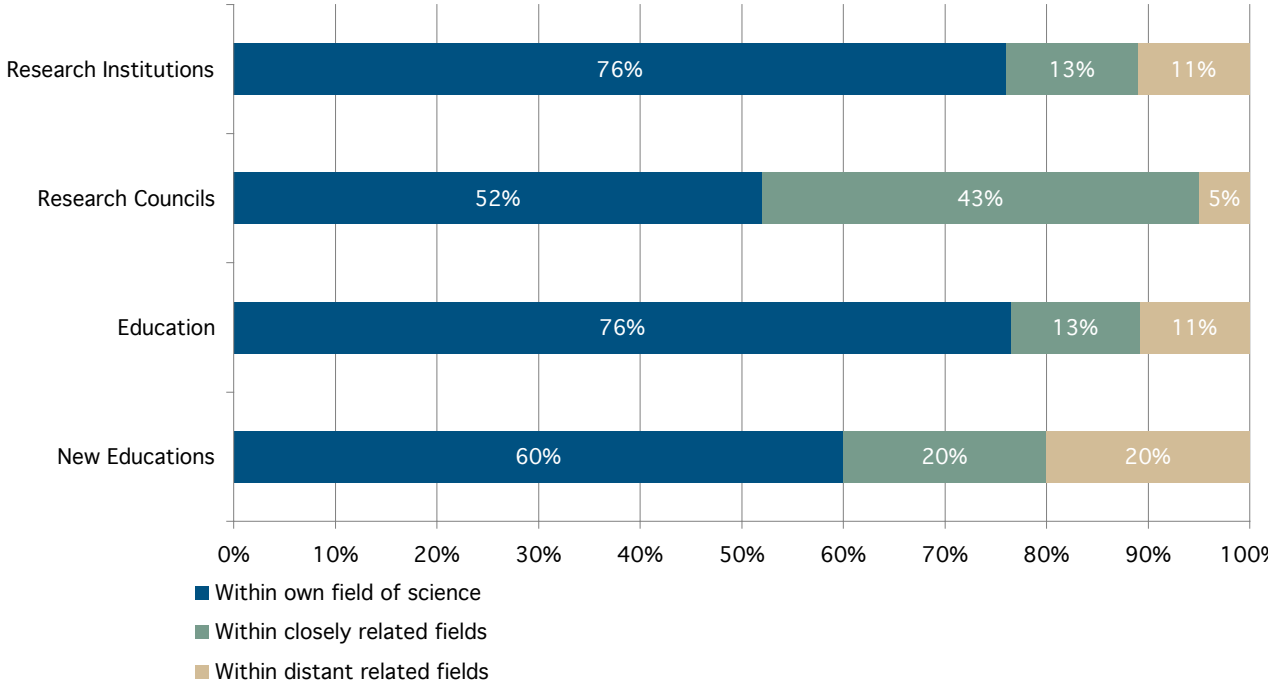
At the same time, the survey data indicate that the interdisciplinary research communities obtain more of their research funds from foreign sources. On average, the interdisciplinary communities receive DKK 67,000 per researcher from abroad, as against an average of DKK 34,000 per researcher within the monodisciplinary communities.

• Only few research and educational communities concentrate on radical interdisciplinary fields.
Even though many research communities and educations have come far in cooperation across disciplinary boundaries, there are in fact very few that seriously cross these boundaries.

About ten percent of the research communities, research council grants and higher education programs are characterized by the type of strong interdisciplinary research and education where there is cooperation across the 'soft' and 'hard' disciplines. One must therefore conclude that the interdisciplinary cooperation which currently exists is characterised by cooperation across fields which lie close to those within which they are already working.

• The interdisciplinary approach should be strengthened, especially within the research council system.
Only five percent of the projects which have achieved support from the research system

The extent of interdisciplinarity in research and education in Denmark



Note: The data for 'research institutions' is based on research statistics for the public sector and covers research and educational institutions which in 2005 had conducted research and development. This applies, for example, to universities, sector research institutes, hospitals, the university colleges and engineering colleges. The data for 're-search council' is based on grants awarded during the period 2005-2007 in the Councils for Independent Research, the Council for Strategic Research, the Danish National Research Agency and the National Advanced Technology Foundation. The calculation of 'education' covers existing and new educational programs in the period 2005-2007, covering short-term, middle-range and academic educations as well as continuing education and in-service training.

Sources: DAMVAD, CFA and EVA, Thinking across disciplines- interdisciplinarity in research and education, 2008

are radically interdisciplinary, i.e., are based upon cooperation across a distantly-related research areas. There are some prominent differences between the research councils. While the Danish Councils for Independent Research (DCIR) [1)] supports very few interdis-ciplinary projects, the Council for Strategic Research supports several interdisciplinary projects.

Among all applications to the research councils, the natural sciences and technical disciplines are clearly the best represented. For example, 57% of all projects awarded under the Council for Strategic Research are for natural sciences, while only 3% of appli-cations are in the humanities.

• Interest in interdisciplinary approaches is increasing

In recent years, there has been an increasing interest in new inter-disciplinary educations. Far more of the new educational programs are interdisciplinary than among the existing educational programs. Every fifth of the new educational programs contains elements which cross-cut the soft and hard disci-plines, whereas this applies to only every tenth of the existing educations. This points in the direction of an increasing tendency toward interdisciplinary approaches in higher education.

1) (DCIR) funds specific research activities, within all scientific areas, that are based on the researchers' own initiatives and that improve the quality and internationalisation of Danish research

Similarly, within research, there has been an increasing interest in working interdisciplinarity. With the 'Index of Interdisciplinarity' that we have developed in connection with this study, we can demonstrate a tendency that the interdisciplinary communities in Denmark have become more interdisciplinary. The index measures an aggregate of all interdisciplinary research communities. Among those interdisciplinary communities in the index, there is an increase from 1.2 points in 2001 to 1.4 points in 2005, corresponding to a 12% increase for the period. The increase is due to more communities beginning to do research within new and different areas than they normally do. In other words, there is a good future potential for increased interdisciplinary approaches in Denmark.

• Small and new research institutions are more interdisciplinary

In the Interdisciplinarity Index, it is possible to divide the research institutions according to how interdisciplinary the research is in the aggregate. The index shows that there are some clear top scorers when it concerns the degree of interdisciplinarity, and that it is generally the smaller and recently established research institutions which score highest on degree of interdisciplinarity. Examples here are the IT University, Roskilde University and Aalborg University.

Top 5 Institutions (Based on research data from 2005)	Value of Interdisciplinarity Index
1. IT University in Copenhagen	3,3
2. Roskilde University	1,8
3. Royal Veterinary and Agricultural University (now part of Copenhagen University and is from now on called Faculty of Life Sciences)	1,7
4. The Danish University of Education (now part of the University of Aarhus)	1,7
5. Aalborg University	1,7

Note: The Index of Interdisciplinarity is based on data from research statistics for the public sector from 2005. The score on the index is obtained by a combination of values: the research areas in which the individual research group is working, the amount of resources the group uses in the given research area, and how different the research areas are. Groups which work with re-search areas considered far apart from each other, e.g., humanities and technical sciences (i.e., with 'radical interdisciplinarity') score highest on the index.

Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

MAIN FINDING 2
THE RESEARCH AND EDUCATION SYSTEM IS NOT PREPARED FOR INTERDISCIPLINARITY.

The survey shows that there are many barriers and challenges to interdisciplinarity in Denmark's research and education system. Large parts of the research and education system are not yet geared to working adequately with interdisciplinarity. This is the conclusion of a survey of attitudes to interdisciplinarity among 120 leading actors within research, education and the private sector in Denmark.

• A major barrier which has been cited is **lack of strategic focus** on interdisciplinarity. The universities' development contracts focus on interdisciplinarity, but it is unclear how they specifically seek to promote it. Similarly, over half the respondents believe that there is a lack of research leadership concerning interdisciplinary research projects, and nearly two-thirds point out that there are too few large-scale research efforts which cut across the established disciplines.

• Similarly, a **lack of incentives** is also a barrier. Nearly three-fourths of the respondents point to the lack of incentives to coop-eration across education programs, e.g., an inflexible system of "payment per graduate" where there are great differences in what the universities receive as subsidies per student depending on the individual degree programs.

The payment per graduate system makes it difficult to combine humanities educations with technical fields. In terms of research, more than half the respondents cite a lack of recognition for interdisciplinary research communities at the universities, e.g., in the review committees assessing research quality.

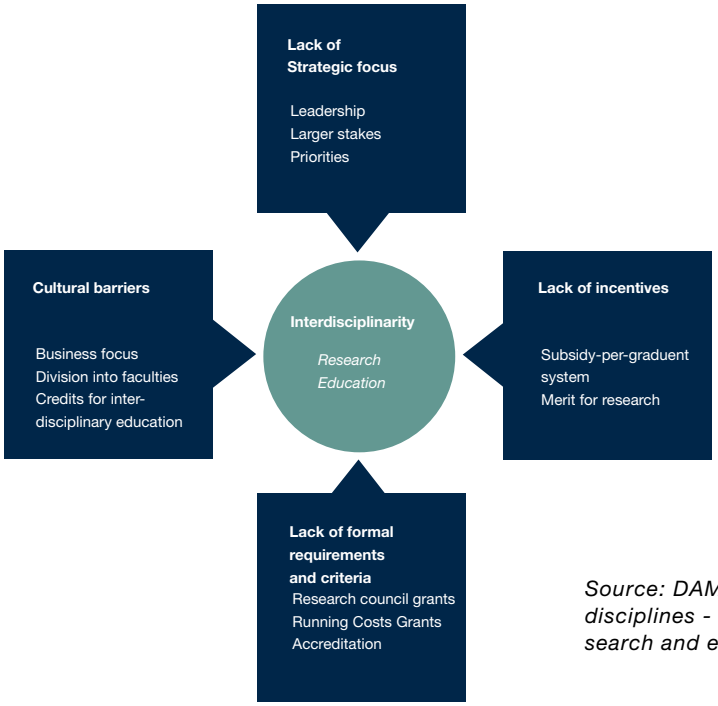
• Similarly, **lack of formal requirements and criteria** is also a barrier. Generally, the research councils do not have formal requirements regarding interdisciplinarity in their legal basis or their grant announcements, even though this is an area which several of the councils seek to promote.

Nearly half the respondents interviewed state that the research councils do not stipulate sufficient requirements for interdisciplinarity in their criteria for awarding of grants. At the same time, over a third of the respondents point out that the disciplinary spread in the composition of the members in the councils is too narrow.

In terms of education, over a third of the respondents point out that there is a lack of requirements for interdisciplinarity in the certification of educational programs, including the accreditation system.

• In addition, there are **cultural barriers** in the research and educational system. Two-thirds of the respondents point out that there are too few incentives for businesses to participate in research and development projects with knowledge institutions. This is a problem, in that interdisciplinarity in research emerges precisely in the encounter between the business sector and the research institutions.

With regard to higher education, three-fourths of the respondents report that it is difficult to obtain transfer credits for courses taken from other education programs, e.g., due to rules about credit transfer and traditional divisions between faculties. At the same time, new data from the Futures Panel of the Ministry of Science shows that only a few students at the universities continue their studies within



Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

fields of study other than that in which they took their Bachelor's degrees.

In this connection, there is much to indicate that the payment per graduate system (in Danish known as the "taxametersystem") has a detrimental effect on students' possibility to create interdisciplinarity in their educations because it does not 'pay off' for the programs to give credits, in that it is seen as lost income for the educational institutions. At the same time, there is evidence the intent of the university law to permit combinations in different educational programs is not really being respected.

MAIN FINDING 3
DENMARK CAN LEARN FROM THE BEST EXPERIENCES ABROAD.

The study shows that there are good foreign experiences with interdisciplinary cooperation in research and education, experiences from which we in Denmark can learn a lot. The study has reviewed 10 cases of educational programs and research communities which build extensively upon interdisciplinarity and conducted interviews with relevant persons associated with these areas. The 10 foreign case studies represent educational and university systems that are very different from that of Denmark. Nevertheless, there are essential elements which we in Denmark should consider:

• Interdisciplinary research often thrives in relatively small centers which draw upon and bring together competencies within otherwise separate faculties and departments. In this way, monodisciplinarity and interdisciplinarity live with each other in a fruitful interaction.

• The centers are used to market the univer-

sities. The creation of centers operates as a contact point between the university and the surrounding community. In the centers, the research is confronted with the realities of business and vice-versa. Research and businesss firms thus become more visible to each other at the centers.

• The interdisciplinary centers offer very varied forms of teaching. Some of them give credit that goes toward the student's major, while others offer different coursework which does not give credit in the student's own progam, but which nevertheless succeeds in attracting students.

• The educational programs are implemented in close cooperation with the firms, which become involved in the organization and implementation of the programs, in various ways; e.g., in developing the curriculum, providing internships, or as employers of the students after they complete their studies.

• The educational programs often have stricter admission requirements and also demand elite-calibre students. Generally, the educations are offered by the leading international universities.

• The educational programs are frequently offered as a collaboration between several educational institutions, and the interaction in education often takes place with other leading research and educational communities.

• The curricula are often based on case-based approaches, use probblem-oriented and application-oriented learning methods. The coursework takes its point of departure in the practical problems faced by the firms. Below is an overview of the 10 foreign interdisciplinary research communities and higher education programs described in this study.

Research community	Institution
Center for Information Technology Research (CITRIS)	University of California, Berkeley, USA
Human-Sciences and Technologies Advanced Research Institute (H-STAR)	Stanford University, USA
Stanford – d. school, Institute of Design	Stanford University, USA
The Media Lab	Massachusetts Institute of Technology, USA
Media and Graphics Interdisciplinary Centre (MAGIC)	University of British Columbia, Canada
Higher education program	**Institution**
Honours Degree in Technology Management	Ludwig-Maximilians-Universität and Technische Universität München, Germany
Bachelor of Engineering program	Fachhochschule für Wirtschaft and Technische Fachhochschule, Germany
Bachelor's program in Materials, Economics and Management	Oxford University, UK
Master's Degree in Bioscience, Biomedicine and Society	The London School of Economics, UK
Leaders for Manufacturing program. MBA or Master of Science	Massachusetts Institute of Technology, USA

Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

FOUR MAIN OBJECTIVES OF THIS PUBLICATION

There are four main reasons why DEA and FBE, with this publication, desire to place greater focus on interdisciplinarity in research and educational policy in Denmark. As a whole, it is our intention to qualify the debate in this area by providing new documentation about interdisciplinarity and thereby create a common and competent frame of reference and knowledge.

OBJECTIVE 1 FROM VISION TO EFFECTIVE ACTION

Interdisciplinarity in research an education has gradually become a fashionable slogan in research and education policy, making it necessary for many people to appear to be 'interdisciplinary' in order to obtain funds. In recent years, significant funds have been allocated for research and education in Denmark, and more funds will be allocated in the future, which is a positive and absolutely necessary development.

The question, however, is how much of these funds can be effectively channelled and prioritized to support genuine interdisciplinarity? How good are we in working across disciplines in the country's research and educational institutions? At the same time, an essential question is how good we are to promote and create incentives for interdisciplinarity in order to creating benefits in terms of solving social problems and especially in relation to strengthening the competitiveness of the business sector? There is a need for a debate about how we proceed from visions to real action.

OBJECTIVE 2
NEED FOR A UNIFIED NATIONAL STRATEGY

Denmark is not the only country in the world that can benefit from increased cooperation across disciplines in research an education. Interdisciplinarity is on the agenda internationally, in that many countries and international organisations have already formulated strategies in this area. Interdisciplinarity is high on the agenda of the OECD and the European Union, especially in the EU's new Research Council. In recent years, countries such as the United States, Sweden, Finland and Norway have formulated clear strategies for the strengthening of interdisciplinarity as a key part of their research and education policies.

It is therefore absolutely crucial that Denmark, in line with other countries, also places interdisciplinarity as a key strategic part of our research and education policy priorities and efforts in the coming years, if we are not to fall behind compared with the leading knowledge nations in the world. The allocations of the globalization pool of funds for the coming years, the Danish Goverment´s new plan for strategic research 'Forsk 2015', the establishing of the new business-oriented bachelor's program – the professional bachelor's degree, and the debate on the environment and planning for the upcoming environmental summit in 2009 are all appropriate areas where we should be placing enhanced strategic focus on interdisciplinarity.

OBJECTIVE 3
QUALIFIED DEBATE BASED ON FACTS

At present we know very little about interdisciplinarity in Denmark, and we find it very difficult to provide qualified answers to questions regarding the extent of, impact of and challenges posed by interdisciplinarity in research and educational programs.
Over time, several initiatives with an interdisciplinary goal or potential have been implemented, but there exists no overview of the effect of these initiatives nor any accessible information about how much genuine interdisciplinary research which has emerged from them. At the same time, there is no assessment of the extent to which research and education under the cross-cutting programs and grants has in fact been interdisciplinary.
Increasing our knowledge and facts about interdisciplinarity in research and education is an essential precondition for our being able to speak in a qualified way about interdisciplinary approaches in research and educa-tional policy.

OBJECTIVE 4
INTERNATIONAL INSPIRATION FOR INTERDISCIPLINARITY

Strong research communities abroad, e.g. Stanford, Oxford and MIT, have for several years worked toward enhancing interdisciplinarity in research and education because they can see that it contributes to strengthening the quality and relevance of research and education. In these interdisciplinary groups, teams have been established consisting of several researchers from fields such as law, linguistics, economics, com-

puter science and physics, all of whom work together on business-oriented problems in areas such as learning, communication and e-business. We in Denmark must become better at learning from such experiences if we are to create strong interdisciplinary communities.

Another essential element in strengthening interdisciplinarity in Denmark is itself to strengthen the interaction with leading research and educational communities abroad, where we must learn from the best and transfer their experiences into the Danish context.

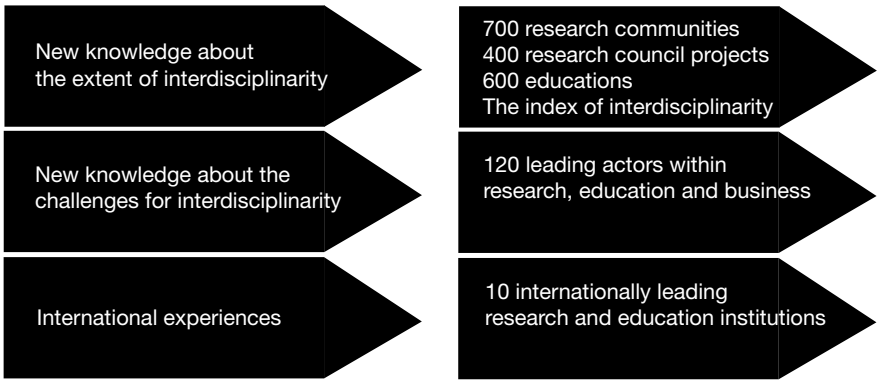
THE ANALYTICAL WORK BEHIND THIS PUBLICATION

This report is based on a comprehensive analysis. For the first time, we have 'taken the pulse' of interdisciplinarity in Denmark. We have mapped out the extent of interdisciplinarity in Danish research communities and higher educational programs, and we have described the challenges that need to be dealt with in order to strengthen interdisciplinarity. In addition, we have placed a focus on foreign experiences in order to harvest the experiences of how the best knowledge and educational communities work with interdisciplinarity and the benefits they derive from it.

This study is among the most comprehensive in this field in an international context. It builds upon the following data:

- A mapping of interdisciplinarity among 700 Danish research and educational communities, a review of 400 research projects under the Danish research councils and 600 educational programs in Danish research and higher educational institutions.
- The establishment of an Index of Interdisciplinarity for research and educational institutions; the index measures the intensity of interdisciplinarity.
- A mapping of the challenges posed by interdisciplinarity, plus the barriers to and experiences of interdisciplinarity among a panel of 120 key decision-makers within the Danish research, education and the business communities.
- Documentation and interviews from 10 foreign research and educational institutions that work intensely with interdisciplinarity in research and education, in areas which are business-oriented and new in a Danish context.

Methodology



Source: DAMVAD 2008

1 ON THE WAY TOWARD INTERDISCIPLINARITY

1.1 KNOWLEDGE ACROSS BORDERS CREATES VALUE

Fewer and fewer people are producing the basis for Denmark's future welfare and prosperity. We therefore need to think of new, alternative ways by which we can utilize our professional competencies in the best and broadest possible fashion. We must be smarter, where other countries are cheaper.

It is therefore important that barriers to interdisciplinarity be removed if we are to create a world-class research and education system. Research and educational systems which have not sufficiently targeted interdisciplinarity risk losing their research potential, falling behind with research and losing many of their most innovative researchers and brightest students. If Denmark is to follow the Government's visions and create research and education of a world-class level, it is not enough to create larger and stronger research communities and institutions of higher education.

There is also a need for the Danish institutions to become better at thinking in new ways and dare to cross existing academic disciplines in order to research new terrain and thereby create fundamental breakthroughs in the intersection between the sciences.

In this sense, there is a need for all types of competencies and knowledge which cut across disciplines which traditionally do not meet. Today we face a great many social challenges, such as climate and environment, the burden of an aging population, demands for better and more health and increased globalization. These are challenges for which we do not always have the answers at hand just now, but which we can address in the future by thinking across economics, technology, branding, cultural understanding, natural science, design, medical sciences, IT, language and innovation.

A report from the Danish Business Research Academy, entitled "When Social Science and Humanities Research generates profit"(November 2007), has shown that firms are intensively searching for and need knowledge about competencies within these areas. New thinking and innovation often occurs in the intersection between existing competencies and knowledge and in the encounter

"It needs to be stated clearly - because it is often overlooked - that good interdisciplinary research can happen only when it is done by disciplinary experts, who remain leaders in their fields".
Keith Devlin, Stanford University

between persons with different professional backgrounds. Firms are therefore seeking out knowledge workers who possess the ability to think across disciplines and to work together with others on common goals and tasks.

In recent years, universities within the leading, international environments have undertaken several initiatives intended to strengthen their interdisciplinary education and research. This is the case, for example, in the communities around Silicon Valley in California, and in Cambridge in the UK. These initiatives have helped create the foundation for these communities to enter the front line of research quality, level of education and obtaining value from research in the form of patents, licenses and knowledgebased products and services.

Interdisciplinarity, however, is not a goal in itself. It is a means of strengthening research and education and to solve specific societal and business problems, which in the final analysis can enhance business competitiveness. This occurs by importing knowledge from one area into another, or by setting up new research fields that integrate knowledge from different areas.

The objective of strengthening interdisciplinarity is therefore:

- To create more quality in research and to contribute to solving new problems which cannot be solved within the individual disciplines alone. New and exciting advances in knowledge come when we cut across disciplines.

- To ensure better educational programs, which give students better ability to work in a problem-oriented way and at the same time the ability to think across fields and interact.

- To strengthen the interaction between the business sector and research, especially in relation to the humanities and social science research and education, where interaction has been especially underdeveloped.

In sum, the objective of interdisciplinarity is to create strong research and educational institutions and graduates with strong competencies, so that we can manage in the global competitive environment and provide firms with the knowledge they need.

Nevertheless, there exist numerous barriers to interdisciplinarity, in our research institutions, in the research councils and in the educational system. The most important challenge is the way in which we structure the public knowledge production, where research councils tend to allocate funds to monofaculty and monodisciplinary units and the way in which we train young researchers, create career paths for researchers, train university students and others in the higher education system. This means that visionary, interdisciplinary projects and educational possibilities run the risk of falling between the gaps, so that Denmark loses its potential to develop knowledge and competencies.

From prior experiences, we know that the establishment of new research and educational communities is a long, arduous task. It takes time, and it is therefore important to begin now with major initiatives. Similarly, there are significant challenges facing research and educational policy actors in supporting and financing interdisciplinary research and education. With regard to research, interdisciplinary research often concerns coopera-

tion between researchers, firms and others; the participants in a project may have quite different professional backgrounds. It will therefore take longer time to build up common learning, experience and methods in interdisciplinary projects than in projects where the participants know each other's areas and research fields.

We lack considerable knowledge about interdisciplinarity in research and education, even though we now have a growing literature in this area. Increased knowledge and facts about interdisciplinarity in research and education is a necessary precondition for our being able to speak in a qualified way about the extent, barriers and challenges posed interdisciplinarity in research and education policy. A key goal of this report is to generate a significant base of knowledge in order to elevate the debate about interdisciplinarity in research and education in Denmark.

1.2 INTERDISCIPLINARITY REQUIRES WORLD-CLASS RESEARCH AND EDUCATION

Interdisciplinarity is not synonymous with poor quality, or that knowledge must be downgraded or lacking in-depth knowledge. On the contrary, interdisciplinarity must be based on well-founded professional expertise. It is not about the individual researcher or student having learned, known experienced a little bit of everything. Interdisciplinarity that sustains quality must be based upon the researcher or the student combining several different disciplinary areas in new and value-creating ways, such that it solves complex societal problems where there is a need for differentiated knowledge and competence.

In other words, there is a need for both monodisciplinarity and interdisciplinarity. It is not an 'either…or' situation but a 'both…and'.

There is often a close association between interdisciplinarity and elite and excellence. Progressive, interdisciplinary research is dependent upon strong and specialised basic research. The disciplinary immersion within one research field contributes to an interest in importing or integrating methods or approaches from this research field into other fields. An important conclusion in the large-scale EU-based project in interdisciplinarity, the MUSCIPOLI project[2] from 2002, points precisely to the fact that interdisciplinarity requires strength and high quality within the individual disciplines.

1.3 INCREASED NEED FOR INTERDISCIPLINARITY

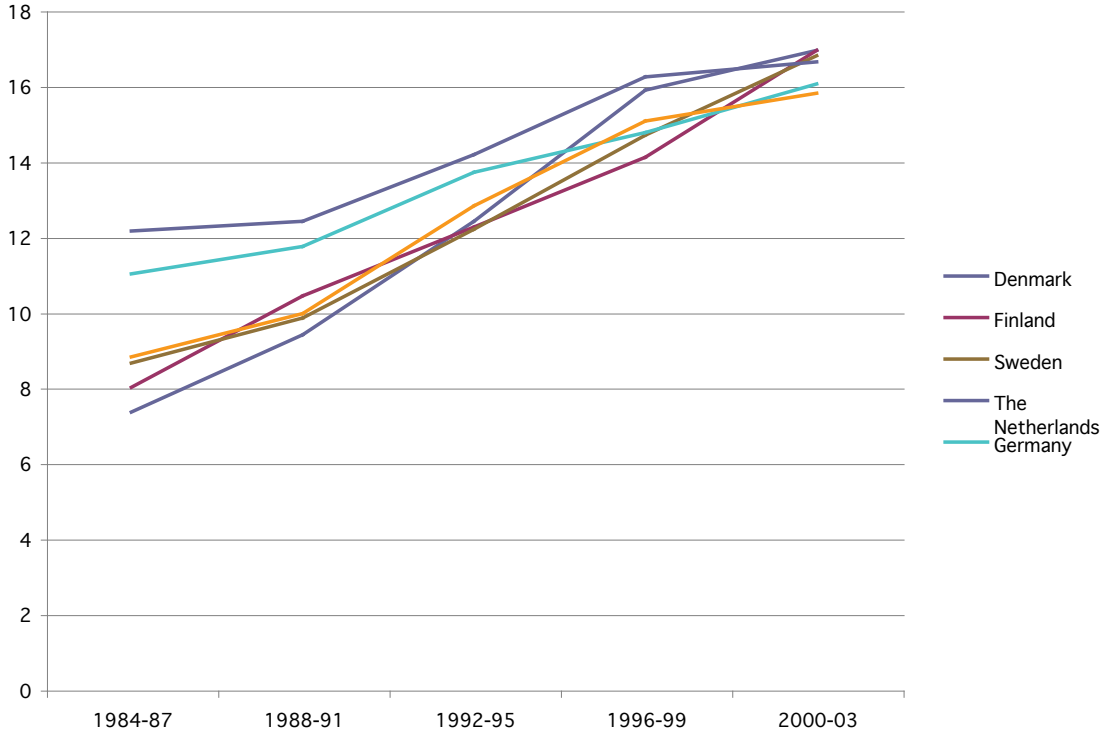
Interdisciplinarity in research and education is not a new phenomenon. Many of our present-day research areas and educational programs were formerly derived from the need to think in an interdisciplinary way, e.g., nanotechnology, genome research, bioinformatics, neuroscience, conflict research, terrorism research, etc.

In the same way, there are many innovative technologies and products and path-breaking knowledge which would not have been developed today without crossing disciplinary boundaries and cooperation across disciplines. This applies, for example, to the discovery of DNA, magnetic resonance, laser treatment, windmill technology, the America moon landing and e-commerce.[3]
At the same time, students are showing an increasing interest in working with large, interdisciplinarity themes such as globalization, environment, social inequality, economic development, combating disease, etc.

Measured by the output of research articles, many countries, including Denmark, have exhibited a growing interest in publishing in

2) See 'The Design and delivery of inter- and pluridisciplinary research', Dansk Center for Forskningsanalyse, 2002
3) See 'Facilitating Interdisciplinary Research', National Academy of Sciences, 2005

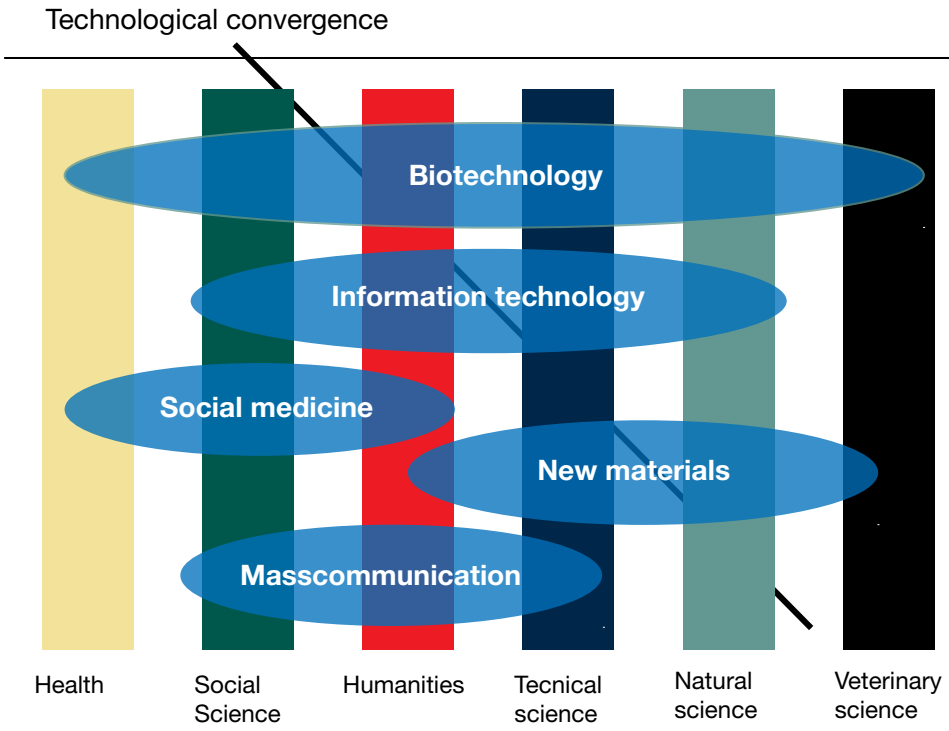
Fig.1.1 Articles catagorized as interdisciplinary as a proportion of the total number of publised articles (in percent) throughout selected countries



Source: 'Tvärvetenskab – en analys', Vetenskabsrådet (Swedish Research Council), 2005

journals which are classified as interdisciplinary, see figure 1.1.
In the future, there will be an increased need to think across disciplines. Figure 1.2. illustrates the new fields which we can expect will increasingly draw upon research within several different disciplines.

Fig.1.2 Interdisciplinarity solves the challenges in society



Source: DAMVAD, 2008, adapted from the 2002 CFA report, 'The Design and Delivery of Inter- and Pluridisciplinarity Research'.

Biotechnology is a good example of a new research field which draws upon existing research within health, social science, humanities, technical sciences, natural science and veterinary science. Information technology is now also a new research area which draws upon social science, humanities, technology, and the natural sciences. Traditionally the technical sciences have dominated information technology, but with the inclusion of other academic disciplines, further insights can be obtained.

In the intersection between health, social sciences and the humanities lies the new research field of social medicine. Formerly, researchers within medicine had to acquire knowledge of the relationship between health and society on their own. Today, this research has been improved by drawing on specialized knowledge from the three disciplines, which among other things benefits research that seeks to combat disease.
In addition to these trends, we see a cross-cutting tendency with techno-logical convergence between the various generic technologies. We can observe an increasing interaction among fields, disciplines and technologies, where the interdisciplinary becomes more complex because more fields and more generic disciplines are being brought together.

1.4 FORCES PROMOTING INTERDISCIPLINARITY

It is difficult to point to a single driving force behind the need and mecha-nism driving the increasing degree of interdisciplinarity in research and education. However, we can point towards at least four areas which can help explain these developments.
First, we see new conditions for business, with globalization and increased competition over knowledge and the best talent. Business is changing rapidly, and the rate of innovation is increasing under the strong effect of a great many strongly intervening factors; new market requirements and new customer demands, the fusion of once separate sectors such as ‘service engineering’, converging requirements for skills, new information and communications technologies, demographic changes, shortage of qualified workers and ruptures in established cultures and norms. These challenges constantly demand that many firms think in terms of new, interdisciplinary educations and research.

Second, there has occurred an increased democratisation of knowledge, where more actors than previously participate in the production of knowl-edge and competencies. We are in an entirely new, modern form of knowledge production, where the creation and use of knowledge is no longer seen as a linear process, where knowledge is created in isolated form by researchers in public research laboratories and then immediately applied in private firms.

Today there is a need for cooperation across boundaries, not only of institutional boundaries, but also across disciplines, sectors and professional areas. It should be recalled that research does not come solely from the universities. The business community is also a producer of knowledge and knowledge development, among other things in close interaction with publicly-financed research. This means, for example, that today’s most advanced research institutions and firms have a great focus on ‘open’ innovation, strategic alliances and synergy potentials with the strongest knowledge communities in the world.

Third, there is an increasing desire on the part of society that our investments in research and education create the greatest possible

social utility. This demand is one of the most essential principles in the Danish government's globalization strategy.

Within Danish government's demand lies the desire that research and education must contribute to solving societal problems and meeting challenges, within areas such as environment, energy, health, communication and cultural understanding. These problems are so complex that there is a need for cooperation and thinking across the traditional disciplinary lines if they are to be solved. An increased use of interdisciplinarity within research and education is an absolutely essential precondition here. Firms can contribute to solving these tasks, which in themselves necessitate increased demand for interdisciplinary competencies in the business community.

Fourth, there is now an increasing business-oriented focus on social sciences and the humanities. There is today increased demand for research-based knowledge and intelligent, highly educated graduates within the humanities and social sciences. This is shown, for example, in the development of the Danish Industrial PhD Program[4]. At the same time, the public investments in research and education in recent years have increased significantly, e.g., admissions of students to social science programs have increased by 15% from 2003 to 2007.

It is important that these investments in the humanities and social sciences yield the greatest possible profit and create increased basis for innovation and competitiveness in business. It is absolutely essential that the cooperation between the scientific disciplines achieves a central posi-tion.

1.5 TIME FOR ACTION

Denmark is not the only country in the world which can derive benefit from increased cooperation across academic disciplines in research and education. Interdisciplinarity is on the agenda internationally, and many countries and international organizations have already conducted analyses and formulated strategies in this area, making interdisciplinarity into a key part of their research and education policies.

Box 1.1 Recommendations from the European Research Council

In 2004, the European Commission's advisory committee for research policy (EURAB) issued a report on recommendations for the relaxation of barriers to interdisciplinary research and education in Europe. The report points out the following recommendations for supporting increased interdisciplinarity in research and education in Europe In 2004:

- Greater interdisciplinary bridges between the disciplines and basic education, among other things, more possibilities to complete coursework under other disciplinary subjects.
- Less overspecialization at the Ph.D. level
- Establishment of an interdisciplinary Ph.D. at the EU level, e.g., the Business Ph.D.
- Establishment of physical interdisciplinary research centers
- Better methods and systems within the research system for assessing and evaluating interdisciplinary research projects and research teams.

Source: Interdisciplinarity in Research, EURAB, April 2004:

4)The Danish Industrial PhD is an industrial research project. The student is employed by a company, and timeshares 50/50 between the university and the company. Approximately 50 % of the company's expenses are reimbursed by the Ministry of Science, Technology and Innovation. The student is enrolled in a Ph.d. graduate school at a University, with the same requirements as for an ordinary Ph.d. plus a business course and a business report. The purpose of the Industrial PhD programme is to educate scientists with an insight in the commercial aspects of R&D, increase R&D and innovative capacity in private companies and to build networks disseminating knowledge between universities and private companies

As concerns educational programs, the European ministers of education, meeting in Berlin in 2003 as part of the Bologna process, issued a communiqué on how a common European educational area could be achieved. Emphasis here was placed upon the inclusion of interdisciplinarity as a key part of the educational developments in Europe with the intention of improving quality in higher educations in Europe.
If we examine individual countries, as shown in box 1.2., the United States, Sweden, Finland and Norway have in recent years formulated clear analyses and strategies for strengthening interdisciplinarity as a key part of their research and education policies.

Box 1.2 Strategies for interdisciplinarity in other countries

- National Academy of Sciences (USA) 'Facilitating Interdisciplinary Research' 2005
- Reserch Council of Sweden 'Tvätvetenskab – en analys', 2005
- Academy of Finland 'Promoting Interdisciplinary Research', 2005
- Resarch Councl of Norway 'Trenger vi nye former for tverrfaglighet og samspill', (Do we need new forms of interdisciplinarity and interaction), 2006

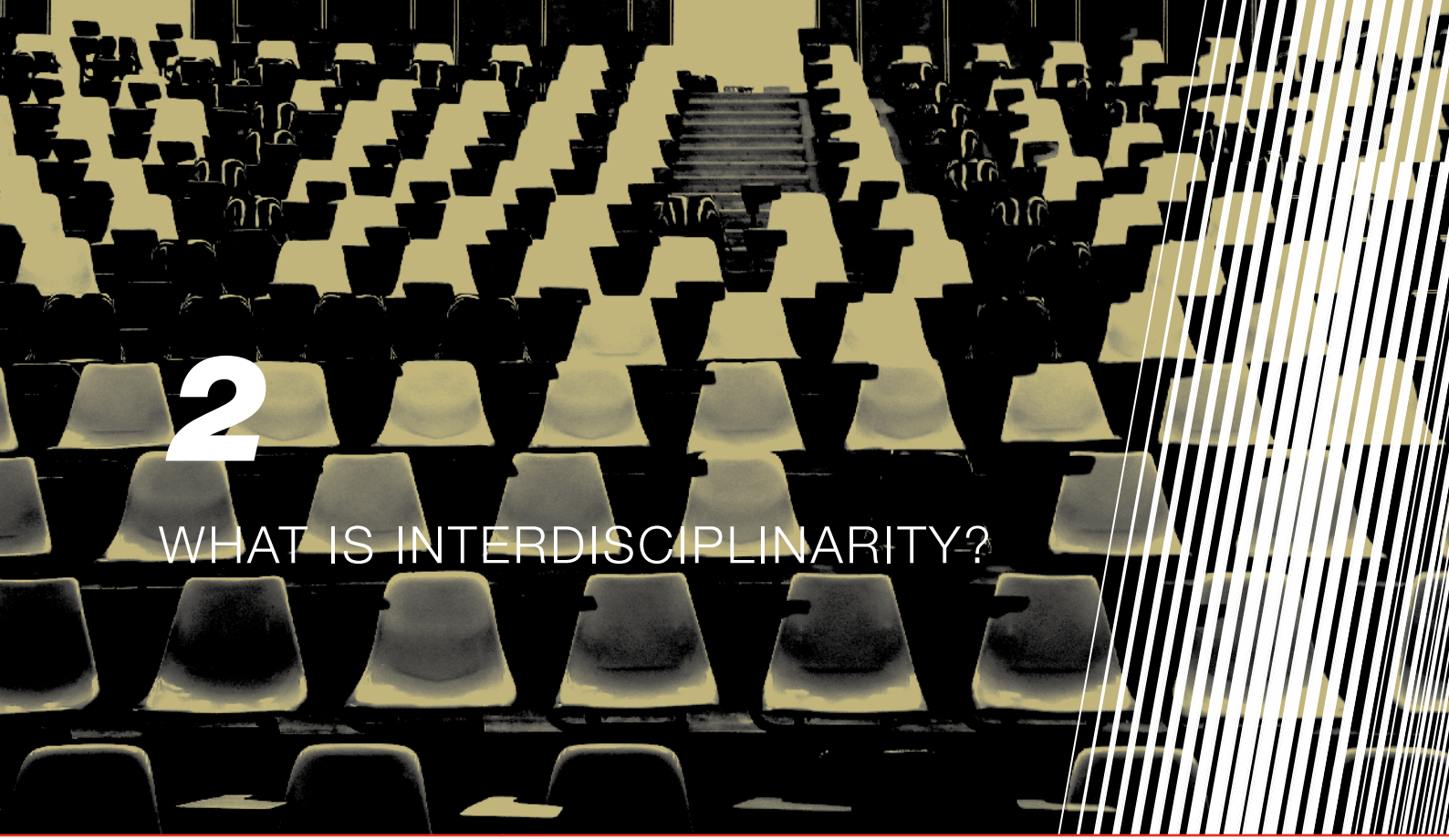
Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

Denmark has not yet seriously placed interdisciplinarity high on its research and education policy agenda. It is important that Denmark, in line with other countries, also places interdisciplinarity as a central strategic part of our research and education priorities and initiatives in the coming years if we are not to fall behind the world's leading knowledge nations.

Implementation of the Danish globalization pool[5] over the coming years, the new plan of action for strategic resource ('Forsk 2015'), the development of new private sector-oriented education programs at the professional bachelor degree, and the environmental debate and follow-up to the forthcoming international environment summit in 2009, to be held in Denmark, are all obvious areas where we ought be putting extra strategic effort on enhancing interdisciplinarity. Similarly, there are great possibilities in increased focus on interdisciplinarity in connection with the merging of educational institutions and departments now going on in the universities and at the professional colleges and in view of the declaration by the Future Panel of the Ministry of Science regarding the need to revise and create more coherence in the research council system.

We thus have a good point of departure and potential for change. The time is right that we begin to think in a visionary fashion. Now is the time for us to undertake the necessary quantum leap which creates the necessary changes.

5) The Danish globalisation pool is for investment in research, education, innovation and entrepreneurship. The pool is to be built gradually to end at EUR 2 billion in 2015. From the pool's funds approximately half is to be allotted to research and development to help Denmark reach the goal that 1 per cent of the GNP in 2010 is to go to public research



2 WHAT IS INTERDISCIPLINARITY?

2.1 THE NEED FOR A COMMON UNDERSTANDING

Interdisciplinarity has been on the international agenda for many years. Internationally, there is broad agreement about the need to promote interdisciplinarity in research and education, and the concept of interdisciplinarity has been the object of a lively academic discussion.

Within the research and education communities, there exist different attitudes toward interdisciplinarity. For some researchers, monodisciplinary research will be more prestigious than interdisciplinary research, just as working in basic research has tended to have more prestige than working with applied research and development work. Conversely, there are parts of the research and education world where interdisciplinary cooperation is a natural part of one's way of working. Outside the universities, especially within the innovation-oriented research and development centers and among political decision-makers, there has been greater focus on promoting cooperation between disciplines and subjects, whereas the universities have been more reserved.

There are many who speak about interdisciplinarity, but there is a need for a common understanding of the concept if we are to make it an area of strength. Today there is a certain conceptual confusion which can hamper our understanding of what 'interdisciplinarity' means.

In order to establish a framework for a debate and understanding of what interdisciplinarity is, it is necessary to distinguish between different forms of how different disciplines and topics and interact. In the following, we present a definition of interdisciplinarity which is often presented in the existing literature within research and education. In this context, we explain how this study elucidates interdisciplinarity in research and education, in that it is the basis for the analyses that carried out in this report, including the interviews, assessments of interdisciplinarity in research and education and the Index of Interdisciplinarity.

2.2 WHAT IS INTERDISCIPLINARY RESEARCH AND EDUCATION?

Before we examine the definition of interdisciplinarity, it is necessary to examine what it is that characterises a 'discipline'. In the literature, it is pointed out that a research community operates within a discipline if their research and working methods are based upon shared perspectives, theories, methods and research fields. An important argument for working or educating oneself within one specific discipline, i.e., monodisciplinarity, can be that it gives the possibility for specialization, and that one becomes an expert within one area.

In practice, disciplines will express themselves in the way research and education is organised, and in university faculties, departments, centers, internal grants, in advertisements for open positions, in incentive structures, educational programs, research councils, career paths, credit systems, publications, etc. The organization of research and education into monodisciplinary frameworks will typically have a tendency to reinforce and maintain such frameworks.[6]

It is customary to divide the main scientific areas or disciplines into six branches: natural sciences, technical sciences, health sciences, agricultural and veterinary science, social sciences and the humanities. In terms of educational areas, specific educations could be classified within the same disciplines and could build upon elements based on these differences, e.g., education in physics (natural sciences) or economics (social sciences).

Interdisciplinarity exists when disciplines mix with and encounter each other, and when different perspectives, methods and academic areas intersect with each other.
In the literature, two forms of interdisciplinarity are described:

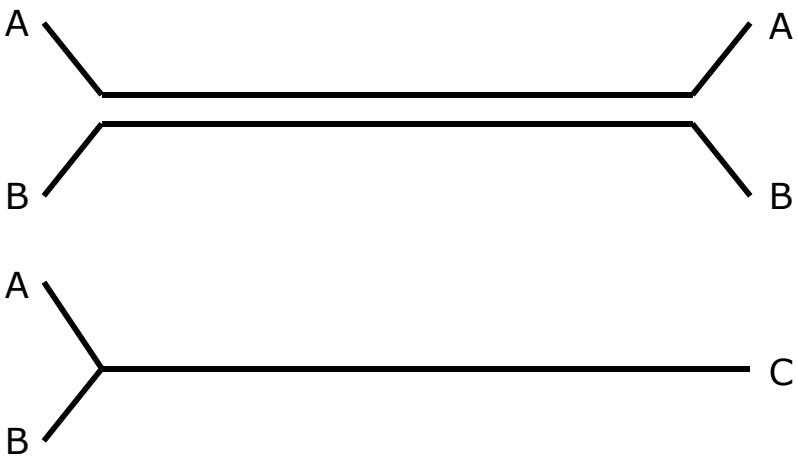
• *'Multidisciplinary'* research and education. This is research cooperation between participants with different disciplinary backgrounds. Each participant contributes to the research with the point of departure in their own disciplinary expertise. Cooperation often takes place by the different disciplines solving separate tasks in one common project, but without the disciplines losing their individual identity. This approach can be transferred to the field of education, where one educational program contains subjects from different fields without these being integrated into a single new educational area.

• *'Interdisciplinary'* research and education. Here it is a case of research cooperation which not only entails a common research topic and some degree of synthesis, integration or fusion of the methods, theories and concepts of different disciplines. Applied to the educational system, an interdisciplinary approach would entail the establishment of entirely new educational programs on the background of synthesis, integration, etc. by different academic fields.

6) See 'Promoting Interdisciplinary Research: The Case of the Academy of Finland', Academy of Finland, 2005.

The two forms of interdisciplinary knowledge production are illustrated in figure 2.1 below:

Fig. 2.1 What is interdisciplinarity?



Multidisciplinarity:

"Join together to work on common problem, split apart unchanged when work is done."

Interdisciplinarity:

"Join together to work on commen problem. Interact may forge a new research field or discipline."

Source: National Academy of Sciences, USA, 2004.

It frequently occurs that 'multidisciplinarity' and 'interdisciplinarity' are brought together under the common label of 'cross-disciplinary' research and education. The concept 'cross-disciplinary' seems to be the most well-suited, if one wishes a broad understanding of research across disciplines without specifying the extent of integration between the involved disciplines.
'Even though the term 'cross-disciplinary' seems to be the most general label for the various types of cooperation across academic disciplines, the term is the least used internationally. While 'interdisciplinarity' has its conceptual weaknesses, it is also the most frequentlyused term to describe cooperation across disciplines with a goal of synthesis. We will therefore, in this report, use this term as a label for cooperation across disciplines in research and education, and the reader may regard it as a synonym for 'cross-disciplinarity'.

2.3 DESCRIPTION OF INTERDISCIPLINARITY IN PRACTICE

In practice, it is not an easy task to describe the different forms of inter-disciplinarity in research and education. However, a crucial requirement for elucidating the scope and challenges posed by interdisciplinarity within research and education is that it is possible to classify research into distinct disciplines. In this study, we therefore take the point of departure in the classification of six scientific branches as carried out in the Danish Research Statistical Database (Forskningsstatistikken); see table 2.1. The six

main branches are natural science, technical sciences, health sciences, agricultural and veterinary science, social science and the humanities. Under these six main areas are several sub-areas, making it possible to further sub-divide research and education into different disciplines.

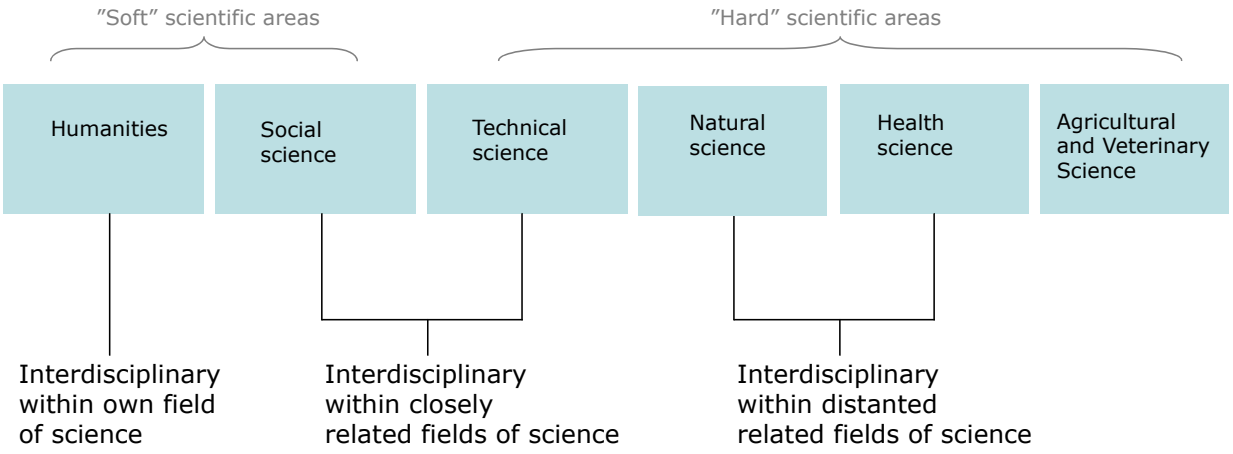
In practice, we can speak of interdisciplinarity if a research activity cuts across the different scientific branches. The degree of interdisciplinarity is greatest if the research activity contains scientific disciplines within the 'soft' scientific areas, i.e., social sciences and humanities, together with the 'hard' scientific areas, i.e., the technical/natural science disciplines.

In this report, we distinguish three types of interdisciplinarity in research and education:

- Interdisciplinarity within the main field
- Interdisciplinarity across closely related fields
- Interdisciplinarity across distantly related fields

Figure 2.2 gives examples of the three levels of interdisciplinarity in research and education:

Fig. 2.2 Examples of the three levels of interdisciplinarity



Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

This report is based on comprehensive analytical work which builds upon new knowledge and documentation of interdisciplinarity among Danish research communities and education programs. The report is among the most comprehensive surveys of this field in Denmark and in an international context. The determination of interdisciplinarity into three levels, as described above, forms the basis for the analyses carried out in this report.

The data for this analysis is based upon the following:

- A mapping of interdisciplinarity among 700 Danish research and education communities, a review of 400 research projects supported by the Danish research councils and a review of 600 educational programs in Danish institutions of research and higher education.

- Establishment of an Index of Interdisciplinarity for research and education institutions which measures the intensity of interdisciplinarity.

- A description of the challenges posed by interdisciplinarity, as well as barriers and experiences of interdisciplinarity among a panel of 120 key decision-makers within the Danish research, education and business communities.

- Experiences and interviews from 10 foreign research and education institutions that work with interdisciplinarity in their research and education in areas which are business-oriented, and which are new in a Danish context.

Internationally, there are several studies which elucidate the extent of interdisciplinarity in various countries; see box 2.1. Such studies are new in a Danish context. The studies conducted abroad show that there are many ways to describe interdisciplinarity in national research systems and in educational programs. In general, attitude surveys are used (questionnaires and interviews) or a description of research production (bibliometric data, e.g., publications and citations) or an analysis of research grants (e.g., from research councils) by type of grant. This Danish study builds upon several of these methods and data types. In addition, an important new element in the study is that it incorporates data from research statistics from the public sector in order to elucidate the research institutions' use of research resources in different scientific disciplines. These data are based on the research institutions' own reporting of research statistics for 2005.

Box 2.1 Foreign surveys of interdisciplinarity

Korean study from 2003. The study shows that 35.6% of applications from individual researchers and 54% of the applications from research teams to the Korea Science and Engineering Foundation (KOSEF) are interdisciplinary.

Academy of Finland, 2005. The survey shows that 42% of the applications to the research council that were awarded grants are interdisciplinary; 28% and 14% of the applications, respectively, are 'narrowly' and 'broadly' interdisciplinary.

Netherlands study from 2001. The study shows that within the field of physics, 36% of research articles were classified as interdisciplinary.

Netherlands study from 1997. The study shows that 76% of research articles within all research areas are written as a cooperative endeavour among several researchers. A third of these articles are interdisciplinary.

Swedish study from 1999. The study shows that 68% of the applicants to the technical science research council and 53% of those applying to the medical and natural science research council considered their research to be interdisciplinary.

Spanish study from 2001. The study shows that four-fifths of the research groups within the health sciences and materials sciences indicate that they use knowledge from other disciplines and that they continually monitor journals from other fields.

British study from 1999. In the survey, researchers indicate that 46% of their time is used for interdisciplinary research.

Study from the Swedish research academy from 2005. The study shows that 42% of the applications to the Swedish Scientific Research Council are interdisciplinary.

Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

In the Appendix, Chapter 8, we present further discussion and explanations of the methodology used in the analyses which form the basis for this report. This applies to the analyses concerning the description of interdisciplinarity, the development of the Index of Interdisciplinarity and the calculations used for the index, as well as the questionnaire survey.

Table 2.1 Classification of professional disciplines: six branches within research and education.

'Hard sciences'	'Soft sciences'
Natural science	***Social science***
Mathematics	Law
Computer science	Political science/administration
Physics (incl. biophysics)	Macroeconomics
Chemistry	Business/economics
Biochemistry	Development studies
Biology	Sociology
Geology, Physics, Geography	Social anthropology/ ethnography
Other natural sciences	Urban and physical planning
	Technology assessment
Technical sciences	Other social sciences
Materials	
Machine construction and production technology	***Humanities***
Electronics, electrotechnology and communication	Music studies
Building, construction and transport	Art and architecture
Bio- and chemical technology	Film and media studies
Apparatus technology	Literature and drama
Energy technology	Linguistics and philology
Environmental technology and pollution control	Philosophy and history of ideas
Other technical sciences	Theology
	History
Health sciences	Archaeology
Biomedicine	Anthropology/ethnography
Clinical health sciences	Pedagogy
Social medicine	Psychology
Dentistry	Other humanities disciplines
Pharmacy, pharmacology	
Other health sciences	
Agricultural and veterinary sciences	
Agricultural plants	
Gardening and horticulture	
Forestry and landscape plants	
Vegetable production	
Veterinary science	
Cattle	
Swine	
Other domestic animals	
Animal production	
Human nutrition	
Food technology	
Agricultural, horticultural and forestry technology	
Agricultural economics	
Other agricultural and veterinary sciences	

Source: Danish Centre for Studies in Research and Research Policy (CFA) Research statistics

3 INTERDISCIPLINARITY IN RESEARCH AND EDUCATION INSTITUTIONS

3.1 KNOWLEDGE INSTITUTIONS ARE IMPORTANT ACTORS FOR INTERDISCIPLINARITY

The universities, the sector research institutions, the university colleges and engineering colleges are important actors in the production of knowledge in our society. With over two-thirds of the publicly-financed research, the universities carry out the major part of knowledge production among the institutions of knowledge. These institutions therefore play an essential role in promoting interdisciplinarity in research. They do so through the way in which they organize their research and by helping to give the proper incentives for interdisciplinary cooperation to the individual researchers and research groups.

With the reorganisation of the Danish universities in 2006 and 2007, which led to the establishment of fewer and larger universities, and where a great deal of the sector research institutions were merged with the universities, a healthy foundation has been created for strengthening interdisciplinarity in research and education.

Similarly, with the establishment of eight multidisciplinary professional colleges, in which each was joined with the existing Centers for Higher Education, and other educational institutions, better preconditions for increased interdisciplinarity have been created. But this does not mean that the educations and research are really or will become more interdisciplinary. This demands stronger incentives directed toward the individual educational administrators, researchers and research units.

At the same time, several institutions have begun to focus on interdisciplinarity in their strategic work; e.g., in several of the universities' development contracts, there is a focus on interdisciplinary problems and areas. However, the question remains as the degree to which these goals have been implemented in practice in the institutions. Proper organisational frameworks and a goal-oriented administrative focus are required in order to create fruitful conditions for interdisciplinary education and research.

This report has taken the pulse of the Danish knowledge institutions' research and education activities. The data show that many knowledge institutions, in both research and education, have become aware of the po-

"The world has problems, the university has departments. But: How to translate "real world" problems into scientifically feasible as well as scientifically atractive problems?" Helga Nowotny. Vicepresident for the European Research Council, ERC

tentials of strengthening interdisciplinary research and education, but much fewer have taken serious initiatives to exploiting these potentials so that interdisciplinarity becomes a part of their daily production of knowledge. This applies especially to the type of interdisciplinary cooperation where the researchers come together bringing with them very widely differing competencies regarding the solution to a problem, e.g., researchers within the social sciences, humanities, natural sciences and technical fields.

3.2 THE EXTENT OF INTERDISCIPLINARITY IN THE RESEARCH INSTITUTIONS

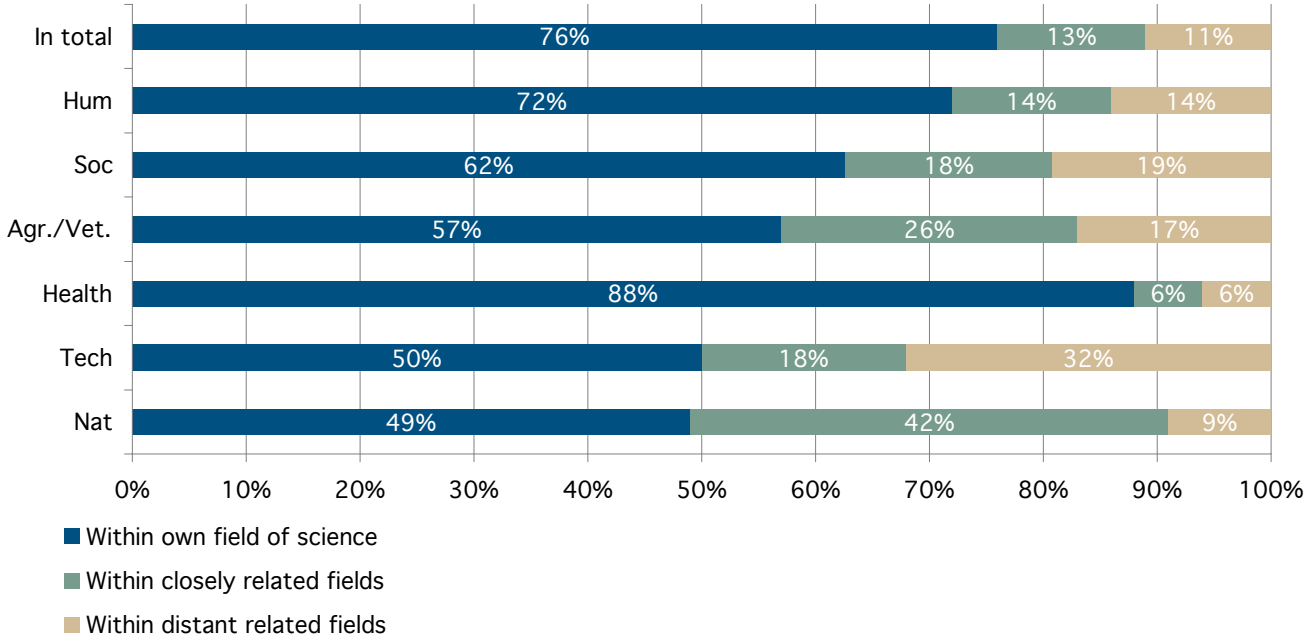
There has not been any registration in Denmark regarding the degree to which the use of research and development funds has interdisciplinary scope or potential. Therefore, we know very little about how much interdisciplinary cooperation occurs in research and development within Danish research and educational institutions.

This report, the first of its kind in Denmark, will seek to shed light on the extent of interdisciplinary research in Danish research and education institutions. The study has covered 700 Danish research and education communities, institutes and research departments and examined the re-search areas on which these communities base their research and development activities.

The research communities in the study vary in size, but common to all of them is that they have some registered research and development activity. Some of these communities do research within one or very few research areas, e.g., natural science, while others include many fields in their research, e.g., natural science, health sciences, social sciences and humanities. The research communities which include many disciplines cutting across distantly-related fields are classified in this study as 'radically' interdisciplinary, cf. Chapter 2 on 'What is interdisciplinarity?' The description of interdisciplinarity is based on the institutions' own reporting, as entered/gathered in the research statistics for the public sector in 2005. In international terms, these data represent a new way of calculating interdisciplinarity. The institutions covered include the universities, sector research institutions and other institutions carrying out research and development activities, such as (research) hospitals, museums, professional schools and engineering colleges. Nearly half the institutions fall within the health field and consist mainly of university-affiliated hospital units.

The main finding of this study is that interdisciplinary research is relatively widespread among research and education communities in Denmark, see figure 3.1. below. About one-fourth of the communities work in areas which lie outside their own disciplinary area. However, less than half of these communities work with areas that are scientifically 'distant' and which crosscut hard and soft areas. As such, only about every tenth of research and education communities in this study can be characterized as 'radically interdisciplinary', i.e., working, for example, within the humanities and social sciences as well as natural and technical sciences.

Figure 3.1 The distribution of institutions by field of science in relation to interdisciplinarity



Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

There remain great differences, however, in interdisciplinarity between the six main academic branches (humanities, social science, agricultural and veterinary science, health sciences, technical science and natural science). The research communities that are most interdisciplinary are found within the technical and natural sciences. About half the communities within these areas work in an interdisciplinary fashion with areas that do not lie close to their own disciplines. By comparison, this is the case for only 12% of the communities within the health sciences and 28% for research communities within the humanities.

In terms of the degree of interdisciplinarity, however, a significantly higher proportion of the communities within the technical fields (32%) are radically interdisciplinary compared to those within the natural sciences= (9%). Here both the humanities (14%) and the social sciences (19%) have a higher proportion than natural sciences, while health sciences lies at the bottom (6%).

3.2.1 THE INDEX OF INTERDISCIPLINARITY GIVES NEW KNOWLEDGE

The calculation of interdisciplinary research communities as shown above provides a good first insight into the number of interdisciplinary research and education communities in Denmark. This tabulation, however, says little about the kind of interdisciplinarity being pursued by the research community or about the depth of interdisciplinarity within the given community. For example, interdisciplinary communities that have both social sciences and technical sciences can invest

in quite different research resources in these areas.

In order to provide a fuller picture of interdisciplinarity among Danish research and education communities, we have constructed, as a part of this study, an 'Index of Interdisciplinary'.

The index takes account of those areas that are the focus of a community's research activity, how different the areas are, and especially how many research resources are invested in the individual areas; see box 3.1. An important assumption is that research and education communities that invest many resources in the different research areas are likely to integrate them into their total research effort, and that these communities can be characterized as being very interdisciplinary.

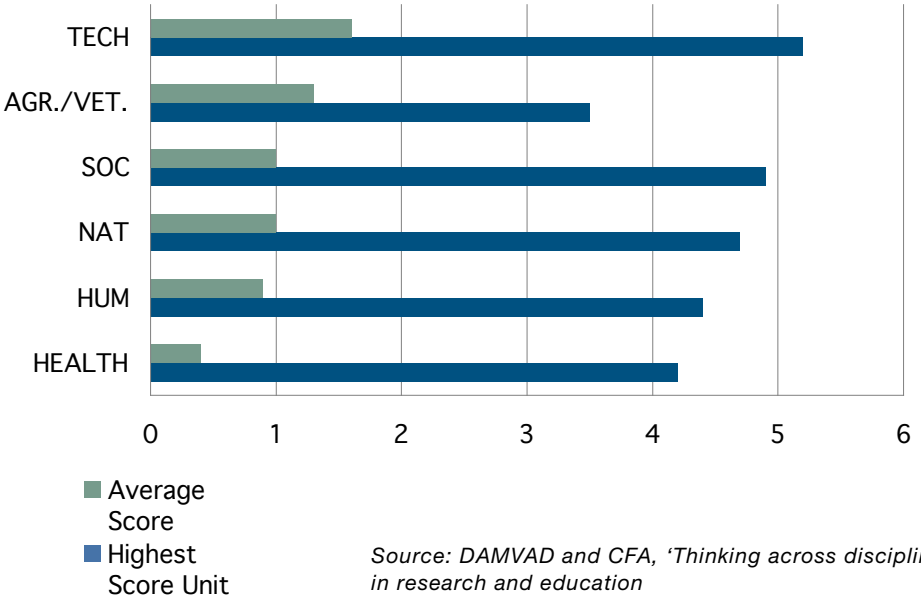
Box 3.1 What does the Index of Interdisciplinarity measure?

The index consists of three dimensions:
- Number of fields – the more fields, the higher the score on the index of disciplines.
- Difference between fields – the more different the disciplines, the higher the score on the index.
- Balance between fields – the more resources the individual department invests in each branch, the greater the score on the index.

Figure 3.2. shows the calculated index of interdisciplinarity in research. The calculation, for each of the six main branches of science, shows both the average interdisciplinarity and the highest scorer on the three interdisciplinarity criteria. In the figure, we have marked how high an index value is necessary before we can speak of different degrees of interdisciplinarity; e.g., the index value must be around 4 before we can speak of interdisciplinarity across distantly-related scientific fields.

The figure shows three main results. First, according to the calculation, there is a great difference in interdisciplinarity within the different main scientific branches. Second, within all the branches, there exist communities which are interdisciplinary across distantly-related fields. Third, all the main branches have communities with the potential for increased interdisciplinarity.

Figure 3.2 The index of interdisciplinarity in research



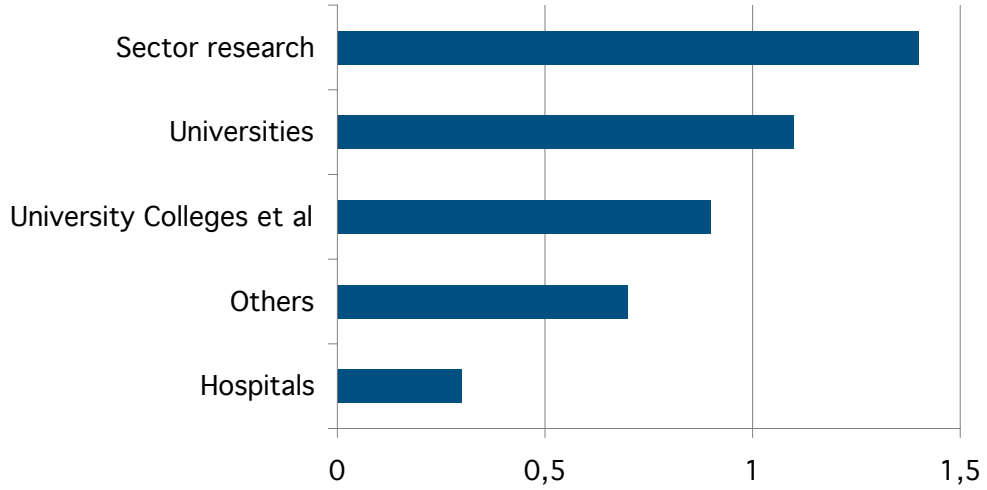
Source: DAMVAD and CFA, 'Thinking across disciplines - interdisciplinarity in research and education

As concerns the great difference in interdisciplinarity within the different areas, the average index value for interdisciplinarity within the technical fields is 1.3, versus only 0.3 for the health sciences. The calculation shows that interdisciplinarity is greater at technical institutes than among the health science institutes and research departments, i.e., those at universities, sector research institutions or other research institutions.

Concerning the high scorers on the Index of Interdisciplinarity among the different main branches, there are communities within each main branch which score so high that they indicate a degree of interdisciplinarity across distantly related disciplines. We find the highest score within technical science, where one research community scores 5.2 on the Index of Interdisciplinarity. By comparison, the lowest of the top-scoring units is within agricultural and veterinary science, where the most interdisciplinary community has an index value of 3.5. Despite its high score within its field, the agricultural/veterinary community distinguishes itself from the top scorers in other branches by being only at the lower limit of what could be characterized by interdisciplinarity across distantly related areas.

As concerns the potential for increased interdisciplinarity, the calculation shows that within all six main branches of science, there exists a potential for increasing the level of interdisciplinarity. For all the areas, there is a great difference between the top scoring unit or community and the average score for the field as a whole. This means that there is a great potential for strengthening interdisciplinarity in the more average communities, so that they can achieve the level of the strongly interdisciplinary communities.

Figure 3.3 Interdisciplinarity in relation to type of institution



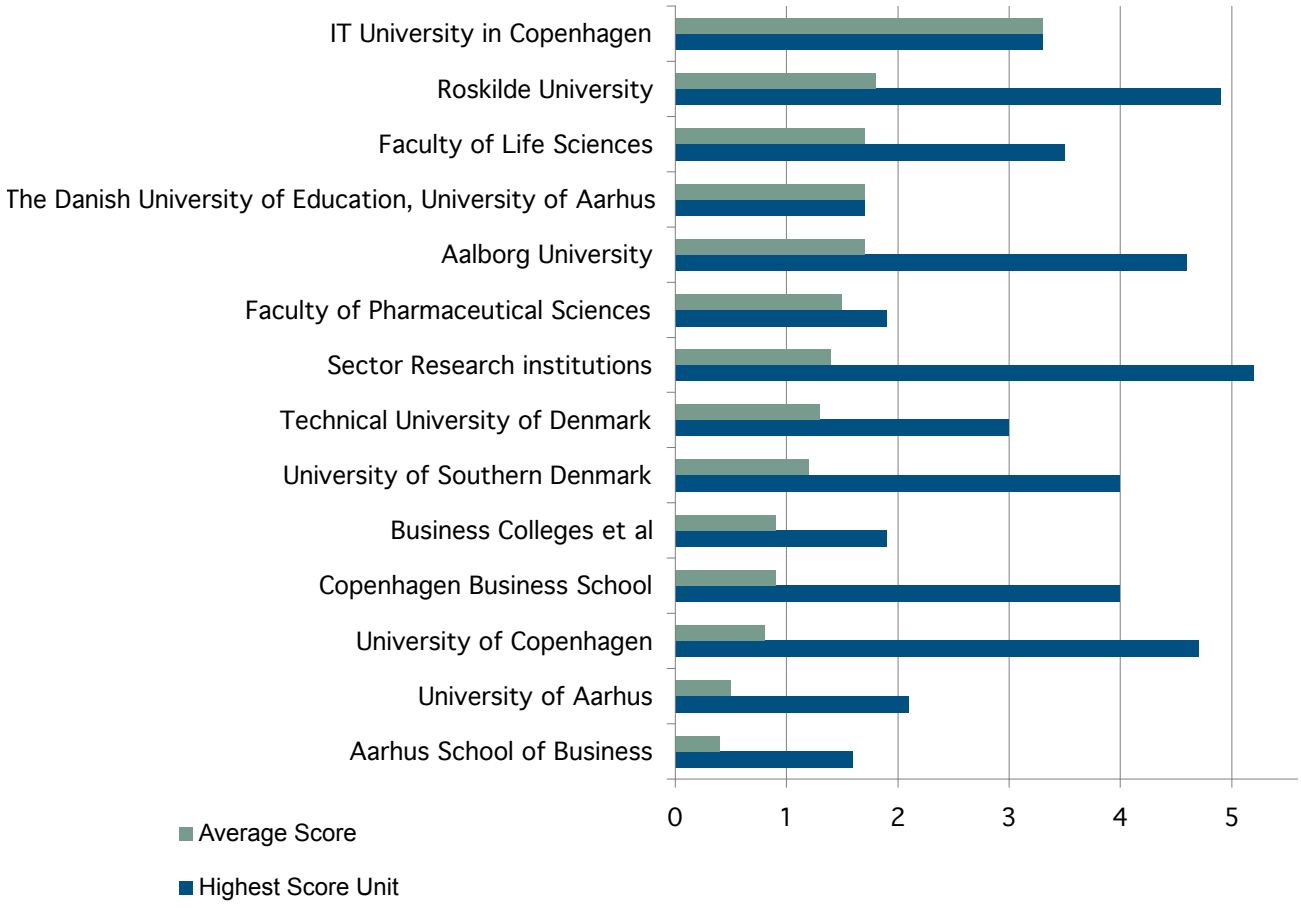
Source: DAMVAD and CFA, 'Thinking across disciplines - interdisciplinarity in research and education

Figure 3.3. shows the calculation of inter-disciplinarity according to type of research institutions. The data indicate that the sector research institutions and universities are the most interdisciplinary research institutions, while the Centers for Higher Education (now university colleges) occupy third place. The hospitals have the lowest value on the index and are thereby the least interdisciplinary institutions according to the data. The other research institutions occupy a composite fourth place with a score somewhat higher than that of the hospitals, but still lower than that of the Centers for Higher Education.

According to the calculations, the sector research institutions (which after 2006/2007 became sector research units within the universities) are the most interdisciplinary type of institution, with an index value close to 1.5. This can be explained by the fact that the sector research institutions have the mandate to carry out problem-oriented, applied research, which is to be used to address current social problems, e.g., in food, environment or energy sectors. The sector research institutions therefore work in close collaboration with the world outside the university, thus making interdisciplinarity more natural.

It is interesting that the Centers for Higher Education occupy a high rank on the index, despite their relatively lowe level of research and develop-ment activity. Nevertheless, the CVUs are the third most interdisciplinary type of institution. The explanation for this relatively high degree of inter-disciplinary activity may be that they have a close relationship with the business sector by virtue of the kinds of training they carry out.
According to the calculation, hospitals are the least interdisciplinary insti-tutions, with a score just over 0.25. Their low position on the index can be due to two factors. First, the calculation may be skewed because hospitals are smaller units and can therefore not be expected to extend over so many fields as would the universities, thus giving them a lower degree of interdisciplinarity. Second,

Figure 3.4 Interdisciplinarity in relation to institutions



Source: DAMVAD and CFA, 'Thinking across disciplines - interdisciplinarity in research and education

the hospitals work with narrow health professional problems which also make interdisciplinarity less likely.

Figure 3.4. shows the degree of interdisciplinarity in several research institutions. The calculation shows both the average score for the institution and the highest scoring group/unit within the institution.The figures show great differences in the average scores for research in-stitutions. Generally, however, there is a higher degree of interdisciplinarity in the more newly established institutions than in the older institutions.

The IT-University in Copenhagen is the most interdisciplinary institution in the index, with an average value which is higher than 3.[7] The other research institutions, by contrast, have an average index value below 2. The least interdisciplinary institution, according to the calculation, is Aarhus Business College, with a score on the index of about 0.5.

According to our calculations, there is a higher degree of interdisciplinarity in the newly established institutions, such as the IT University in Copenhagen, Roskilde University, The Danish University of Education (University of Aarhus) and Aalborg University. The explanation may be that research in these newer institutions is typically more problem-oriented than in the more traditional institutions. However, the index shows a generally low degree of interdisciplinarity in the older institutions, such as the universities of Copenhagen and Aarhus. The explanation here can be that these older institu-

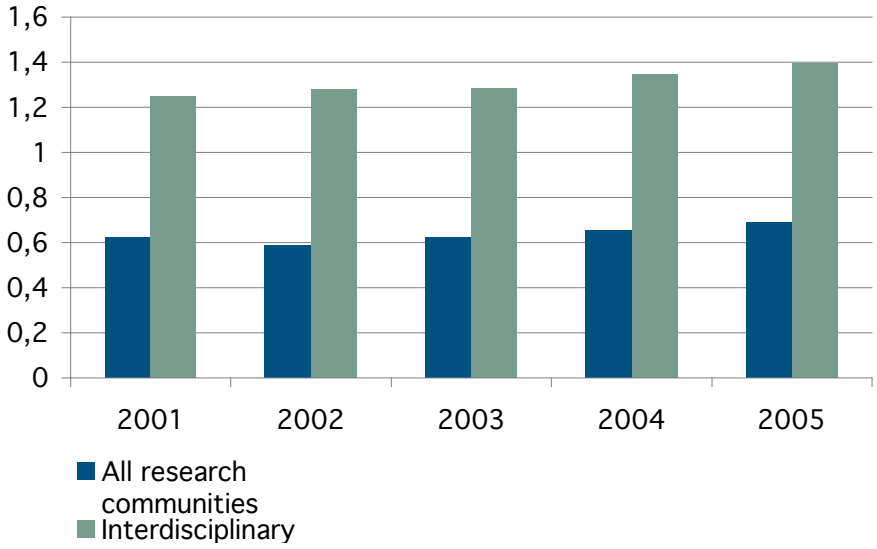
7) The average score and the high scorer are the same for the IT University in Copenhagen, as the university has reported its research area as a single unit.

tions have tended to retain the traditional division into faculties and departments.

Figure 3.5 shows the development of interdisciplinarity from 2001 to 2005. The calculation shows the development in all research communities and for specific interdisciplinary communities. According to our data from the index, interdisciplinarity the number of institutions carrying out interdisciplinary work has not increased when one examines developments in all the research communities taken together; the cumulative index score for all the years remains relatively stable, at around 0.6. There is considerable evidence, therefore, that the recent five-year period has not seen more interdisciplinary communities.

Nevertheless, the calculation shows that the currently existing interdisciplinary communities have become even more interdisciplinary, in that there is an increase of 12% in the degree of interdisciplinarity for the interdisciplinary communities. In 2001, the index value was thus about 1.2, while in 2005 it increased to nearly 1.4; see figure 3.5 below. The increase can be due to the fact that there are more interdisciplinary communities beginning research activities in areas other than those they had heretofore worked. It is difficult to say whether the increasing interest has any association with a generally increased motivation among the individual researchers or with an increased focus on the benefits of cooperation with the business community.

Figure 3.5 Development in interdisciplinarity, 2001-2005



Source: DAMVAD and CFA, 'Thinking across disciplines - interdisciplinarity in research and education

3.2.2 The most interdisciplinary research communities

Table 3.1. shows the five most interdisciplinary communities within the six main branches of science. The data show that the interdisciplinary communities are found in all types of research institutions and within all research areas. Common to all the communities is that the interdisciplinary communities all work with socially relevant or business-oriented problems.

Table 3.1 Top five research and education institutions within major branches of science

Top five institutes/departments	Institution	Index value
Natural sciences		
Department of Exercise and Sport Sciences	University of Copenhagen	4,7
IT University in Copenhagen	IT University in Copenhagen	3,3
Danish National Space Center	Danish National Space Center	3,0
Biocenter, Food Research Center	Technical University of Demark	2,7
Department of Systems Biology, Centre of Advanced Food Studies	Risø DTU, National Laboratory for Sustainable Energy	2,4
Technical sciences		
System Analysis Department	Risø, DTU, National Laboratory for Sustainable Energy	5,2
Aarhus University	Business and Engineering College, Herning	3,5
Mads Clausen Institute (MCI)	University of Southern Denmark	3,5
COM, Center for Communications, Optics and Materials	Technical University of Denmark	3,0
National Institute for Building Research		2,9
Health Sciences		
Rehabilitation and Research Centre on Torture Victims		4,2
Institute for Sports Sciences and Clinical	University of Southern Denmark	4,0
Biomechanics	University of Southern Denmark	3,4
Institute of Public Health	National Hospital of Denmark	3,1
The Neuroscience Centre, Neurology		3,0
UNI*C The Danish IT Centre for Education and Research		
Agriculture and veterinary sciences		
Center for Forest, Landscape and Planning	Royal Danish Veterinary and Agricultural University	3,5
Danish Research Centre for Organic Food and Framing (FØJO)	Faculty of Agricultural Sciences, University of Aarhus	2,4
Department of Veterinary Pathobiology	Royal Danish Veterinary and Agricultural University	2,4
Department of Large Animal Sciences	Royal Danish Veterinary and Agricultural University	2,4
Department of Basic Animal and Veterinary Sciences	Royal Danish Veterinary and Agricultural University	2,4
Social sciences		
Department of Environment, Social and Spatial Change	Roskilde University	4,9
Department of Informatics	Copenhagen Business School	4,0
Department of Development and Planning	Aalborg University	3,5
VIA University College (VITA)		3,3
Roskilde University Library	Roskilde University	3,2
Humanities		
Department of Architecture and Design	Aalborg University	4,4
Aarhus School of Architecture	Aarhus School of Architecture	4,2
School of Architecture	Royal Danish Academy of Fine Arts	4,1
VIA University College (Vita)		3,3
VIA University College (JCVU)		3,1

Note: Translator's note: the Danish word 'Institute' can cover a large academic institution or could be as small as a standard university department. Within a Danish university, each faculty would normally have several 'institutes'. Because of the merger of the sector research institutes with the universities in 2006/2007, several of the research communities in this tabulation have changed their names and organisational affiliations. The appendix to the Index of Interdisciplinarity contains a listing of the research communities' current institutional affiliations and status.

Source: DAMVAD and CFA, 'Thinking across disciplines - interdisciplinarity in research and education

Box 3.2 contains a description of the highest scoring departments on the Index of Iterdisciplinarity within the six main areas.

Box 3.2 Highest scoring institutions on the Interdisciplinarity Index among the six main disciplines

Institute for Sports – score on the index: 4.7
Sports is not only about good physical shape, muscles and movement. It is also about lifestyle, play and attitude. Therefore, the 29 researchers at the Institute of Sports at the University of Copenhagen work in an interdisciplinary fashion, combining knowledge from health science, natural science and technology with the newest insights from the social sciences and humanities. The researchers' backgrounds are wide-ranging: from biology, medicine over to psychology, pedagogy and art.
The institute has a vision of developing the interdisciplinary practice within their field. The diversity of knowledge and competencies represented among the institute's researchers is used to obtain more knowledge about, for example health-promoting and lifestyle-forming effects of motionfootball, or how sport can be used as learning and play among children and youth.

Institute for Architecture & Design – score on the index: 4.4
Good housing has a positive significance for our well-being. Therefore, technicians, engineers and architects at the Institute of Architecture and Design of Aalborg University work not only with technology when they are developing a new concept for a house. They also focus on lifestyle and the way in which we experience space, materials and functions. The 41 researchers at the institute link architecture and design together with creative dimensions of both technical and aesthetic character, e.g. through digital design.
One research project at the institute concerns the development of intelligent forms of housing for the elderly in the form of IT-based solutions in the home which can make everyday life easier for the elderly and which at the same time meets the demands of the elderly for user-friendliness, ergonomics and aesthetics.

Center for Rehabilitation and Research on Victims of Torture: score on the index: 4.2
A total of 14 researchers work at the Center for Rehabilitation and Research on Victims of Torture, documenting torture on the basis of a health science perspective. Work is carried out in clinical research, treatment and rehabilitation of torture victims and prevention of torture and organized violence. The center also does research on social science perspectives, such as in the study of local communities and the effects of torture and organized violence on social, political and economic conditions. Torture often takes place in underdeveloped countries, and the research at the center also includes anthropological and psychological studies of how people in different cultures and under different living conditions experience and handle traumatic experiences.

Institute for Environment, Society and Spatial Change: score on the index 4.9
How do we thrive best at our work places? This is one of the questions that occupies the Institute for Environment, Society and Spatial Change at Roskilde University. The institute's areas of work are the interaction between people and our environmental, social and spatial conditions. The institute houses over 100 researchers and always chooses to work with problems which encourage interdisciplinary cooperation. One of the institute's research projects, for example, concerns sustainability at the work place, which is a study of working life and the mental working environment, technical challenges and social legislation. The project involves researchers from economics, psychology and sociology. The health professional science and the humanities are also represented, however.

Economics, Politics and Operational Planning – score on the Index: 3.5
At the Faculty of Biosciences 41 researchers work within the area of economics, politics and operational planning with current social questions in relation to people's use of and relationship to nature in forest and landscape, both nationally and internationally. Agricultural and veterinary science is supplemented with knowledge from the humanities and social sciences, including historical conditions, ethical and sociological aspects of people's relationship to and use of nature. A high level of interdisciplinarity is an important aspect in the research; for example in studying conflict management researchers focus on understanding of the complicated interaction between biological, economic and social aspects of administration of forest and natural resources.

Department of Systems Analysis – score on the index: 5.2
The Department of Systems Analysis at the National Laboratory for Sustainable Energy at contains an international staff of 70 researchers who collaborate in research communities across traditional disciplinary boundaries. The department deals with technological projections centered around the significance of future technological developments for society, including future trends and socioeconomic aspects of forthcoming technologies. This work is carried out for both national and international clients who work with different forms of technology. Work is carried out in several scientific areas, including technical sciences, social science and natural science.

3.3 CHALLENGES TO INTERDISCIPLINARITY

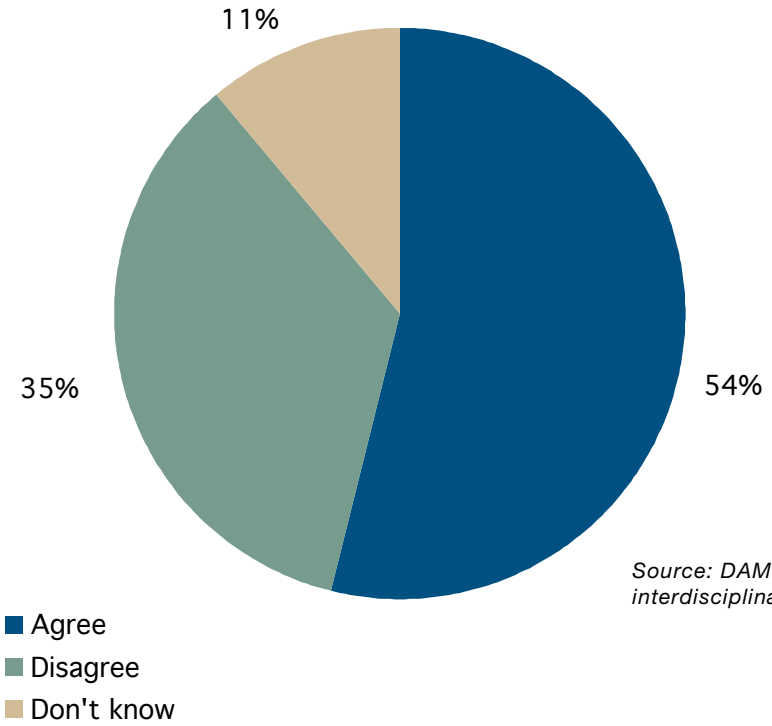
While the previous section has described initiatives and extent of interdisciplinarity within Danish research institutions, the following section describes what the involved actors, including the knowledge institutions and firms, believe are the challenges facing the development of more interdisciplinarity in Denmark.

3.3.1 Incentives for business cooperation

An important characteristic of interdisciplinary research is that it takes its point of departure in socially relevant or business-relevant problems. It is often when the researchers encounter the firms and their specific challenges that research is challenged and the need for interdisciplinary thinking emerges. It is precisely this cooperation between business and research that is one of the focal points in the interviews we have conducted with leading actors within research, higher education and business.

In terms of business cooperation, 54% of the respondents in the questionnaire survey point out that incentives are lacking for cooperation with business on knowledge sharing, while 35% disagree with this assertion; see figure 3.6. The data indicate that cooperation between institutions of knowledge can be expanded if the incentives are strengthened.

Figure 3.6 Lack of incentives for cooperation with the business sector concerning knowledge sharing



Source: DAMVAD, Questionnaire survey about interdisciplinarity, 2008.

In the openended questions, the respondents indicate several relatively clear answers to what is needed in order to strengthen the incentives for expanding cooperation. In box 3.3, several of the challenges are described on the background of the anonymous responses to our interviews with leading actors within research, education and business.

Box 3.3 What do the survey respondents think?

The firms:

- The firms must have the same economic conditions for research as do the universities.
- It should be required that there be both private and public participation in research projects.
- It should be required that research institutions interact with their beneficiaries. They will, as a rule, place emphasis on interdisciplinarity.
- It is important that the business community be more involved in the design/organisation of research and higher educations.

The research institutions:

- There is a need to develop a more experimental research culture, something which is presently being hampered by the ideas of 'value for money in research'
- Larger pools of funds should be offered which specifically focus on interdisciplinarity, courage and creative thinking.
- The patent policy needs to be changed so as to include more emphasis on cooperation between industry and the research institutions.
- Research should be more resolute in grounding their work in the firms' problems, and analyzing them from a technical, commercial, humanities, social science perspective.
- The tasks should be presented by the user/beneficiary with demands for a comprehensive solution with focus on part-processes, which is the glue that creates coherence in the problem-solving. The point of departure should be that diversity creates renewal and gives an applied-oriented meaning.
- It is important to get business and culture to demand new ways of solving well-known problems. And to be willing to invest in new interdisciplinary research with funds which supplement the public research support funds.

Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

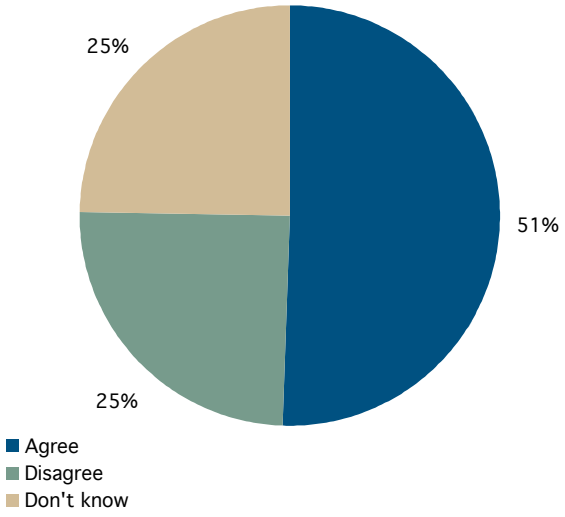
'From a management point of view, one cannot manage through development contracts. The way forward is through incentives, interdisciplinary research programs, including research programs which contain the possibility for cooperation with the business community (public and private), subsidies for development of interdisciplinary educations and better payment per student for interdisciplinary education programs.' Anonymous respondent

3.3.2 Lack of leadership focus and strategic focus

The study also documents that there is a great need to develop a greater management and strategic focus on Danish research institutions in developing interdisciplinarity.

Half the research institutions and firms surveyed believe that there is a lack of focus on research management in relation to interdisciplinary research projects; see figure 3.7. Every fourth respondent, however, disagrees with this statement, and just as many are uncertain of what they should answer here, as indicated in figure 3.7.

Figure 3.7 Lack of focus on research management in interdisciplinary research projects



Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

An important tool for creating greater management and strategic focus are the existing development contracts. Development contracts are formulated as three-year agreements between the Ministry of Science and the university's board regarding the university's activities.

The development contracts describe the university's strategic goals and focus areas, with an emphasis on the four core tasks: education, research, knowledge-sharing and research-based service to the state authorities. The development contracts contain both quantitative and qualitative indicators for the universities' activities and objectives.

The objective of the development contracts is to create a mutual understanding between the universities and the Ministry of Science regarding medium-term objectives. The contracts must help to strengthen the insight into and understanding of the individual university's activity. The development contracts must thus help to make visible the universities' visions, focus areas, results and priorities and create the framework for the general research and educational strategies.

Our review of the content of the development contracts for 2006-2008, however, shows that there does not yet exist an adequate and obligatory focus on interdis-

'From a management point of view, one cannot manage through development contracts. The way forward is through incentives, interdisciplinary research programs, including research programs which contain the possibility for cooperation with the business community (public and private), subsidies for development of interdisciplinary educations and better payment per student for interdisciplinary educational programs.' Anonymous respondent

ciplinarity in the contracts. This is related to the fact that there is generally no obligatory element in the development contracts, in the form of, for example, rewards such as increased operational runds as a reflection of good results and fulfilment of objectives.

At the same time, many of the development contracts are not clear as to how the universities will specifically support and create incentives for interdisciplinarity in their research and education. In several of the universities, University of Copenhagen and the University of Southern Denmark, for example, the development contracts contain no explicit and articulated focus on interdisciplinarity.

Similarly, it is important that funds be distributed according to quality and relevance, just as the universities should be encouraged to focus on interdisciplinarity in cooperation with the business community.
Table 3.2 presents a summary of the universities' development contracts with a special focus on interdisciplinarity.

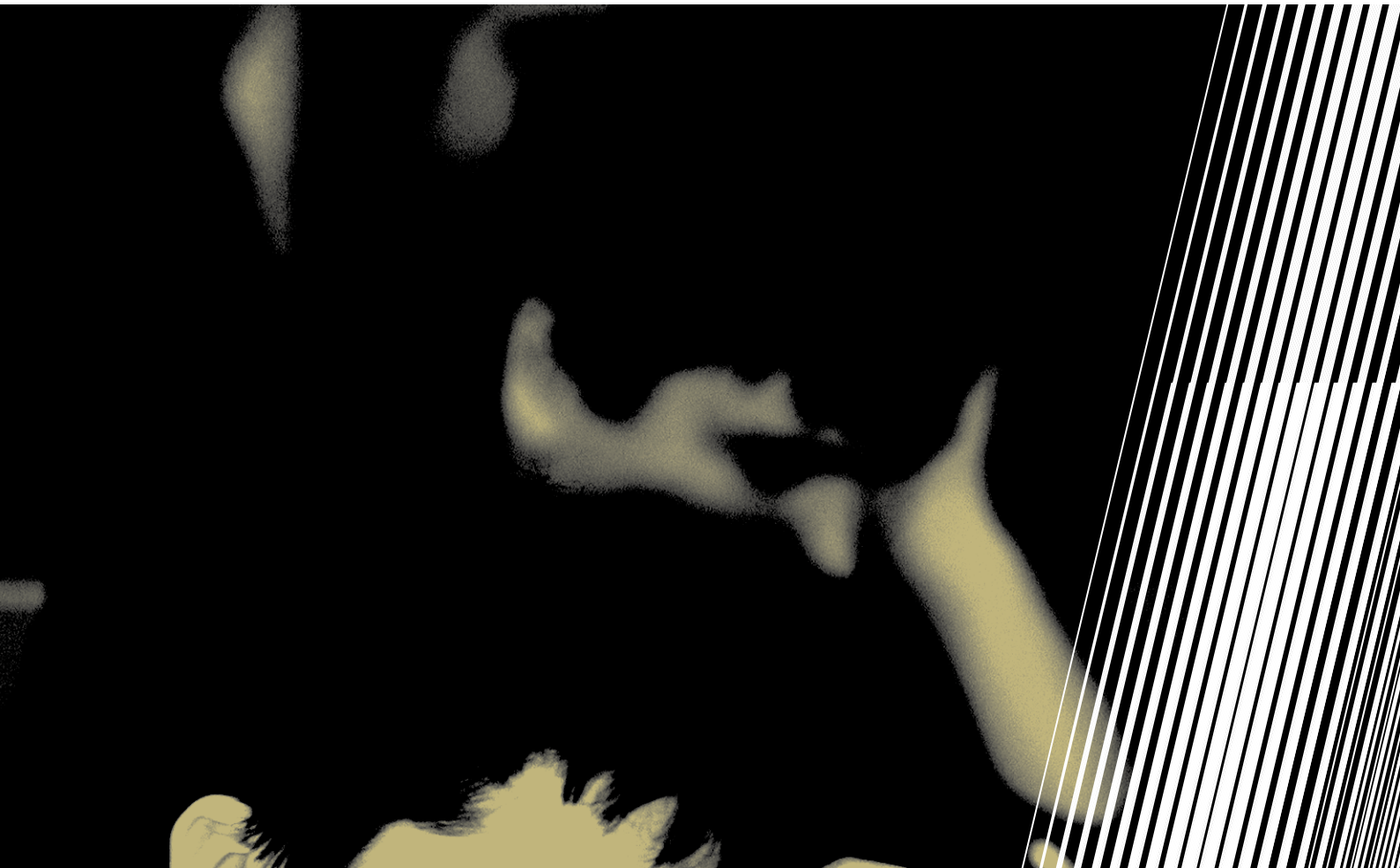


Table 3.2 Interdisciplinarity in the universities' development contracts

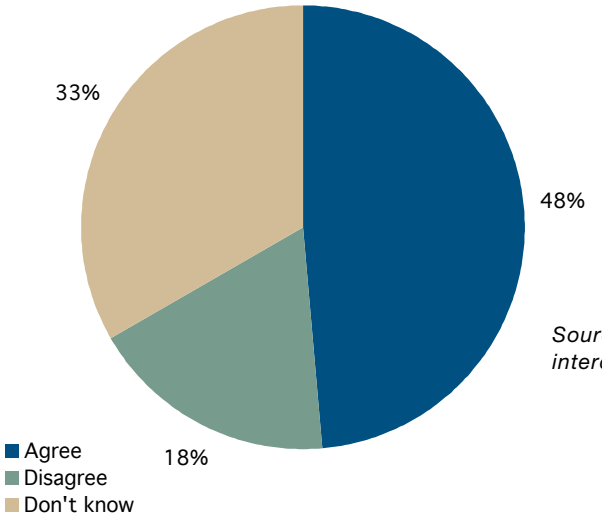
University	Focus on interdisciplinarity in the universities development contracts
Aalborg University (AAU)	As one of its special research focus areas, Aalborg University will give higher priority to the following interdisciplinary initiative areas: 1) Sustainable energy, environment and construction 2) Global production, innovation, knowledge development of cohesion 3) Information technology and embedded software 4) Nanotechnology and production 5) Entertainment technology and design
Aarhus University (AU)	Aarhus University will strengthen interdisciplinarity within research and education by focusing its research efforts on the following six areas where the university already has strength: 1) Globalization 2) Molecular medicine 3) Nanoscience and nanotechnology. 4) Religion as norm setting 5) Theoretical natural science. 6) Knowledge society. Within several focus areas, we can observe an especially marked desire for cooperation between the humanities and social science areas. Aarhus University ///?/// will also place focus on flexible combinations of educational programs which integrate insights from various scientific disciplines.
Pharmaceutical University of Denmark (DFU)	The DFU views interdisciplinarity as a precondition for the understanding of innovation within the area of drugs and medicines. Cooperation across disciplines is therefore already seen as an integrated part of DFU's research and education program, which includes knowledge from the natural sciences, health sciences and technology as well as from the social sciences and humanities disciplines. The development contract does not contain initiatives for further interdisciplinarity.
The Danish University of Education(DPU)	The DPU has a goal of intensifying systematic cooperation between the middle-level higher educations. Beyond this, however, interdisciplinarity is not a dominant objective in DPU's development contract.
Technical University of Denmark (DTU)	In connection with their course offerings, DTU has the goal of ongoing development of new combination education programs in order to meet the needs of society. Beyond this, interdisciplinarity is not a priority goal in DTU's development contract.
Aarhus Scool of Business (ASB)	Interdisciplinarity is not mentioned in the development contract
Copenhagen Business Scool (CBS)	In its development contract, CBS cites four interdisciplinary focus areas which will receive special priority: 1) Innovation, entrepreneurship and leadership 2) Experience economy 3) Enterprise and policy 4) Cultural and area studies HHK also cites coordination and synergy across programs and areas as a part of their educational strategy
IT-University (ITU)	According to the development contract, interdisciplinarity is integrated into ITU's educational programs, which, to a greater or less degree, contain elements from all parts of ITU's area, spanning a triangle with the following three corners: 1) Natural sciences. 2) Art, design and humanities 3) Business-related utilization
University of Copenhagen	Interdisciplinarity is not mentioned in the development contract
Royal Veterinary and Agricultural University	The College seeks to strengthen an already close cooperation between strong research groups, as this is seen as a success criteria for the expansion of the biomedical area BEST. Beyond this, interdisciplinarity is not a prominent objective in the College's development contract.
Roskilde University (RUC)	RUC has set up nine missions, one of which states that emphasis should be placed on research and education, which develops interdisciplinary dimensions.
University of Southern Denmark (SDU)	Interdisciplinarity is not mentioned in the development contract.

Note: The data in the tables on the research institutions is based on the university structures that existed prior to the organisational mergers that took place in 2006/2007.
Source: DAMVAD, based on the universities' development contracts, Ministry of Science, Department of Universities and Buildings.

3.3.3 Inadequate allocation criteria

Asked directly whether there is a lack of relevant, interdisciplinarity-promoting criteria in the allocation of the universities and research institutions' basic grants, 48% of the respondents state that this is the case, while only 18% disagree; see figure 3.8. However, 33% of the respondents had no position on the issue.

Figure 3.8 Relevant allocation criteria that are promoting interdisciplinarity in the universities and research institutions' basic awarding are missing.



Source: DAMVAD, Questionnaire on interdisciplinarity, 2008.

The open-ended answers from our interviews with leading actors within Danish research, education and business again provide several indications regarding the allocation criteria used in providing the universities and research institutions' basic grants, as described in box 3.4.

Box 3.4 What do the interviewees say?

- We must establish interdisciplinary arenas for the individual institutions and create a corresponding incentive structures for the staff to participate in these projects.
- It will make a difference if priority areas are fixed with interdisciplinary conditions at the large universities.
- There is a need for the amalgamation of research programs into very large programs.
- Interdisciplinarity is often emphasized in rhetoric, but in fact, it is still the traditional disciplinary-oriented research which is rewarded.
- Grants are allocated on the basis of a principle of 'cut the cake equally for each disciplinary tradition'. This is a barrier to interdisciplinarity.
- There is a tendency for reviewers' decisions about project applications, even though they have been chosen with different professional qualifications, to not consider interdisciplinarity as a strength in a project. The reviewers often assess the project on the basis of their own professional orientations and find it difficult to assess the quality of the interdisciplinary aspect.
- There are organisational and grant-related barriers between departments and faculty (college) units at the universities which form an impediment to interdisciplinarity.

Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

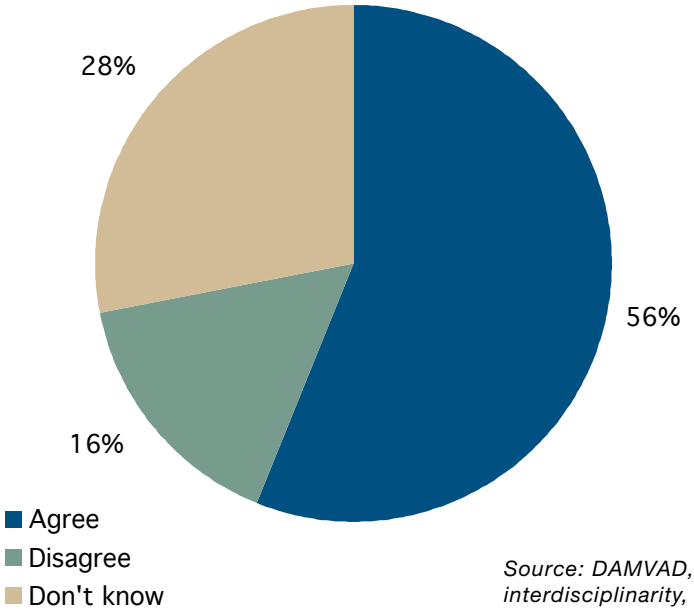
The many 'don't know' responses (33%) show that it is especially the firms that lack knowledge about the grant-giving system and therefore also find it difficult to take a position regarding how the funding criteria operate. This is also expressed in the survey, in that it is especially the researchers with humanities backgrounds who are critical of the criteria used in the grant-giving system.

An important challenge facing increasing interdisciplinary cooperation, especially in terms of radical interdisciplinarity, is that most of the universities in Denmark have retained the traditional disciplinary and faculty divisions. The majority of the research funds are allocated in connection to these disciplinary and faculty administrative units in the institutions. This applies to both the internal funds which the institutions themselves administer, and the outside funding which comes, for example, from the research councils. At the same time, the traditional disciplinary structure is an important framework for the career potential of young researchers, in that many often choose to specialise within the disciplinary orientation in which they find themselves. Furthermore, professors, lecturers and administrative personal are employed within these frameworks, in the same way as the physical framework and research facilities are organized on the basis of traditional discipline and faculty structure.

3.3.4 A need for broader certification of research

A significant part of those in our survey of research and business leaders (56%) believe that there is a lack of recognition of interdisciplinary researchers at the universities and research institutions, e.g., in the review committees which assess scientific quality; see figure 3.9. This generalized attitude is confirmed in the openended statements from the participants in the questionnaire survey. Informants expressed the desire that career advancement mechanisms be established which can give relevant rewards to interdisciplinary research.

Figure 3.9 There is a lack of acknowledgement of interdisciplinary researchers at the universities and research institutions, e.g. in the committees that assess the scientific quality



Source: DAMVAD, Questionnaire survey about interdisciplinarity, 2008.

Others express the view that cultural barriers must be removed before interdisciplinary researchers can be adequately recognized. There are several ways to create increased recognition of interdisciplinary research at the universities and research institutions.

One way is to promote publication possibilities for research that creates interdisciplinary results. There now exist several international journals which provide possibilities to publish interdisciplinary research results, see box 3.5.

Box 3.5 Examples of international interdisciplinary scientific journals

Natural science, IT and technical sciences:
- IMA Journal of Mathematical Control and Information
- Journal of Statistical Computation and Simulation

Biology, medicine and veterinary science:
- Human Biology
- Agricultural and Biological Chemistry

Social science and natural sciences:
- International Journal of Computer & Information Sciences
- Ethology Ecology & Evolution
- Journal of Biological Education

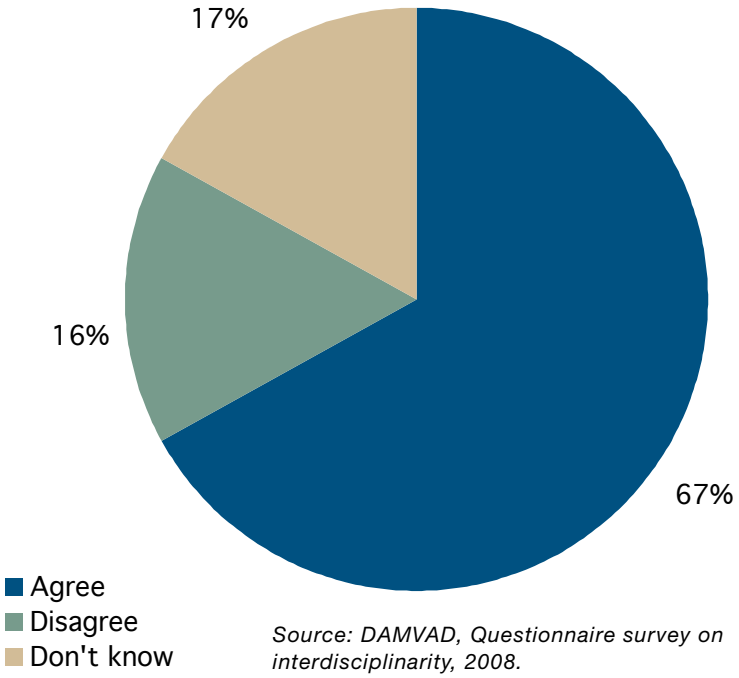
Source: DAMVAD, Thinking across disciplines -interdiciplinarity in research and education, 2008.

3.3.5 Better frameworks for institutional interaction

It is a well-known challenge that cooperation between research institutions which cuts across institutional and disciplinary boundaries can be more difficult to carry out than cooperation in more traditional projects which keep themselves within the more familiar institutional frameworks.

Two-thirds of those questioned state that the problem lies with the incentives to cooperate across research and education institutions, as shown in figure 3.10.

Figure 3.10 Lack of incentives to cooperate across research and education institutions, e.g., universities and university colleges



Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

Several of those interviewed emphasize that the incentives could be strengthened if there were also greater demand by external clients and donors for interdisciplinary research. The argument here is that interdisciplinary research seldom emerges by itself in the individual research communities, but is stimulated by specific problems in business which require interdisciplinary solutions, thus providing an incentive and a pressure among the research institutions to cooperate

3.3.6 Knowledge centers in interdisciplinary cooperation

The Danish knowledge centers are far advanced in terms of interdisciplinarity. This can be seen form the Index of Interdisciplinarity which has been developed in connection with this study. In recent years, there has been a political vision to strengthen the professional colleges (formerly known as Centers for Higher Education (CVUs) and the role of the individual medium-term educational institutions (MVUs) in creating growth and welfare in all parts of the country. The objective has been that the educational institutions' knowledge should be converted and applied in practice, including cooperation with businesses.

More concretely, the vision has resulted in a program where all those educational institutions offering vocational shorter term educations (KVUs) and the middle-level educational programs (MVUs) should establish a regional knowledge center and development function. As a result, these institutions have had the possibility to apply for funds each year from a pool administered by the Ministry of Education which goes toward the development and establishment of regional knowledge centers based on cutting edge competencies within specific areas. In 2004 and 2007, the ministry awarded funds to 27 such knowledge centers, see box 3.6.

The experiences show that the knowledge centers have generally gone a long way toward achieving their goals, and that the funds quite clearly have made a differences

for those partners in the knowledge centers who obtained support, these partners having chosen to focus on cutting-edge competencies within evaluation, natural science didactics, management and innovation. It is a good point of departure for the professional colleges to be able to cooperate more with each other and with the more research-oriented institutions, such as the universities, and thereby potentially contribute to further developing interdisciplinary knowledge and competence

Box 3.6 Overview of existing knowledge centers

Integrated Energy Design (IED)
National Knowledge Center for Mathematical Didactics
Knowledge Center for Health, Diet and Exercise for Children and Youth
National Knowledge Centre for validation of prior learning
Knowledge Center Learning Aids
The Animation Workshop - Knowledge Center for Animation (TAW)
National Knowledge Center for Inclusion and Exclusion
Knowledge Center for Tourism and Experience Industry
Knowledge Center Dellabs
Knowledge Center for International Innovation
Knowledge Center for Technological Innovation
Knowledge Center for Rehabilitation and Physical Activity for Citizens with Chronic illnesses
Knowledge Center for Power Line Technology
Knowledge Center on Coherent Patient Processing and Rehabilation
Knowledge Center for Management
Knowledge Center for Evaluation in Practice
Knowledge Center for Innovative Processes
Center for Applied Natural Science Didactics
Knowledge Center in Management and Learning
National Knowledge Center for Reading
Knowledge Center for E-learning (eKnowledge Center)
Health Technologies in the Home (SIH)
Center for Wireless Technologies and Economy
Knowledge Center for Better Teaching of Bilingual Pupils in the Educational Systems
Knowledge Center for Education and Business guidance
Knowledge Center for Food and Health
Knowledge Center for Industrial Construction (VIB)

Source: The Danish Ministry of Education, 2008

4

INTERDISCIPLINARY RESEARCH GRANTS

4.1 THE RESEARCH COUNCILS CAN CREATE IN-CREASED INTERDISCIPLINARY DYNAMICS

Much of the financing of research in Denmark comes from the research councils. About a fourth of all public research grants are allocated by the research council system, and the majority of these funds go to the universities. Thus, the research council system plays a key role in creating development and dynamics within research. In this context, the research councils also play an important role in developing interdisciplinary research through their grants to researchers, research centers and institutes and firms.

On this background, it is relevant to examine the kinds of visions and legal obligations under which the research councils operate, and how their administration and organisation interacts with the desire to promote interdisciplinary in research. The survey has therefore focused on the research council system's application processes and analyzed the degree of interdisciplinarity among the approximately 400 applications for research projects that received grants from the councils.

In recent years, the system of research councils has been modernized. The renewal of the state research council has had the objective of sharpening the competition for grants and at the same time improving coordination of research and innovation areas. Through a more coherent council structure, the division of labour between the free and strategically business-oriented research has been made more transparent. At the same time, new frameworks for grants have been created, and hereby frameworks for developing interdisciplinarity.

An important innovation was the establishment of the Council for Strategic Research, which supports research on thematically delimited as well as political priority areas. The council has a special role in helping to establish interaction between public and private research.

A significant initiative has also been the Danish National Advanced Technology Foundation, established in 2005 with the scope of stimulating research and innovation efforts within technology areas where Denmark has special prerequisites and potentials.

"We're looking at anyplace where technology intersects with human communication and expression. That's in-herently an interdisciplinary mission."
Michael Bove, Jr. Principal Research Scientist and Director, Media Lab, MIT

An important main finding of this study is that a considerable amount of funds are awarded for interdisciplinary projects, especially in the Council for Strategic Research and the Advanced Technology Foundation, but few of these awards are made to projects that could be considered radically interdisciplinary. Our survey of decision-makers in the research and education sector points to several challenges for increasing interdisciplinary research, including lack of formal criteria for interdisciplinarity, lack of incentives for involving the business sector, and lack of will to implement larger strategic efforts with a focus on interdisciplinarity.

4.2 THE EXTENT OF INTERDISCIPLINARITY IN RESEARCH COUNCIL GRANTS

In order to investigate the extent of interdisciplinarity in those projects that have been or will be implemented with financing from the research councils, this study has examined applications from the Danish National Research Agency, the Advanced Technology Foundation, the Councils for Independent Research and the Council for Strategic Research in the period from 2005 to 2007.

We have endeavoured to review all projects which have received grants of more than DKK 3,000,000 from the councils during this three-year period. The amount of DKK 3,000,000 was chosen based on an assumption that interdisciplinary projects must necessarily involve several different researchers from different institutions, which in itself requires a budget of a certain size.

A total of 400 applications have been reviewed, giving a solid basis for assessing the extent of the interdisciplinary project proposals under the Danish research council system, as shown in table 4.1.

Table 4.1 Overview of the reviewed applications from the research councils, 2005-2007

	Reviewed project proposals 2005-2007	Total number of project grants awarded over DKK 3,000,000, 2005-2007	Percent analysed
Danish National Research Foundation	24	24	100
Danish National Advanced Technology Foundation	51	52	100
Councils for Independent Research	213	232	92
Council for Strategic Research	109	187	58
Total	397	495	80

Note: For the Councils for Independent Research and Strategic Research, we have had direct access to only parts of the total amount of approved projects, which explains why not all the project proposals have been analyzed.

Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

The respective representation of the social sciences and the humanities in the rewiewed applications is in return more modest. For instance, the humanities is only a part of 3 percent of the funded applications under the Strategic Research Council. Without having considered the content of the respective applications, a conclusion could be that if the research councils shall demonstrate a greater extent of radical interdisciplinarity, then the representation of the applications from the socalled “soft areas” needs significant upgrading.

The question is what level of coorperation one can expect between distant related fields The respective representation of the social sciences and the humanities in the rewiewed applications is in return more modest. For instance, the humanities is only a part of 3 percent of the funded applications under the Strategic Research Council. Without having considered the content of the respective applications, a conclusion could be that if the research councils shall demonstrate a greater extent of radical interdisciplinarity, then the representation of the applications from the socalled “soft areas” needs significant upgrading.

The review of the funded applications to the research councils shows that the natural and technical sciences are best represented across the different research councils. For example, the natural sciences comprise 57% of the projects which received grants under the Council for Strategic Research, while the technical and health sciences are also well represented, as shown in table 4.2

Table 4.2 The representation of the discipline in funded application to the research councils (in per cent)

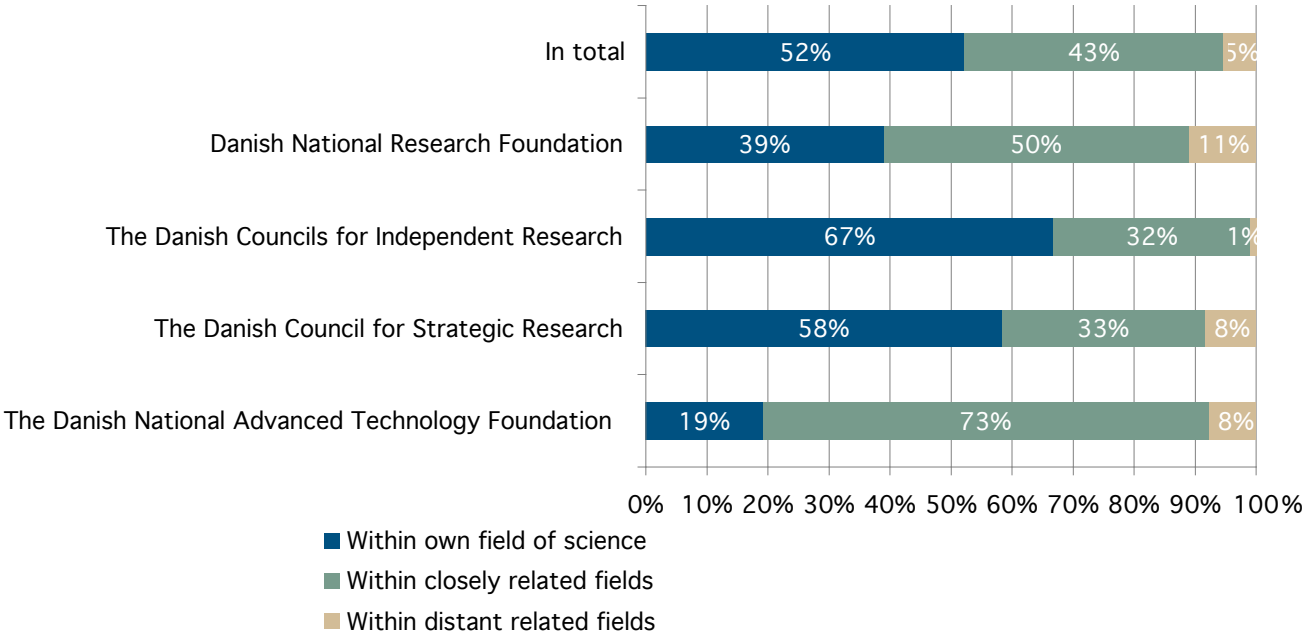
	Natural Science	Technical Science	Health Science	Social Science	Agricultural and Veterinary Science	Humanities
The Danish Council for Strategic Research	57 %	44 %	40 %	17 %	25 %	3 %
The Danish Councils for Independent Research	52 %	25 %	16 %	15 %	15 %	16 %
The Danish National Advanced	71 %	77 %	29 %	6 %	12 %	4 %
Technology FoundationDanish National Research Foundation	88 %	21 %	17 %	8 %	0 %	8 %

Source: DAMVAD, ‘Thinking across disciplines - interdisciplinarity in research and education

Looking more closely at the extent of interdisciplinarity in the reviewed applications within, respectively, own branch, closely related branches (e.g., technical and natural science) and distantly related branches (e.g., natural sciences and humanities), it can be seen that while there are many applications to the research councils with interdisciplinarity within one’s own branch, there are few which combine distantly related branches (see figure 4.1.).

Only 5 percent of the funded applications contain research areas crosswise distant related fields, while 43 percent contain research areas on closely related fields. 52 percent of the applications is build upon monodisciplinary knowledge or on knowledge within own research field.

Figure 4.1 The extent of interdisciplinarity under the research councils in Denmark



Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

The question is what level of coorperation one can expect between distant related fields. There are only few other studies for which we can draw comparisons and conclusions. A Swedish study of research applications, however, shows that a fifth of the proposals can be said to be interdisciplinary across distantly related main fields.[8] With a starting point in this comparison with Sweden alone, you can therefore say that there is room for improvement for the applications under the Danish Research Council.

However there is a major difference across the research councils in the extent of interdisciplinarity among those projects that received funds. The Councils for Independent Research has awards the fewest grants to the group of most interdisciplinary projects. Only about one percent of the projects in the study are listed as 'radically interdisciplinary', i.e., as projects that build upon an interaction of knowledge across distantly related branches. By comparison, 11% of the projects funded by the Council for Strategic Research are awarded to radically interdisciplinary groups; it should be recalled that one of the goals of the Council for Strategic Research is to initiate research which is policy related, with a point of departure in special social and business-related problems.

With reference to the Danish National Advanced Technology Foundation, a great portion of the funded projects are interdisciplinary, but it is an interdisciplinarity where the research areas tend to be closely related, primarily technical sciences and natural sciences.

An important question for this study has thus been whether there are special conditions

8) Sandström, Ulf et al., (2005): Tvärvetenskap – en analys. Vetenskapsrådets Rapportserie 10:2005.

for the Danish research councils which can be important for the levels of interdisciplinarity described above. In this report, we have examined in detail how and to what degree themes and intentions around interdisciplinarity appear from the objectives, legal foundation, calls for proposals, mission statements and strategies, and in the composition of the individual research and grantgiving councils in Denmark (see table 4.3.)

The results here are also very clear. Table 4.3 shows that although the councils have desired to promote interdisciplinarity as a part of their mission and strategy, this does not appear from their formal objectives, just as is it not a part of their legislative basis as concerns the individual council. Similarly, the individual councils generally do not issue calls for specifically interdisciplinary research proposals. It is only the Council for Strategic Research which has evaluation criteria in all their announcements that, 'Emphasis is placed on the supported research activities, where relevant, being carried out in an interdisciplinary interaction with different research areas'. In the Program Committee for Health, Food and Welfare, there is additionally added, 'As such, an increased integration of humanities, social sciences, health and natural science research is preferred'.

Differences exist in the composition of the boards of the individual councils. For the Councils for Independent Research, representatives from all six scientific branches sit on the board, while in the other councils, fewer branches are represented and are very clearly concentrated on natural science and technology. The same picture reveals itself when one examines the composition of the individual scientific council. Of course, the councils thus face challenges, if the applications, which include other disciplines, are to be assessed.

Table 4.3 Overview of research and grant-giving councils in Denmark with special focus on interdisciplinarity.

	Councils for Independent Research	Council for Strategic Research	Danish National Research Agency	National Advanced Technology Foundation
Objective	Supports quality and internationalization within all scientific branches in Denmark with point of departure in the researchers' own initiatives.	Supports research in politically defined and thematic areas. Objective of supporting the interaction between public and private research.	Supports basic research within all areas. Special emphasis is placed on the elite of Danish basic research through the establishment of 'centers of excellence'.	Supports growth and employment, partially through a focused priority on bio-, nano- and information technology.
Explicit requirements to promote interdisciplinarity:				
Legal foundation	No	No	No	No
Call for proposals	No	Yes	No	No
Mission and strategy	Yes	Yes	Yes	Yes
Composition of board	Board (9 members) with all 6 branches represented.	Board (9 members) with 5 branches represented, though concentrated on technology and natural sciences.	Board (9 members), with 4 branches represented, though concentrated on natural sciences.	Board (9 members), with 3 branches represented. All within technology and natural sciences).
Composition of council	Research Council for Culture and Communication: 1 branch represented. Research Council for Nature and Space: 1 branch represented. Research Council for Society and Business: 1 branch represented. Research Council for Health and Disease: 2 branches represented. Research Council for Technology and Production: 4 branches represented.	Program committee for Health, Food Products and Welfare: 5 branches represented. Program Committee for Sustainable Energy and Environment: 4 branches represented. Program Committee for Strategic Growth Technologies: 2 branches represented. Program Committee for the Creative and Innovative Society: 3 branches represented. Program Committee for Non-Ionized Radiation: 2 branches represented. Program Committee for Transport and Infrastructure: 3 branches represented. Program Committee for Education and Competence Development: 2 branches represented. Program Committee for Individual, Health and Society: 3 branches represented.		

Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

4.3 CHALLENGES CONFRONTING INTERDISCIPLINARITY

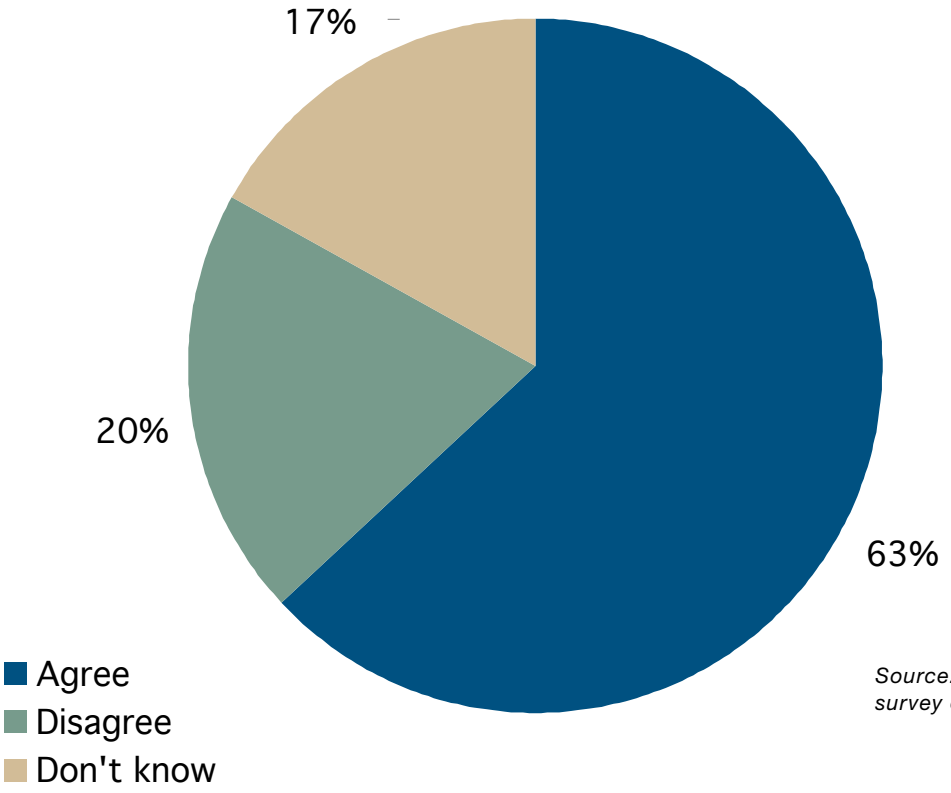
While the preceding chapters have described the extent of interdisciplinarity within the framework of the research council allocating and granting system, the following section describes challenges to the development of more interdisciplinarity in Denmark as viewed by key actors working in institutions of knowledge and in the private sector.

4.3.1 Few strategic initiatives and limited interaction

On the background of the descriptions above, one conclusion could be that the institutional and regulatory frameworks for the research council system do not adequately aim to promote interdisciplinarity in research in Denmark. Such a conclusion seems to be confirmed in the responses from the researchers and the firms who have participated in the questionnaire survey.

Figure 4.2 shows that 63% of those responding to the survey believe that there are too few incentives for firms to participate in public research and development projects.

Figure 4.2 There are too few incentives for the companies to participate in public R&D projects.

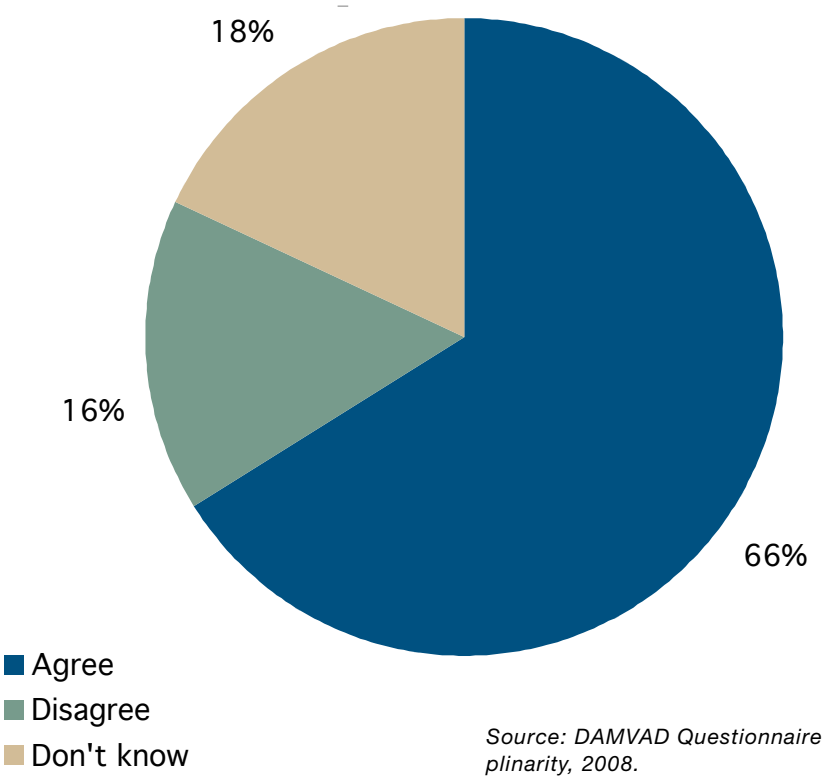


Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

An even higher proportion of respondents (66%) state that there are too few major research initiatives in Denmark which cut across the disciplines, while only 16% disagree with this assertion, cf. figure 4.3. This is one area which has been the subject of increasing focus in recent years, e.g., in the Danish Government's globalization strategy.

Most recently, the Government's Future Panel has expressed the view that there should be significantly greater initiatives in special areas so as to facilitate larger research projects, where researchers and firms can work together across institutions, disciplinary traditions and routines.

Figure 4.3 There are too few large research efforts in Denmark which cut across disciplines.



Source: DAMVAD Questionnaire survey on interdisciplinarity, 2008.

4.3.2 Narrow composition of councils and inadequate criteria

A research and grant-giving council system, as has been discussed above, does not give much encouragement to the promotion of interdisciplinarithy in research in Denmark. If improvements are to take place in promoting interdisciplinarity, the council system must do more to place interdisciplinary themes on the agenda in their calls for research proposals. A declaration of intent regarding interdisciplinary research could just as well be written into a declaration of objectives and in the legal foundation under which the councils exist. Box 4.1 indicates the attitudes of the interviewees

Box 4.1 What do the interviewed persons think?

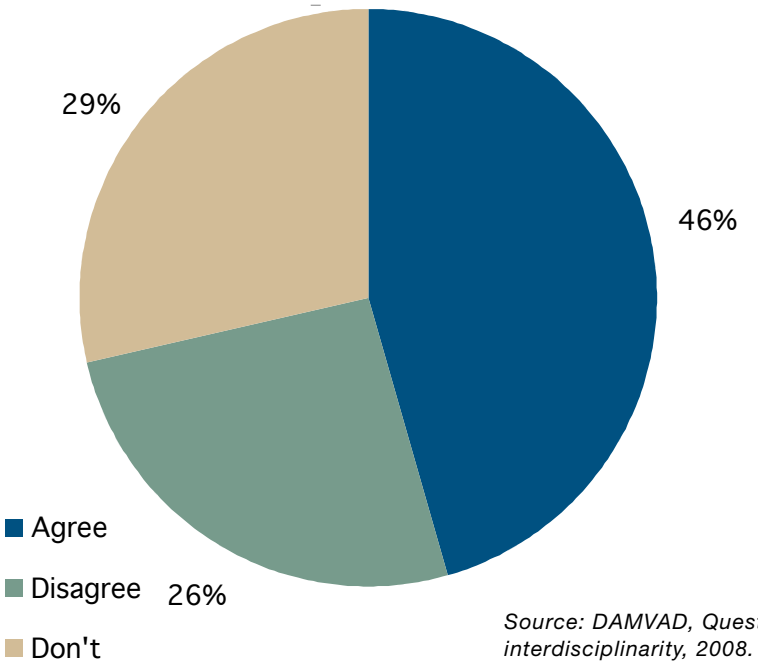
- There should be more support for interdisciplinary research financially via the research councils, and it should be easier to apply for support for interdisciplinary seminars and network formation.
- There should be better cooperation among the academic research councils.
- Funds should be explicitly allocated to interdisciplinarity, in that the research councils are poor at handling interdisciplinary applications.
- The research councils must be more open towards interdisciplinary research. It is often the case that they fall between the gaps in the system.
- Grants from the research councils must be conditioned so that there is an interdisciplinary element.
- A special assessment of research applications should be developed so that the applications are not to be compared with the non-interdisciplinary.
- Regarding the research grants, one should place demands on interdisciplinarity and communication of interdisciplinary research, and education must be supported.]

Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

In figure 4.4. it can be seen that nearly half (46%) of those interviewed state that no explicit demands are made for interdisciplinarity in the criteria for awarding of funds.

This corresponds well to the results of the review of the institutional and regulatory frameworks and practice as described for the application announcements; see figure 4.4

Figure 4.4 No explicit demand is made for interdisciplinarity in the criteria for the awarding of funds



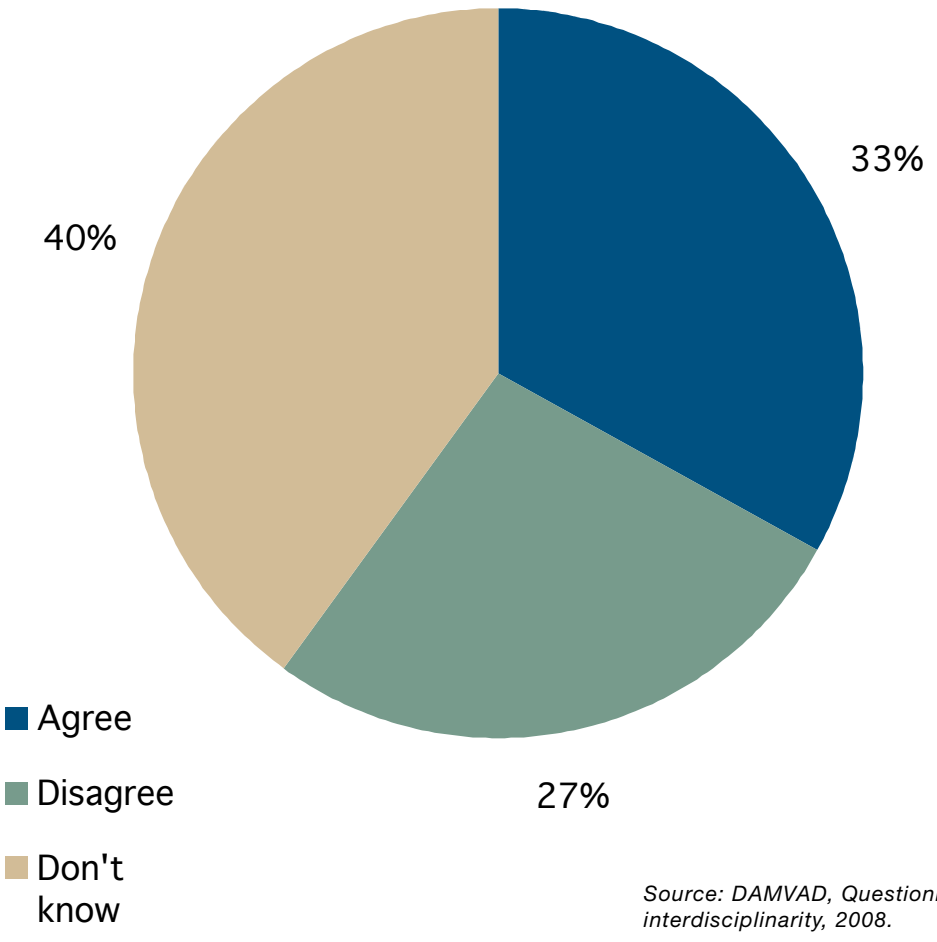
Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

"There is a need to allocate explicit funding because the research council system is bad at managing interdisciplinary applications". Anonymous respondent

At the same time, one could probably go far in terms of promoting interdisciplinary research projects if representatives from several different branches could sit on the individual councils. It would also be appropriate to allow the firms and other representatives with different professional research competencies onto the councils and review boards, even though they do not have direct affiliation to the universities.

There is, however, a greater uncertainty among those interviewed in relation to whether the professional diversity among members of the research councils is too narrow. Thirty-three percent of respondents think this is the case, while nearly as many (27%) disagree with this view. Forty percent were unable to take a position on this question, see figure 4.5.

Figure 4.5 'There is too little professional diversity in the composition of members in the research councils and program committees, etc.'



Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

5

5 INTERDISCIPLINARITY IN THE EDUCATION SYSTEM

5.1 INTERDISCIPLINARITY MUST STRENGTHEN THE RELEVANCE OF EDUCATIONS

The Danish government, in its globalization strategy, has declared an objective that Denmark must have world-class educational programs. In the educational area, reforms of the shortcycle, middlecycle and higher education programs have been implemented since 2001 as regards the volume and efficiency of education, admissions criteria, drop out rate, certification and quality assurance. In addition, there is the corresponding political focus on the relevance of these education programs, and that the students attain competencies which correspond to the needs of society and of the labour market.

In this connection, interdisciplinarity is also an important factor in ensuring the relevance of these educations. The firms' ability to develop, produce and market new knowledge and new products poses demands that workers are able to work across the traditional disciplinary boundaries. The idea is that new ideas emerge in the intersection between different disciplines.

Increased interdisciplinarity in Danish education programs places great demands on the educational institutions' ability to develop their program offerings. At the same time, it also poses demands for a flexible educational system. This report shows that the Danish educational system is well on its way toward promoting interdisciplinary educations, but that there is still room for improvement. The report builds upon an analysis of interdisciplinarity in about 600 current higher education programs, supplemented by over 200 newly established programs (in 2005-2007). The analysis thus constitutes a solid extension of the existing knowledge in this area.

A major conclusion is that interdisciplinarity is more prominent in continuing and vocational training than in the ordinary educational programs. Our data also indicate that relatively many new interdisciplinary educations are being developed at the universities, and fewer in the shorter and middlerange educations. Moreover, the analysis shows that there is a gradual increase in interdisciplinarity – as the term is defined in this study- over time.

At the same time, the analysis has identified

'The universities ought to work so that their educational programs are organised in a way that stimulates the interdisciplinary and creative qualities among the students.' Ministry of Science, Future Panel

several barriers to increased interdisciplinarity in the educational system within the framework conditions for the educational programs; e.g., there is much that indicates that the intentions in the university law to allow students to combine different subjects in their education are in practice not really respected, among other things because of cultural barriers and a lack of economic incentives. At the same time, there are great challenges in obtaining accreditation to combat the need for interdisciplinarity and recognition of new education programs, the interaction between educational programs and incentives for establishing a more flexible career path for the individual student.

5.2 THE EXTENT OF INTERDISCIPLINARITY IN EXISTING EDUCATIONAL PROGRAMS

Interdisciplinarity in the educational programs can be achieved by the students themselves combining their studies on the basis of the options they find, or by the individual study programs in themselves being interdisciplinary. An important result of the analysis below is that it can be fruitful to increase focus on genuine interdisciplinary educations rather than allowing the individual student to create their own interdisciplinary combinations. The foreign cases presented in this report (Chapter 7) are examples that greater synergy can be obtained by linking together the disciplines in the education programs. In other words, there is room for the Danish tradition of interdisciplinarity by supplementing the student's freedom of choice in their coursework with genuine interdisciplinary educational programs.

In practice, there is a challenge in defining when an educational program is interdisciplinary. Several existing disciplines build on interdisciplinary elements, e.g., political science, which is composed of law and economics; or architecture, which draws on areas of sociology, engineering and aesthetics. Similarly, there are many educations within the vocational field, which emerged as interdisciplinary; nursing, for example, builds on knowledge from health, the humanities and natural sciences. An important criterion for defining an education as monodisciplinary (and others as interdisciplinary) is whether the education in question has developed its own 'domain' and has established itself as a bona fide field, such as political science. For several educational programs, however, it is a matter of judgment whether one considers a given field of study to be monodisciplinary or interdisciplinary.

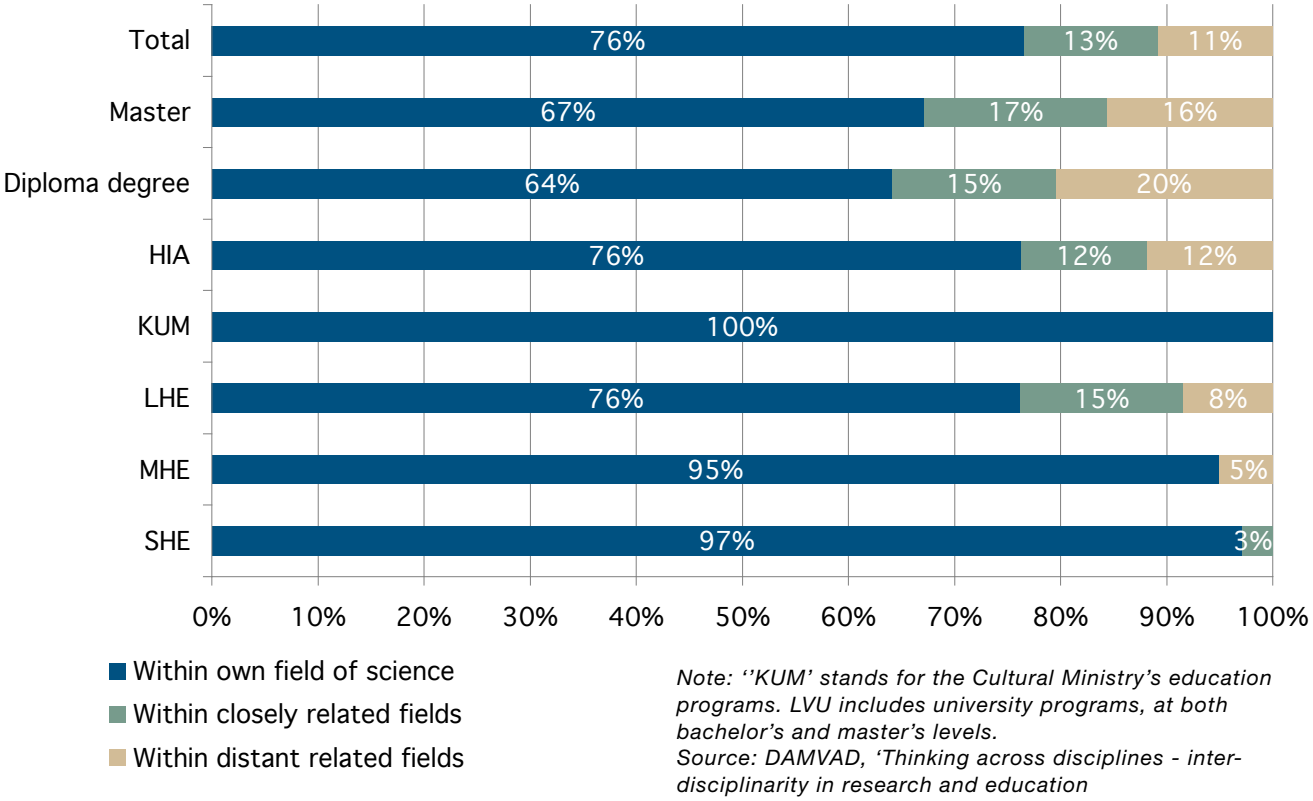
In this description of interdisciplinarity in Danish higher education, it is a matter of judgement as to the degree to which an education is an inter- or monodisciplinary. For example, the master's degree program in Health Information Technology, which cuts across health and natural science, is categorized as interdisciplinary. Conversely, the bachelor's degree in nursing is categorized as monodisciplinary even though the curriculum concerns not only the health sciences, but also the humanities traditions. Nursing has its own 'domain' and has established itself as an independent professional tradition, and is now classified by the Ministry of Education as a health science education program.

The point of departure for Denmark is that with the delimitation of interdisciplinarity used in this study, there in fact exist many interdisciplinary educational programs. If one surveys the various educational areas, it is especially at the master's and certificate

programs at the university and in continuing and vocational training (VVU[9], that interdisciplinary educations are offered.

Figure 5.1. shows that 16% and 20% of, respectively, existing master's and certificate programs are interdisciplinary, bringing together distantly related fields, i.e., are 'radically' interdisciplinary. If the interdisciplinary educational programs within closely related areas are included, the proportion rises to 33% and 35%, respectively. Among the ordinary educational programs, the figures are different. As concerns existing university-level bachelor educations (LVU),[10] only 8% of the long higher educations (it is not possible in the data used here to distinguish between bachelor's and master's levels in the university area) and 5% of the middle-cycle education programs (MVU)[11] , are interdisciplinary in terms of distantly related areas. In the educational programs administered by the Ministry of Culture (KUM), the survey does not identify any interdisciplinary educational programs.

Figure 5.1 Current educations classified by level of education



Note: ''KUM' stands for the Cultural Ministry's education programs. LVU includes university programs, at both bachelor's and master's levels.
Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

9) The figures for VVU, certificate and master's programs have a degree of uncertainty. This is due to the fact that it is the programs themselves that report to Vidar (the Ministry of Education data base for higher education, including continuing and in-service training), and the survey identifies several education programs which have not been recorded, e.g., new master's programs which have been certified by the Ministry of Science, but which do not appear in Vidar.

10) This calculation is based on figures from the national higher education application system (Koordinerede tilmeldning/KOT). This means that the number covers only the university bachelor programs, in that the student applies to a bachelor's program and not a master's program. Admission to master's programs is carried out within the universities themselves, and these data are therefore outside the KOT system. However, figure 5.2 contains information about new educational programs, both certification and university bachelor's and master's educations, so that that this cannot be directly compared with the calculation based on the KOT data.

11) Medium-cycle, university and vocational bachelor educations under the Ministry of Education, e.g., nurses, teachers and engineers.

The analysis of existing education programs shows that the degree of interdisciplinarity is higher in the continuing and inservice training (VVU, certificate programs and master's programs) than in the conventional programs. One explanation could be that these programs have closer contact to the business community due to the fact that the students are parttime and that their training emanates from needs required by their jobs.

The tradition for cooperation with the beneficiaries is thus stronger for the certificate and master's education programs, and this is reflected in the educational offerings. Experiences from the evaluations of certificate and master's programs, conducted by Denmark's Evaluation Institute (EVA), shows that certain challenges connected with interdisciplinarity can be found primarily in the continuing and in-service training rather than in the regular programs. For example, the evaluation by EVA shows that there can be a gap between the certificate and master's programs as they are formally offered, and the programs when they are actually up and running. This is due to the fact that these programs are subordinated to market mechanisms and therefore not structured in the same way are ordinary higher educations.

The point is that what on paper appears to be a high degree of interdisciplinarity can in reality end up targeting relatively few students, if indeed the programs are established at all. Hence, there were 16,445 and 2,205 students enrolled in, respectively certificate and master's programs during the period 2001-2004.

By extension of this, it is interesting that the study of the foreign interdis-ciplinary programs, described in Chapter 7, shows precisely that interdisciplinarity is found largely in the ordinary educations. Several of the foreign cases have variants of the education in Denmark, but these take the form of certificate or master's educations. This means that there is a possibility to promote interdisciplinarity in Denmark by converting interdisciplinary educations from continuing and in-service training into the ordinary educational system. Box 5.1 shows examples of both conventional and continuing and in-service educations in Denmark, with features of their interdisciplinarity.

Box 5.1 Examples of interdisciplinary education programs in Denmark.

Multimedia design program- short-cycle program
A multimedia designer works with communication, in the broadest sense of the word. A multimedia designer works as project coordinator, designer or programmer and planner, and may be a manager of multimedia productions. Students are taught about organisational cultures and processes in connection with multimedia development and multimedia. Studies are interdisciplinary, covering areas such as communication and dissemination, graphic design, audio/video and animation, aesthetics, marketing, journalism, IT-systems and data communication. In the program, the student specializes in one of the main areas of communication, visualization and concept- or interaction development. The program concludes with an examination project where a specific task is solved.
The multimedia design educations are offered by the university colleges.

Diploma engineer in technology and economy: Middle-cycle education program
This program combines technology and economics and equips the student with the technical skills and understanding of business economics, organisation and legal foundations. The student thus focuses on design of user interfaces and functionality, e-business and IT solutions, business law and financial management. The educational program is newly established and is offered in cooperation with the Technical University of Demark and the Copenhagen Business School. On graduation, candidates can find jobs at firms which need an engineer with an understanding of both the production-related and commercial challenges facing a firm.

Humanistic-technological basic program – Long-cycle education LVU
This program combines humanities education, technology and design. The purpose is to give the students practical and theoretical understanding of how new design and new technological knowledge is created in interaction between users, designers, traditions and institutions, and between knowledge-based, methodological approaches and creative ideas. The program is newly established and has not yet formulated a specific occupational profile. The program is offered at Roskilde University.

Academy Profession Degree in Technology
This program combines social science and technical sciences and focuses on innovation, production and product development. The student learns to analyze, plan and assess problems within innovation and production optimization in private and public firms. Possible career positions are in fields such as strategic planning for public and private firms who need workers able to optimize cooperation between people with different educational, language and cultural backgrounds. The program can be studied at several of the Academies of Professional Higher Education.

Technological certificate in human ecology – certificate program
This program combines social science with natural science and focus on the human effects of ecosystems and natural resources and solution of environmental problems through technology, environmental management, sustainability, ecology and technological- and environmental assessment methods. The vocational goal is generally that of occupational competence within the environment field. The program is directed towards teachers, communicators, employees in public authorities and private firms, especially those working in environment-related areas. The program can be studied at Aalborg University.

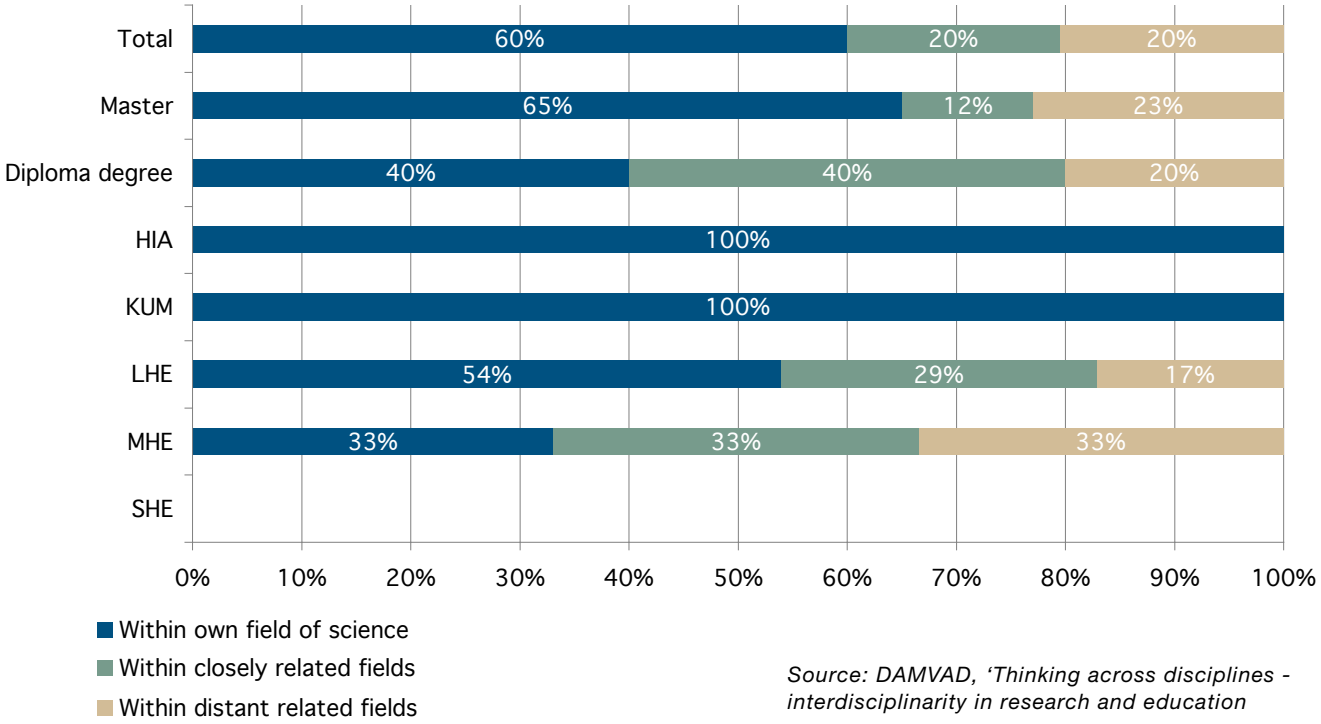
Master in disaster management
This program combines technical, natural science, humanities, social science and health science disciplines. The program gives the students competencies related to dealing with interdisciplinary, multicultural tasks which arise in working in international disaster management in an economic, political, environmental and health perspective. The occupational prospects are primarily Danish and international organisations and NGOs that work in the world's flash points and send staff to conflict areas. The program can be studied at the University of Copenhagen.

Source: DAMVAD og EVA, Thinking across disciplines – interdisciplinarity in research and education

5.3 INTERDISCIPLINARITY IN THE NEWLY ESTABLISHED PROGRAMS

In order to assess whether there are special developmental tendencies in the extent of interdisciplinarity, it is interesting to examine how many of the new educational programs are interdisciplinary. Figure 5.2 shows that four out of ten of the new educational programs approved in the period 2005-2007 are of interdisciplinary character. Half of these are interdisciplinary across distantly related fields. The proportion of interdisciplinary educations in the new educational programs is thus higher than it is among the existing educational programs. This may signal a general tendency that the higher educations are moving towards becoming interdisciplinary.

Figure 5.2 Approved new educations 2005-2007 by level of education



Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

The top-scoring educations in terms of interdisciplinarity are the middle-cycle educational programs (MVU). Here it can be seen that 33% of the newly created educational programs are interdisciplinary within related fields and 33% within distantly related areas, which is considerably higher than among the existing educational programs. This covers, however, only the nine new programs, so that this sector must be followed more closely before we can conclude that the tendency is significant for the middle-cycle educations as such.

Nevertheless, there is a great difference in interdisciplinarity when one looks across the educational levels in the newly approved educations. Here one finds the same tendency as for the existing educations; namely, that interdisciplinarity is more prominent in the

university educations and educations within continuing and in-service training. Thirty-six percent of new long-cycle (LVU) higher educations (76 in all), including both bachelor's and master's educations, are interdisciplinary across closely or distantly related fields, while the proportion is 35% for the 109 new master's programs.

A review of these new educations also shows a general tendency towards an increase in the number of interdisciplinary education programs in the period 2005-2007. This tendency applies generally for all educational levels, with the exception of the shorter-cycle (KVU) and Ministry of Culture programs, where no new interdisciplinary programs were approved during this period. Even though there is a tendency toward increasing interdisciplinarity in the Danish higher education system, it is an important question, naturally, whether there is adequate momentum to this trend.

In recent years, the education sector has been characterised by a long series of reforms which have both impeded and facilitated the establishment of new interdisciplinary educations. The university law, the law on professional colleges and the Government's globalization strategy are but examples of political measures which have been initiated to strengthen higher education in Denmark in different ways. Among these initiatives, there are varying degrees of changes and measures which have consequences for interdisciplinarity in education.

In other words, several reforms have been implemented which in many ways create space for interdisciplinary education programs to be developed in the academies of higher professional education, the professional colleges and in the universities. The reforms have been a challenge to the universities, professional colleges and professional academies, and they have meant that these institutions have had to develop their existing educations by themselves. The reforms can have had an affect on the amount of available resources they could use to develop new educational programs. The reforms are also a first step toward more improved frameworks for interdisciplinarity. Increased flexibility in the educations, mergers of institutions and closer cooperation with the business community are factors which can be expected to create a basis for increased interdisciplinarity.

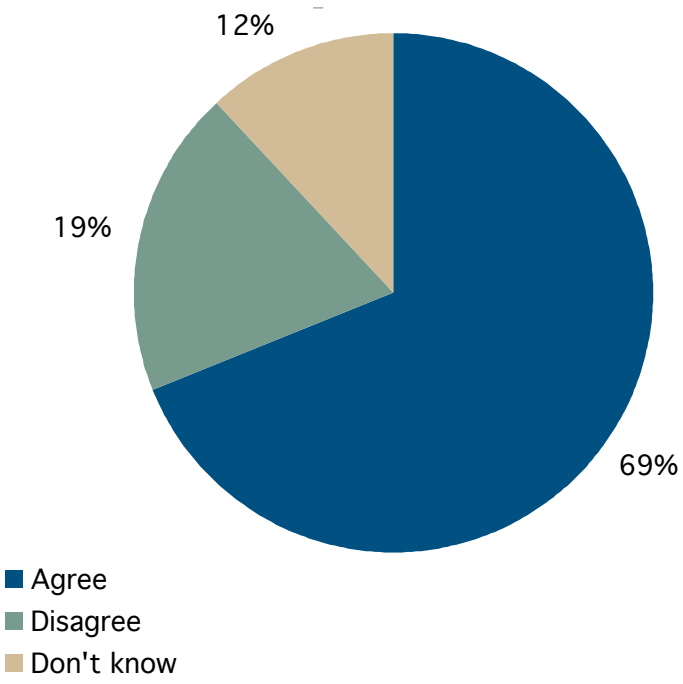
5.4 CHALLENGES TO INTERDISCIPLINARITY

As described in the previous chapter, reforms have taken place throughout the Danish higher education system. These reforms have created certain improvements in the frameworks for interdisciplinarity in the education programs.

Yet, there continue to exist several challenges to increased interdisciplinarity. The challenges are especially clear from our interviews that we conducted among leading actors within research, education and the busi-ness community. For example, respondents point out that there continues to be a lack of incentives for the education institutions to place more emphasis on increased cooperation and development of interdisciplinary educational programs and to give the students even better possibilities to move across disciplinary fields in relation to the needs of society and of the firms.

"There is a need to implement incentive structures that support interdisciplinarity, for example in form of increased Student FTE (Student full year's work equivalent) to interdisciplinary educations or earmarked grants to interdisciplinary research". Anonymous respondent.

Figure 5.3 Lack of incentives to cooperate across educations, e.g., because of the system of funding per full-time graduate



Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

5.4.1 Lack of incentives for interdisciplinarity

In order to strengthen interdisciplinarity in the education system, there is a need for incentives. This is confirmed in figure 5.3, which shows that 60% of the respondents believe that there is a lack of incentives for cooperation across programs. Nineteen percent disagree, while 12% of the respondents said that they 'don't know'. There is thus general agreement on this point.

The explanation of lack of interdisciplinarity lies primarily in the Danish system of granting state subsidies to higher education, (known as the 'taxameter system'). Under this system, the state allocates funds to institutions based on student progress, such as completed examinations or degrees. The amounts paid per student are fixed politi-

Table 5.1 State subsidy per full-time students in various disciplines, 2008.

Area of study	Payment per student/year in DKK
Humanities	40,400-65,600
Social sciences	40,400.65,600
Natural sciences	40,400-96,000
Technical sciences	40,400-96,000
Health sciences	65,600-96,000

Source: Ministry of Research, Department of Universities and Buildings, 2008
Note: In June 2008, 1 EURO=DKK 7,5888

cally for the different academic branches on the basis of socioeconomic needs, the type of education and the operating costs (equipment, preparations, etc.). This means that the education programs obtain different amounts of money per student, according to the academic field.

Table 5.1 shows that the technical, natural science and health science branches obtain the highest subsidies per student, while the soft disciplines such as social science and humanities receive the lowest payments.

The payment per student system based on their progress through they system creates challenges for the development of interdisciplinary educations. The different payments mean that an interdisciplinary cooperation between, for example health sciences and social science would put the two areas in an unequal relationship, and in certain cases the interdisciplinary cooperation would be more profitable for one field than the other. The persons interviewed in this study express the following views on this topic, see box 5.2.

Box 5.2 What do the persons interviewed say?

- There is a need to introduce incentive structures which support interdisciplinarity, e.g., in the form of increased payments per student for interdisciplinary educations or to earmark grants for interdisciplinary research.
- There is a need to ensure that firms are involved in defining and planning the programs.
- The differences between allocated funds per student should be equalized; social sciences in Denmark receives less than natural science.
- There is a lack of incentives to develop new educations. There are problems with transferring credits in different places, but I am not aware that this problem is linked with interdisciplinary studies.
- A corps of external examiners should be established where it is possible to draw on several of them, and a flexible education system should be set up so that we avoid having students who find themselves 'in between'.
- Interdisciplinary educations must function alongside the standard mono-disciplinary educations.
- Framework conditions should be assured for the middle-cycle educations, so that realistic possibilities are established interdisciplinarity.

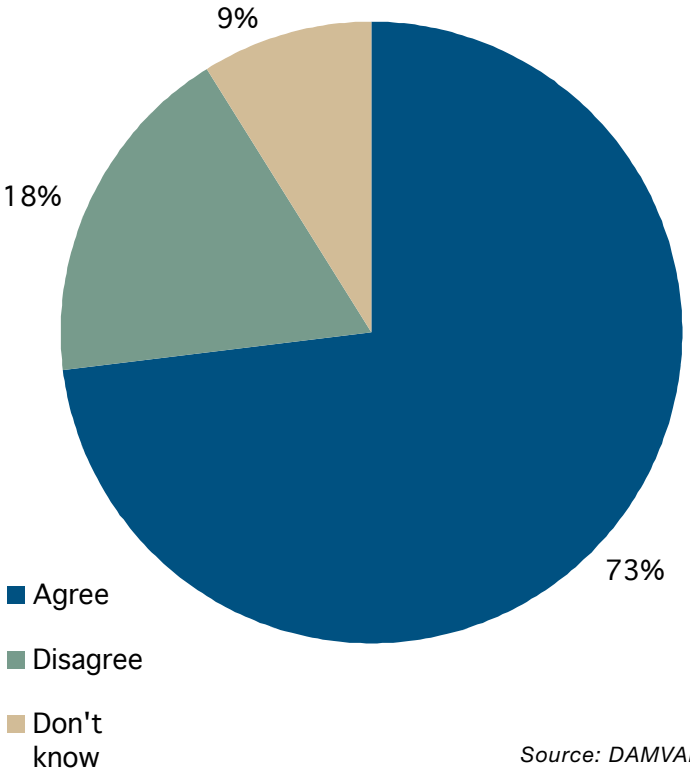
Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

A report from the Danish Evaluation Institute (EVA) in 2005 observed that the payment-per-student administration of the Danish education system has been criticized in the public debate, e.g., for focusing on quantity over quality in the educational programs. At the same time, the report shows that the system is also cited as a positive measure which, for example, promotes efficiency and focuses on the end user, the students. The payment-per-student-progress system, however, was developed to deal with students studying traditional disciplines. Hence, the fields of health, social and sciences are kept separate, not only culturally but also financially. The system does not contain mechanisms to support interdisciplinarity. There are thus both positive and negative views of

the payment-per-student-progress system as it is administered in the Danish education programs.

Beyond the challenge to interdisciplinarity posed by the system of paying universities by students' progress, the students also face a challenge to their own possibilities to create their own interdisciplinarity by combining courses and credit systems in the education system. The credit transfer rules are individual and set by the individual programs and schools, and the practice in the educational system is very different. Many programs have standardized administrative procedures and flexible credit transfer arrangements, especially those programs where the students often study abroad. Other programs have very few credit transfer cases because there is no tradition for studying at other institutions or abroad.

Figure 5.4 Difficult to receive credits for subjects from other educational programs, e.g., because of credit transfer rules.



Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

Figure 5.4 shows that 73% of those persons interviewed believe that it is difficult to obtain credit for subjects taken from other programs. Eighteen percent of respondents disagree with this statement, while 9% of the participants state that they 'don't know'. Hence, there is general agreement that this is a complicating factor.

If a departmental curriculum committee accords credit for examinations passed elsewhere, it means that the student does not have to take these examinations in their home institution. In terms of the Danish payment-per-graduted system, it means that the home institution does not receive a state subsidy for these specific examinations. Credits accumulated elsewhere can therefore be viewed as lost income for the educational institutions. In this way, the economic incentives to keep students 'home' work against the students' possibility to create interdisciplinarity in his or her education. It basically 'doesn't pay' for the educational programs to award credit for study elsewhere.

5.4.2 Culture and rigid structures are an impediment to interdisciplinarity

Just as the system of payment per student progress is structured around traditional disciplinary boundaries, the educations are also traditionally organized and anchored primarily in traditional disciplinary areas. The tendency is to view the traditional disciplinary boundaries that structure educational planning and the organisation of educational institutions as being largely culturally conditioned. There are strong feelings of identity within the education sector.

This is especially prominent at universities, which are predominantly marked by organisational and discipline-based communities divided by faculty/college and with traditions that have been in place for decades. It is a marked discipline-based orientation. This tendency is less prominent in the professional colleges and business academies, which for several years, due to political influence, have been compelled to work in an interdisciplinary style, although the tendency toward clear disciplinary boundaries still remains.

In concrete terms, it means that many students who begin their educations become part of a given disciplinary tradition which in organization, practice or identity is not oriented toward interdisciplinarity, or toward other disciplines. Rather, it takes its point of departure primarily in its own traditions and ways of doing things. These factors are partially supported by the descriptions above. Of course, there is an ongoing development of the individual educations, but from the student's point of view, he or she studies from a given point of orientation, 'to be a nurse', to get a degree in 'economics' or 'to be an architect'. One does not study an interdisciplinary, individually composed education program. Educations, in other words, evolve into their own 'domain'. In addition, teachers and researchers are also carriers of the same disciplinary and 'domain' orientation for which the institution itself is an expression.

Finally, for many disciplinary communities, it is a new and thereby cultural challenge to enter into cooperation with the business sector. That certain disciplinary communities have not been accustomed to orienting their activities toward the needs of the labour market, and are therefore in a period of reorientation on this point, can also explain why interdisciplinarity is not more integrated into the culture of the educational institutions.

In practice, it means that even though structurally – e.g., in carrying out the intentions of the law on universities – students have the possibility to study interdisciplinary programs as these appear the course descriptions, and even though the student has the possibility to pursue an interdisciplinary degree on his or her own initiative, there still

Box 5.3 What do the interviewees say?

- There are all too rigid discipline-specific cultures and traditions at the individual faculties and institutes.
- There are geographic barriers. Even though the law on professional colleges has brought the number of institutions down to eight, the buildings are spread out over many localities.
- Different teaching systems make it difficult to carry out common course scheduling between the institutions. Here we should make the most rigid programs more flexible.
- The educations ought to contain project work of great 'realism', which makes visible and challenges the need for interdisciplinary understanding and engagement.
- More holistic thinking should be done in the building up of the educations, and more interdisciplinary thinking about the processes and projects in the program
- Project tasks should be established which cut across the institutions of the different educations, and innovation projects/days/workshops should be set up where focus is on bringing different disciplines together.

Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

exist cultural barriers to the development of genuine interdisciplinary communities. Box 5.3 shows comments by our interviewees.

There are indications, however, that within the educational community, there also exist cultural barriers to the exploiting the potential of interdisciplinarity which already exits, due partly to the aforementioned reforms. For example, there exists no complete overview of the students' study sequences, including the university students' use of the possibility to go on to a master's degree in a field different than bachelor studies.

Table 5.2, which only includes selected fields of study, shows that fewer students continue their studies within entirely different fields than their Bachelor education.

Table 5.2 Further educational pathways for bachelor's degree candidates from 2004, for selected fields of study

Bachelor's degree field	Continued to master's degree program with same content as bachelor's degree program.	Continued to another master's degree program within the same general area.	Continued to master's degree program within another general area.	Did not go on to master's program
English, Bachelor	73% (191)	11% (29)	5% (12)	11% (29)
History, Bachelor	84% (237)	4% (11)	3% (9)	9% (24)
Danish/Nordic, Bachelor	78% (254)	7% (24)	2% (7)	12% (39)
Economics, Bachelor	97% (274)	-	1% (2)	2% (7)
Law	99% (581)	-	-	1% (6)
Computer Science,	91% (84)	4% (4)	-	4% (4)

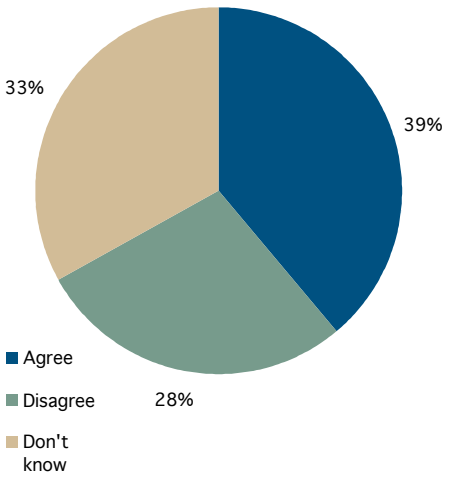
Note: The figures indicate choice of study field per October 1, 2005 for bachelor's degree candidates from 2004.
Source: Danish Ministry of Science, Department of Universities and Buildings, 2007.

There is some indication that the educational institutions have not ex-ploited the possibilities for increased interdisciplinarity, possibilities which are presently not being fully utilized. This is true not only for the 3+2 structure of the university sector (3 years' bachelor study followed by 2 years of master's in the same field) and for the possibility to combine a bachelor's program from one educational institution with a candidate degree from another. However, it also applies to the university mergers and the establishment of multidisciplinary professional colleges, which also give increased potential for interdisciplinarity.

5.4.3 Accreditation lacks focus on interdisciplinarity

In 2007, the Danish Parliament passed the law on accreditation, which entails that all higher education programs must be accredited according to criteria for relevance and quality in order to be certified or to continue to receive certification.

Figure 5.5 Lack of demands for interdisciplinarity in the certification of educations, i.e., accreditation of new educational programs.



Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

It is important that quality and relevance in educations are ensured and developed in an ongoing fashion, and the introduction of accreditation in all higher education programs will be a positive contribution to this. Accreditation is viewed as a well-suited tool for meeting the goals of the Bologna process on comparability, transparency and movement in higher education, especially in relation to the new 3+2 structures, and to strengthening the national educations as actors in a globalizing world.
The new accreditation system does not take an explicit position on inter-disciplinarity, and in the accreditation decisions, no emphasis will be placed on interdisciplinarity as an independent value. The criteria for relevance and quality do not touch on the issue of interdisciplinarity.

Figure 5.5 shows that 39% of those interviewed agree with the statement that there is a lack of requirements for interdisciplinarity in the certification of educational programs, 28% say that they disagree with this statement, while 33% answered that they 'don't know'. Hence, there is widespread disagreement about this issue.

The description of the new educational programs shows that it is often a single institution which applies for the certification of an educational program rather than cooperating with several institutions. A prominent feature of several of the foreign cases in Chapter 7 is that the interdisciplinary educations are supported by – or even implemented under – cooperation between several institutions. In Denmark, there is no significant and general tendency for cooperation between educational institutions in offering educational programs, as demonstrated by our analysis.

6 INTERDISCIPLINARITY STRENGTHENS KNOWLEDGE-SHARING AND QUALITY

6.1 INTERDISCIPLINARITY IS NOT A GOAL IN ITSELF

Interdisciplinarity in education and research is not a goal in itself. Rather, interdisciplinarity in education and research is something we must focus upon as a means of providing us with new insights and to ensure better and more relevant knowledge and competencies. We need the strengthened knowledge base if our businesses are to create increased value and competitiveness.

In the following, we focus on the benefit we obtain from investing more in interdisciplinary public research as a supplement to the conventional disciplinary research. However, it is not easy to measure the concrete effects of interdisciplinarity research, just as it is not easy to elucidate the full effects of investment in research, development and education. Research is a long-term process, and the effects of research are diffuse. They enter into a broad range of areas such as knowledge-construction among the researchers, networks with business and general scientific understandings. It makes it difficult to precisely delimit and quantify the effects of research activities and link these to specific economic and measurable effects. This is also the case for research activities which cut across branches and disciplines.

Hence, we have found few studies which examine the significance of interdisciplinarity in research and educations, even though there is an increasing interest in this area by the research community, the business sector and from the political system; see box 6.1.

Box 6.1 New study of innovation and diversity

A new study by the Research and Innovation Department, 'Innovation and Diversity', shows that within the private sector, it has great significance for the power of innovation that employees with different competencies are put together into teams to develop new products and services. The study shows that firms marked by diversity and interdisciplinarity among their employees have a 150% greater success in developing new products and services than do other firms.

Source: Department of Research and Innovation, 2007

"Higher quality in your research, better problem-solving possibilities, increased cooperation with business, increased access to funding, better education and students, higher international rankings etc."
Professor at Stanford Bernard Roth, when he was asked about the advantage of working interdisciplinary.

In order to produce new knowledge in this area, we have, in this study, analyzed whether there is a statistical association between interdisciplinarity in research communities and their interaction with and ability to obtain financing from external partners. More concretely, the figures in the analysis build upon comprehensive statistical calculations that examine whether there is an association between the Danish research communities' score on the Index of Interdisciplinarity and their interaction around research and external funding. In an international context, this method is new and provides several unique results in its elucidation of interactions in interdisciplinarity in research and the development of public research communities.

The main finding of the tabulations is that the interdisciplinary institutions more often cooperate with external partners about research and development than do those research institutions that work solely within their own research field, regardless of the type of collaborating partners, including the business community, national or international research communities. Another main finding is that interdisciplinary research communities have greater external funding of their research than do communities that work solely within their own research field. The statistical calculations are summarized in table 6.1.

Table 6.1 Statistical correlations between score on the Index of Interdisciplinarity and cooperation and external funding

Variable	Association with high score on the Index of Interdisciplinarity
Cooperation:	
With foreign research communities	+*
With other Danish research communities	+*
With business sector	+*
Financing	
Total sum (in millions of DKK)	+*
From ministries (share of total financing)	+*
From foreign sources (share of total financing)	+*
From research councils (share of total financing)	+*
From private sector (share of total financing)	÷

Note: + denotes a positive association, - denotes a negative association and denotes a significance association*
Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

Below we provide a more detailed description of the main findings from the statistical tabulations of the association between interdisciplinarity in the research communities and type of interaction as well as the degree of external funding.

6.1.1 Interdisciplinary communities are more open toward cooperation

The interaction around research and development is interesting to examine because it says something about the relevance of knowledge-sharing of the research and development which takes place in research and educational communities, including the universities, professional colleges and engineering colleges.

The study has therefore focused on the formalized interaction with other actors in research and development activities, as indicated by these research and educational communities in the 2005 research statistical data base; see box 6.2. Formalized interaction is but one of a broad range of ways in with research and education institutions cooperate with their surroundings on knowledge development. Among other forms of interaction are participation in conferences, networks and popular dissemination, which will often have a more informal character, and the sale of knowledge and offering of educational programs. Similarly, many institutions cooperate with others in conducting educational/training activities.

Box 6.2 What is formalized cooperation about research and development?

By formalized research and development is meant the institution's active participation in common projects with other institutions concerning research and development. The cooperation should also be formalized in the form of a contract or something similar, and with clear agreements regarding division/sharing of publication and rights.

Source: Danish Centre for Studies in Research and Research Policy, Research statistics for the public sector

The analysis calculates the statistical correlations between the institutions' position in the Index of Interdisciplinarity and the extent of their formal cooperation with external partners.

The main finding of the analysis is that there is a statistically positive cor-relation between the extent of formalized cooperation on research and development by research institutions and their position on the Index of Interdisciplinarity; see table 6.1. The higher the rank in the index, the more cooperation. Interdisciplinary institutions thus cooperate more often with external partners on research and development than do research institutions which work only within their own research field. This applies regardless of whether this cooperation takes place with foreign research communities, other Danish research communities or with the private sector.

The results indicate that there is more knowledge-sharing of research by interdisciplinary communities that have extensive cooperation with exter-nal partners than among communities where the cooperation is more limited.

Table 6.2 provides figures regarding the extent of the formal cooperation. The figures

show that 93% of the most interdisciplinary research communities (i.e., those cooperating across distantly related fields) has some form of formal cooperation with external partners, whereas this applies to only 71% of the monodisciplinary research communities.

If one examines the individual cooperating partners, the figures are generally higher for the interdisciplinary communities than for the communities which work only within their own fields. For example, nearly 70% of the communities where there is a greater degree of interdisciplinarity (i.e., across distantly related fields) have formal cooperation with the business sector, compared to only 40% of the monodisciplinary communities.

If one examines international cooperation, the figures show that the most interdisciplinary communities (i.e., those working across distantly related fields) have more cooperation with foreign knowledge communities than do monodisciplinary communities. Nearly 80% of the radically interdisciplinary communities cooperate with foreign knowledge communities, versus 40% of the monodisciplinary communities.

This says something about the possibility to recruit researchers back home to Denmark through an increased effort for interdisciplinarity. Interdisciplinary communities are a more effective tool for the recruitment of knowledge from foreign knowledge communities. The importing of knowledge is crucial for a small country such as Denmark, which provides only very few percent of the world's total knowledge production, and therefore cannot in itself produce all the knowledge we need. At the same time, it says something about the quality of the interdisciplinary communities in Denmark in that foreign research communities regard the Danish interdisciplinary communities as more attractive collaborating partners.

Table 6.2 The extent of formal cooperation in relation to interdisciplinarity

	Mono-disciplinary	Interdisciplinary within a single scientific field	Interdisciplinary across closely related scientific fields	Interdisciplinary across distantly related scientific fields
Coorperation (pct)				
All	71	79	91	93
Business Firms	41	53	69	66
Institutions	61	71	76	86
Outside of Denmark	43	59	73	77

Source: DAMVAD and CFA, Thinking across disciplines -interdiciplinarity in research and education, 2008.

6.1.2 Interdisciplinary communities attract the most external funding

Beyond the public institutions' basic grants, e.g., those that the universities receive from the state, institutions normally receive grants from external sources. These sources would include businesses, research councils and research foundations, and from public authorities or foreign actors, including EU grants.

The proportion of external financing differs widely across the various research communities. A research community's external funding is interesting because it provides indications about the research community's ability to attract research funds to finance its research. Hence, external financing can be an important indicator of the quality and relevance of this research and development work carried out by the given community.

The analysis calculates the statistical correlations between the institution's rank on the Index of Interdisciplinarity and the extent of their external funding, see table 6.3. The figures show a statistically significant positive association between the ability to attract external financing from actors such as ministries, research councils and foreign donors and the institution's position on the Index of Interdisciplinarity. The higher the rank on the index, the greater proportion of external financing. Taken as aggregate, interdisciplinary research communities have morer external financing of their research than communities which work alone within their own research field.

If one examines the actual figures, the most interdisciplinary communities, i.e., those which work with distantly related research areas, have, on average, double the external financing as the monodisciplinary communities, see table 6.3. The figures show that the most interdisciplinary communities on average receive DKK 430,000 per full time researcher/year versus only DKK 274,000 per researcher/year in the monodisciplinary communities.

In this connection, an interesting result is the figures for external financing by foreign donors, e.g. EU programs. The data show that the most interdisciplinary research communities received an average of DKK 67,000 per researcher/year from foreign sources, versus only DKK 34,000 per researcher/year in the monodisciplinary communities. The figures thus show a 100% difference between mono- to radical interdisciplinarity in terms of the ability to attract foreign funding. This supports the previously cited data regarding the interdisciplinary communities' potential strength in relation to internationalization and obtaining knowledge and competence from abroad.

Table 6.3 Association between funding and interdisciplinarity (in thousands of DKK/employee)

	Mono-disciplinary	Interdisciplinary within the individual scientific fields	Interdisciplinary across closely related scientific fields	Interdisciplinary across distantly related scientific fields
Source of funding (in thousands of DKK per full-time employee at the institution):				
Total	274	312	289	430
Public	105	172	155	261
Private	134	95	89	101
From abroad	34	44	44	67

Source: DAMVAD and CFA, Thinking across disciplines - interdisciplinarity in research and education

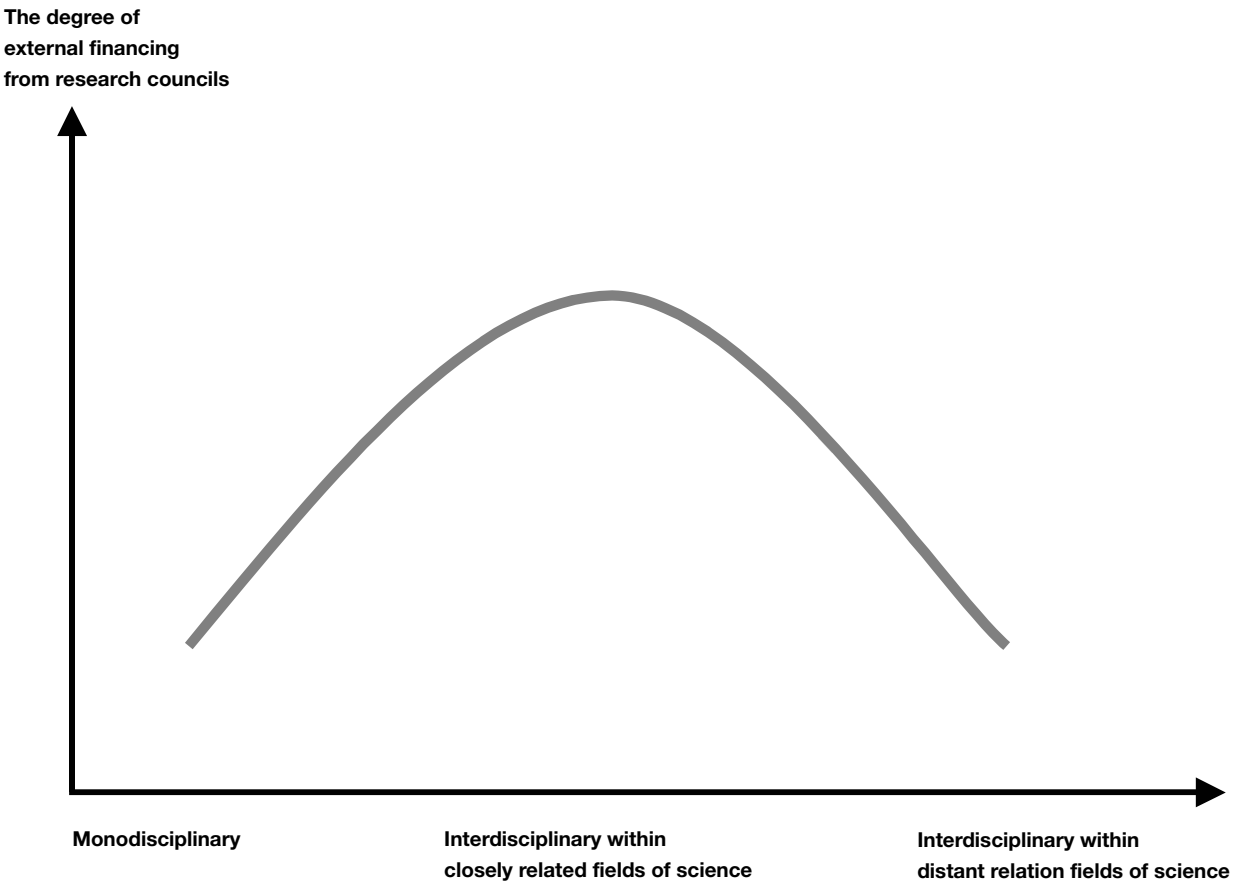
In terms of external financing of research from the business sector and the degree of interdisciplinarity, the data do not show a very positive correlation. The data show a negative, statistically significant association between the amount of external financing from firms and the research communities' score on the Index of Interdisciplinarity; see table 6.3

The data show that firms donate an average of DKK 134,000 per researcher/year to monodisciplinary research communities, while giving about DKK 100,000 per researcher/year to the interdisciplinary communities; see table 6.3 above. One explanation for this association can be that a very large part of the private funds given to public research communities in Denmark come from the medical/pharmaceutical industry, earmarked for medical and health research. However, it is difficult to cite specific figures in this area. In the foregoing section, it was shown that health science research tends to be less interdisciplinary (in Denmark) than research within the other areas, such as the technical sciences, including IT, or the social sciences.

As concerns financing from the research councils, i.e., the Danish National Research Foundation the Danish Councils for Independent Research and the Danish Council for Strategic Research, the figures are not so uniform compared to other findings of this study. The statistical data show that interdisciplinary research communities, taken together, receive more funds from the research councils, but among those communities that are classified as interdisciplinary, there is much difference.

There is much to indicate that communities with very radical degree of interdisciplinarity, i.e., communities that work across distantly related research areas, are less able to attract funds from the research councils than are communities which are less interdisciplinary. This finding lends support to the conclusions in Chapter 4 on 'interdisciplinarity in research funding', where it was pointed out that despite the research councils' rhetoric of supporting interdisciplinary projects in the research communities, projects with radical interdisciplinarity tend to receive less support. This means that the association between interdisciplinarity and external funding from the research councils can be depicted as an inverted 'U'-shaped association, as shown in figure 6.1.

Figure 6.1 Association between interdisciplinarity and levels of funding from re-search councils



Source: DAMVAD and CFA, 'Thinking across disciplines - interdisciplinarity in research and education

7

INTERNATIONAL EXPERIENCES

7.1 INTRODUCTION AND BACKGROUND

The 10 cases to be discussed below all illustrate extensive degrees of interdisciplinarity within research and education. We have analyzed 10 cases of educational programs and research communities, all of which base emphaize their interdisciplinary character We interviewed relevant persons affiliated with these areas and several of the interviewees are part of the case histories.

The cases include educational and university systems that are very different from that of Denmark. Nevertheless, several key elements are worth noting for the Danish context:

• The interdisciplinary research often thrives on relatively small centers which draw upon and link together competencies within otherwise distinct faculties and departments. In this way, mono-disciplinarity and interdisciplinarity thrive in a fruitful interaction.

• The centers are used to market the universities. The centers operate as contact points between the university and the outside world. In the centers, research is confronted with the more reality-based problems of the private firms and vice-versa. Via the centers, research and the firms thus become more transparent to each other.

• The interdisciplinary centers offer very varied forms of instruction. Some of them allow for the transfer of credits, while others offer various programs but do not give credits that can be used for the student's own program. Nevertheless, they succeed in attracting students. These are typical characteristics of the international interdisciplinary research communities and educations.

• The interdisciplinary education programs often have higher admis-sions requirements and also require that the students be of elite calibre. Generally speaking, the educations are offered by leading internation universities.

• The educational programs are frequently offered in cooperation between several institutions and often interact with other leading research and educational communities.

• The educations often build upon case-based approaches and problemoriented and applicationoriented methods of learning,

which take their point of departure in the firms' practical problems.

The cases presented here are in no way representative or all inclusive for the international spectrum of interdisciplinary research communities and educations. The selection of cases occurred on the background of prior knowledge among the investigating team, supplemented by referrals from interviews and resource-persons who were part of the study. Nevertheless, we believe they are representative of some of the best practices in the area of interdisciplinary research and education.

Table 7.1. presents a summary of the ten case studies.

Program	Field	Institution
Honours Degree in Technology Management	Digital high technology and management. Elite program	Ludwig-Maximilians-Universität and Technische Universität München.
Bachelor of Engineering	Environment and sustainability. Economics/business and engineering.	Fachhochschule für Wirtschaft, Berlin, and Technische Fachhochschule, Berlin.
Materials, Economics and Management (MEM), bachelor program.	Materials technology combined with knowledge of theories and practices of management. Broad education.	Oxford University, UK
Master in Bioscience, Biomedicine and Society (BBS)	Focuses on influence of biomedicine and biotechnology on the social science area. Broad education.	London School of Economics (LSE).
Leaders for Manufacturing program (LFM). Program awards an MBA or Master of Science	Economics/business and engineering science. Elite program.	Massachusetts Institute of Technology (MIT).
Research	**Field**	**Institution**
Center for Information Technology Research (CITRIS)	Information technology for improvement of human conditions and development.	University of California at Berkeley, USA.
Human-Sciences and Technologies Advanced Research Institute (H-STAR)	Improvement of interaction between people and technology by developing more user-oriented technologies	Stanford University, USA.
Stanford – d. school.	Cross-disciplinary design thinking.	Stanford University, USA. Institute of Design.
The Media Lab	Development of technology which can create a better future for people and people's view of technology.	Massachusetts Institute of Technology (MIT), USA.
Media and Graphics Interdisciplinary Centre (MAGIC).	Computer-based and computer-associated media.	University of British Columbia, Canada.

Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

"I enjoyed working in an interdisciplinary team which was able to leverage its individuals' knowledge to shape products from a very first idea to a functional prototype within just 4 months." Student.

7.2 PRESENTATION OF THE 10 FOREIGN EXPERIENCES - EDUCATION

7.2.1 Ludwig-Maximillians-Universität and Technische Universität München

- Honours Degree in Technology Management

Interdisciplinarity is not about 'soft' group work, sitting around talking and superficiality. In Bavaria in Southern Germany, it is about ruthless competition, hardnosed training, hard work and concrete results when finished. Interdisciplinarity here is about mastering several scientific areas in order to be able to move readily around in the border zone between them. What is required is nothing less than double the workload as that of a normal university degree.

GOAL-ORIENTED TEACHING

The above summary encapsulates the essence of the two-year Honours Degree in Technology Management, an interdisciplinary education program which brings together the technical/natural sciences and the commercial programs. Here the students learn how to move around in the area between high technology and business understanding, thus becoming equipped to be leaders in business environments where knowledge of these areas is essential. The education takes place at the Center for Digital Development (CDTM), a cooperative endeavour between the two southern German universities, Ludwig-Maximilians-Universität and the Technical University in Munich.

The curriculum distinguishes itself from traditional coursework by not being disciplined-defined, with courses such as 'biology' or 'quantum physics'. The instruction can best be labelled as goal-oriented, where students are not kept within separate disciplinary boundaries. Instead, there are subjects such as 'Web 2.0' or 'Mobile Technology'. This means that many different areas are included in order to solve the problem. The course in 'Mobile Technology', for example, does not simply include electronics and technology, but also sales, user-friendliness and cost management. This poses very high demands on the student, because it is in fact expected of them that they master the relevant areas, so that there can be a genuine critical dialogue which is not controlled by the disciplinary-based, 'nerd' experts. The universities complement this with an extra amount of teaching, so that it becomes possible for the student to master the various fields. The program's action- and solution-oriented character can be seen in its organisation, which is divided into the following four areas: technology management, product development, entrepreneurship and marketing.

INTERDISCIPLINARITY REQUIRES AN ELITE

CDTM's attitude toward interdisciplinarity is very clear: only individuals with exceptional abilities are able to work in a truly interdisciplinary way. The student must be able to master the relevant areas in order for the interdisciplinarity to 'work'. That this requires hard work seems to be the mantra among the universities.

It is extremely hard work, when one observes that the program is set to 56 ECTS (nearly 4 normal semesters) and that this is be carried out alongside the normal studies of the candidate degree (also 4 normal semesters). That is, that the student must complete what amounts to a four-year program in two years. At the same time, the program does not have the status of a bona fide educational degree program, as the

student does not receive a degree in 'something', but simply a certificate of completion. That the quality of the education must be high and the potential great afterwards is necessary in order to convince the students to withstand such conditions. That this is not any problem is indicative of the solid nature of the program and the recognition it has received.

Very hard work can be carried out only by very gifted students. This explains why CDTM has very strict admissions procedures. That we are talking about an elite appears clearly when one observes that only 20 students are admitted per year, and that only 10% of graduates from any one class year are considered for admission. The admissions requirements include a required minimum of six months' work experience, residence abroad, a statement of motivation and two rounds of oral interviews.

SIEMENS, MIT, VODAFONE, BERKELEY AND BMW

Throughout the entire educational program, the firms are fully included, appearing as guest lecturers and acting as advisors and coaches. During the program, the student must either enter a business internship or participate in an exchange program. The business internship often takes place among high profile firms such as Siemens, Vodafone and BMW. Alternatively, the student can go abroad, typically to the best European, North American or Asian universities, such as Berkeley, MIT and Wadeda University in Tokyo. While on an exchange program or firm internship, students receive administrative and financial support from CDTM.
By the end of the program, it is not surprising that the graduates have been offered jobs by a major international firm. Such firms might be the large international corporations such as Siemens, Vodafone or BMW or a well-known consulting firm such as McKinsey and Co. or Boston Consulting Group. The remainder of the graduates, about 30%, go on to doctoral studies.

THE BASIC STRUCTURAL CONDITIONS: THE ELITE NETWORK

The Elite network (Elitennetzwerk) was established in 2004 by the Bavarian state government. The program is a major political initiative, the goal of which is to have more than 2000 students, together with the establishment of over 220 academic positions of world class calibre. From the political side, the desire is to turn the brain-drain into a braingain, which is the background for their having invested the equivalent of DKK 100 million in this program.

The network bears the mark of being a decentralized knowledge-disseminator and network-creator, with enough resources to be significant for academic developments in the area. The goal of the network is to establish network-based elite training between places with an already strong and established research tradition.

This policy initiative can very well help to place Bavaria, which is already a financial node, on the map. Both the Ludwig Maximilians Univeristät and the Technical University in Munich have rapidly moved up in the international university rankings (Times Higher Education) from, respectively, 98th and 82nd in 2006 to 65th and 67th in 2007.

7.2.2 Fachhochschule für Wirtschaft Berlin - Business Engineering

There are many reasons to move to Berlin, and this educational program is perhaps

Link: http://www.cdtm.de/

"... I am enjoying the wide content afforded by the mixed course. Engineers learn how to make a system work but, as scientists, we learn why things work and I enjoy developing this perspective. I am also enjoying the Economics and Management side of my course. It is very interesting to look at Economic problems..." *Student.*

one of them. The training of engineers with competence in the social sciences lies at the heart of the transition between the new and old Europe. The training offered here is in environment and sustainability with an interdisciplinary foundation.

Interdisciplinary and practical/academic
The goal of this program is to give students a Bachelor of Engineering degree with interdisciplinary properties in 3.5 years. The program is offered in cooperation between the Fachhochschule für Wirtschaft Berlin and Technische Fachhochschule Berlin.

The students are trained in economics/business and engineering. As such, they are equipped with interdisciplinary qualifications and key competencies. Among the obligatory social science courses are statistics, marketing, and economic management, while computer engineering, chemistry and mechanics are taken the technical/scientific subjects. The program contains both an academic component and a more hands-on component. The basic component is the most academically oriented, where the students learn basic economics and engineering skills, while the main component consists of an obligatory internship semester. The internship semester consists of economics and a natural science sequences and various optional specialties. Applicants to the program are expected to have good mathematical and natural science skills. In addition, all prospective students must complete a technically-oriented preparatory sequence. In addition, it is expected that they have reasonably good English skills, as the courses are conducted in both German and English.

THE PERFECT COMBINATION

The combination of technical and economics/business-oriented competencies is not entirely atypical among the interdisciplinary programs surveyed here. There is clearly both a market and an interest in equipping engineers with business-oriented skills and business candidates with technical skills. The difference in this program and others of the same type is the specific focus on environment and sustainability, an area which is currently high profile. The program places emphasis on teaching the student to be able to understand the general and global changes in the environment. The schools describe themselves as 'environmentally oriented', which means that all areas of the program must prepare the graduates for their subsequent work and career in business. The schools are also very active internationally, with more than 70 partnerships abroad in exchange and research cooperation arrangements, including countries such as China,

That the education is very attractive derives from the combination elements in the program. Work is carried out in an interdisciplinary fashion, topical areas such as environment and sustainability are popular, focus is on teaching the student to be prepared for change and finally, the practical experiences that form part of the program all play in role in encouraging students to select this program

A graduate of the Business Engineering – Environment and Sustainability program can look forward to a career in a German or international firm within the fields of environment, development and sustainability. In many cases, the new graduate will find employment in a firm where they worked during their internship semester. The Fach-

hochschule für Wirtschaft Berlin has cooperative agreements with 480 firms, all highly motivated to utilise the students.

The two schools which have established this joint program both have good reputations in Germany. The cooperation is largely professionally divided, with the Fachhochschule für Wirtschaft Berlin responsible for the 'soft' areas such as economics and business training, while the Technische Fachhochschule Berlin handles the 'harder' technical and natural science areas. Therefore, there is no costly and administratively cumbersome program, as the cooperation is mainly at the disciplinary level and requires only slightly more in coordination costs than having a regular student. The skills acquired by the graduate do not suffer under this division, as the subjects studied at the two schools complement each other so well and are selected so as to enter into this program.

7.2.3 Oxford University - Materials, Economics and Management (MEM)

Without saying so directly, the MEM program at Oxford University is clearly a management training program within the technical field. Alongside subjects such as materials structure, the students have career planning and are virtually pushed out into the business world during their studies.

THE EVIDENT INTERDISCIPLINARITY

The training in materials science is itself interdisciplinary, lying as it does between the natural sciences and the technical sector. Subjects such as physics, chemistry, mechanics and mathematics come together in the disciplines of engineering science and materials science. In addition to subjects which are taken at the Department of Materials, the faculties of the Department of Economics and the Said Business School are also included, and teaching is also carried out in management and economics.

The blending of these three different areas produces a Master's of Engineering degree that enables the student to manage projects within the engineering and finance sector. Hence, while the first part of the education concerns mostly materials, mathematics and the like, the focus slowly changes towards more business-oriented subjects. In the fourth year, the coursework is mostly in fields such as accounting, marketing and strategic planning.

The finished candidate will be able to effectively lead projects because knowledge is obtained within all the relevant areas. The MEM graduate can discuss cement mixing while also knowledgeable about the strategy for financial management. As project manager, the MEM graduate becomes a specialist within precisely the relevant areas. The program evades the scenarios whereby the new manager does not have respect because he or she lacks professional expertise, or the specialized 'nerd' manager who has technical knowledge but cannot manage.

Admission to this program requires a very high level from secondary school, as there are high requirements for grades and for the courses studied. It is recommended that the student already have completed the highest level courses in mathematics, physics and chemistry. Prior to admission, the student will also be interviewed by the admissions committee. Only a few students are admitted to the program. The entire Department of Materials admits 30 students per year, divided between Materials Sciences and the

Link: http://www.fhw-berlin.de/index.php?id=276&L=1&L=1

MEM program.

OUT INTO THE REAL WORLD FROM THE FIRST DAY

Factory visits, career planning and summer projects carried in firms are integral elements of the four-year Master of Engineering, Materials, Economics and Management (MEM) program at Oxford University. Large parts of the program aim to get the students out into 'real life'. This goal of getting the students into contact with and working in firms is revealed if one casts a glance at the program's organisation, which beyond the general theoretical subjects contains:

- Project work with firms during summer vacations for 6 weeks (years 1,2,3)
- Career planning (year 1)
- Industrial visits (year 1)
- Industrial visits (years 2,3)
- Industrial talks (year 2,3)
- Career fairs (year 4)
- Concluding six-month management project within a firm

The education is also structured so that the finished candidate has a suitable job profile. As such, the intensive involvement of private firms gives the student the possibility to really determine which qualifications are important when the education is finished, at the same time as the established network between firms and students is consolidated. It is not any kind of firms that take in the MEM students. The following are examples of companies which have had students in internships while they were writing up their project assignments: Benetton (Formula 1), Shell UK, Citibank, and Ford Motor Co. The project work in the firms is serious. Emphasis is placed on finding the appropriate firms which in fact are prepared to receive the students and to give them a base from which to conduct their work. The most recent places in which students have worked are Beijing, Colorado, Santa Barbara and of course various towns in Great Britain. This shows that the school's students clearly have an impact which is recognized by the firms. That the school views the firm visits as an integral part of the education and not simply a 'break' from the studies means that they are willing to send them abroad 'just' to make a visit to a firm. The most recent destinations for such visits have included Beijing, Munich and Toulouse.

On completing their educations, the MEM students can work practically any-where. An overview of the first job placements for several graduates shows that they have obtained work in everything from oil companies, accounting firms, the military and among investment banks. This underscores the fact that the interdisciplinary approach, combined with the high admissions requirements and coursework, ensures that the candidates can be employed nearly anywhere on completing their educations. Somewhere between 33 and 50 percent of the students choose to study further, either by taking a doctorate or a further one-year master's degree. However, most of the students go directly out into the real world, and rightly so, since there are good jobs waiting for them.

7.2.4 London School of Economics - Master in Bioscience, Biomedicine and Society

Advances in the technical and natural sciences are so great that they often intervene directly in our society; both at the individual and collective levels. We can optimize pro-

Link: http://www.ox.ac.uk/admissions/undergraduate_courses/courses/materials_economics.html

duction of agricultural goods with the help of genetic manipulation, or we can decide whether an unborn child is healthy enough to allow it to be born with the help of risk assessment and amniocentesis. The paradox is often that science forces us to take an ethical position on issues that we have not previously faced.

ONE-YEAR MASTER'S PROGRAM WITH FOCUS ON ETHICS

This topic has typically been studied from a mono-disciplinary perspective, but the London School of Economics (LSE) is attempting to change this tradition. They want to actively link the social sciences with developments within the health sciences and technical fields. The rationale here is that paradoxes such as these have obtained increasingly greater influence, and in the coming years will become even more pronounced.

Therefore, LSE offers a one-year Master's Degree in Bioscience, Biomedicine and Society (BBS), where the object of study is precisely this interface between the technical sciences, medical sciences and society.

AN INFINITE NUMBER OF PROBLEMS

The value of the program is that all the disciplines are given the opportunity to contribute with their insights to the program of study. The program equips the students to work within, for example, policy development or lobbyism, where it is necessary to understand the technical sciences in order to understand the consequences it will obtain for people and for society as a whole. If one understands how medical science conducts a risk assessment of a foetus, it is also easier to optimize the legislation around this issue; for example, by specifying the term limit for abortion. At the same time, it is also easier to discuss these issues with representatives of the technical sciences.

This is simply one example of what is studied, but in reality, the problems touched by the program are infinite. Many topics are studied using international approaches, such as that of multinational systems of regulation. At BBS, there are untapped potentials for what can be studied under this interdisciplinary umbrella, which is offered by the Department of Sociology in cooperation with the Center for the Study of Bioscience, Biomedicine, Biotechnology and Society (BIOS). Hence, topics such as the cultural con-struction of the body, sustainability in economics, trade and technology and regulation of new medical technologies are also studied under the interdisciplinary approach.

CULTURAL AND PROFESSIONAL MELTING POT – AND OBLIGATORY COURSES

The program is offered as a full-time and part-time education and takes, respectively, one or two years. BBS has two obligatory courses:

- Key Issues in Biomedicine, Bioscience and Society
- Key Methods in the Social Study of Bioscience and Biomedicine

The course on Key Issues in Biomedicine, Bioscience and Society gives an introduction to different areas within research and the social problems when the health sciences and technical area are to be developed. It is an interdisciplinary course where different social science perspectives are reviewed on developments within DNA research, fertility treatment, neurology and pharmacology. The course on Key Methods in the Social Study of Bioscience and Biomedicine includes

"My next stop after Oxford Materials, Economics and Management (MEM) has been the venture capital arm of Siemens … Whilst I am not likely to be called upon to design a state of the art aircraft wing anytime soon, the knowledge I gained through the Materials course stands me in good stead to understand the intricacies of technologies we are investing in." Student.

a theoretical and practical introduction in quantitative and qualitative methods at a higher level. Besides the two obligatory subjects, the students choose an optional field of study among 30 possible choices.
In a way, the breadth of problem fields recurs in the professional and cultural diversity. Even though the program admitted only 16 of 42 applicants in 2006, the BBS can best be described as a cultural and disciplinary melting pot. The students can have a medical or bioscientific background. They can come from sociology, law or economics. At the same time, they come many different countries. Common to the student group is that they concentrate on topics where technology obtains consequences for society, and that they have a high professional level within their specific fields.

RESEARCH-BASED VALUE-ADDED

The education has a high professional level, as it draws on knowledge from the BIOS research center. BIOS was established in 2002-03 and also has an interdisciplinary approach. The center is a joint initiative between the Departments of Sociology and Social Psychology at LSE and is supported by the Departments of Government and Law and the Centre for Philosophy of Natural and Social Sciences.

About 20 researchers from different faculties are affiliated with the center. Research is conducted on social, legal, ethical, political and economic aspects of the health sciences and the technical sciences with a special focus on developments within biomedicine and biotechnology. In the composition of the research team as well, the international aspects play a role. The affiliated researchers come from universities all over the world. BIOS is part of the research cooperation with Bionet (Ethical Governance of Biological and Biomedical Research: Chinese – European Co-operation), ENSN (European Neuroscience and Society Network) and PLSSG (Postgraduate Life Sciences and Society Group).

The affiliation with the research center ensures that the students attain a high professional level. The researchers function as teachers within the program, and at the same time several seminars and conferences are arranged which exploit the center's international network. For the student, there is also the possibility that they can carry out empirical studies within a given topic.

7.2.5 Massachusetts Institute of Technology - Leaders for Manufacturing

Interdisciplinarity works when it can be used in business. This is the idea at the Massachusetts Institute of Technology (MIT), which has developed a two-year supplementary 'Leaders in Manufacturing' program, which is organized and conducted in close cooperation with the business community. The purpose of the program is to equip the students with interdisciplinary key competencies in economics/business and engineering, which are directly useful in business.
What will technology managers be managing?

The graduates will take up management positions where their interdisciplinary competencies can be of greatest value. Because the education supplements technology with business understanding and psychology, the value will be created because of the ability to combine knowledge from the three areas. For example, by providing a technician in software development with the ability to analyze marketing potential for computers. Here it is not enough to be an expert in

Link: http://www.lse.ac.uk/resources/graduateProspectus2008/taughtProgrammes/MScBiomedicineBioscienceandSociety.htm

software technology or market analysis. One must be an expert in both areas. I addition, one has to be able to manage. Here the tools from psychology come into play. In order for leadership to succeed, the manager has to motivate and manage toward change.

The value of MIT's interdisciplinary program, therefore, lies in its training of students to look forward, to the marketing possibilities of the future, to link them to the firm's production factors, and to manage the strategy. The students obtain two degrees: Master of Science from the MIT Sloan School of Management and a Master of Science from the School of Engineering. On completing the two-year program, most of the graduates pursue a career within industrial or operational firms. The typical positions are those of product manager, operations manager, or supply chain/material quality manager.

THE FIRMS DETERMINE ONE-THIRD

Unique to this program is that the students obtain interdisciplinary competence by the firms being included in their educations. The program is managed jointly by three parties: the School of Engineering, the School of Management and various participating firms. The tripartite management develops the educational elements of the program. This means that the firms, which occupy a third of the seats around the table, obtain great influence on the form of the program and thereby also on the students' qualifications. The firms can thus make an impact on the kind of qualifications they want the students to acquire.

It is not only through their participation in the curriculum that the firms are major players. The development of professional competence also occurs with the direct inclusion of the firms in the students' education. For example, each student must undergo a six-month obligatory internship with one of the business partners, attempting to solve a problem formulated in cooperation with the firm. A typical problem would be to compare methods for deciding the quantity of production a software firm.

At the same time, the students are continually trained to convert theoretical knowledge into practice through visits to firms and from experts from industry who visit the program and give lectures for the students.
The visits to the firms are an important part of the training and are conducted both in the summer semester and in January, where there is a two-week intensive business internship. In January 2007, students made study visits to the Ford Motor Company (Detroit), General Motors Corporation (Detroit), The Boeing Company (Seattle), Amazon.com (Seattle) and Honeywell (Phoenix).

A POPULAR PROGRAM – AMONG FIRMS AND STUDENTS

The firms involved in the program are very active in the hiring of the graduates. Most of the graduates obtain jobs among the program's industrial partners. This means that the program succeeds in training the students according to the demands of the business community, and that the students and firms, through the program, establish networks that help the students find good jobs when they graduate.
The program meets a demand. The students are enthusiastic about the program, which each year receives about 200 applicants for 40-50 places.

If one examines the partner firms that participated in this tripartite arrangement, there

"This pioneering MSc programme offered by the BIOS centre concentrates on the regulation and ethical issues raised by biotechniques. It responds to the developmental paradoxes associated with bioscience that perplexed me during my medical science training in Beijing." *Student*

is no doubt that the firms see it as a very relevant form of education. The 25 partner firms include 'heavyweights' such as the Boeing, Dell, Intel and Motorola.

HIGH ENTRANCE REQUIREMENTS

In order to be good at combining interdisciplinary fields, there must be a solid professional foundation. Students applying to the program must therefore not only have a solid background in a technological discipline but also business experience. As a prerequisite for admission, the program requires that applicants possess a bachelor's degree in some technical field, such as biology, chemistry, computer science or physics and a minimum of two years business experience. The business experience counts just as much as the academic qualifications and students with three to five years' business experience are preferred.

7.3 PRESENTATION OF 10 FOREIGN EXPERIENCES - RESEARCH

7.3.1 University of California, Berkeley - CITRIS

'The firms do not know what is going at the universities, and the universities do not know what the firms need.' This problem is heard often. A solution was found at UC Berkeley, not far from San Francisco.

CONTACT POINT BETWEEN THE UNIVERSITY AND THE OUTSIDE WORLD

In 2001, the University of California at Berkeley established a new, comprehensive interdisciplinary research center, called CITRIS, the Center for Information Technology Research in the Interest of Society. CITRIS is a collaborative research endeavour bringing together four California universities: Berkeley, Davis, Merced and Santa Cruz. The objective of CITRIS is to develop information technology which can contribute to solving pressing social, environmental and health-related problems in society. A total of 200 researchers are affiliated with CITRIS, coming from a large number of different institutes in the four collaborating universities.

CITRIS functions as a point of contract between the university and the outside world. In this way, university research becomes visible to the outside world by being related to current social problems, while the outside world becomes visible to the researchers by highlighting the demand for research results. CITRIS is one among many centers and institutions in the American university system which acts as a point of contact between the university and society.

CITRIS' research activity is organized around specific themes:

- Delivery of Health Care
- Energy and the Environment
- Humanities and the Arts
- Intelligent Infrastructure
- Service Science and Technology
- Technology for Emerging Economies

Within these themes, CITRIS offers assistance so that researchers and the outside world can find each other. This is done by offering possibilities to find seed money in order to work out ideas for new centers, assistance in creating contacts with relevant researchers at other institutions and help in forming contacts with strategic partners who can ultimately assist in financing projects for their full cost.

Link: http://lfm.mit.edu/

FLEXIBLE ORGANISATION PERMITS RAPID RESTRUCTURING

The researchers who contribute to the individual themes maintain their affiliation to their home institutions but contribute to the projects under the common center while also providing lectures and advice to the students. The center, located in Berkeley, consists of a relatively small secretariat, from which there are affiliated researchers, who, with a base in their home institutions, occupy various positions in the common center. There are also affiliated students at master's and doctoral level, but they must always have an advisor from their own faculty. CITRIS participates in a cooperation arrangement with the Haas School of Business and the School of Information Management and Systems to develop a joint master's program for students at the three colleges. Thus, there is a very flexible organisation which makes possible rapid restructuring and adaptation of the research agenda to new problems. The flexibility also involves those students who, via their education at the respective home institutions, must be able to qualify themselves to study at the center and obtain a degree from it.

CITRIS thus functions as an umbrella organisation for a number of smaller networks, all of which focus on more specific problems or more directly enter into the organisation of political meetings, policy discussions etc. An example of such a network is C-GRACE, the CITRIS Global Research Alliance for Climate and Energy, which is involved in preparing the forthcoming summit on climate change, to be held in Copenhagen in December 2009. The network offers possibilities for academics, business people and policymakers to come together and discuss common problems. As preparation for the Copenhagen climate change summit, C-Grace is arranging two conferences in Copenhagen, in June 2008 and May 2009, where common possibilities of action can be elucidated and discussed.

INTERDISCIPLINARITY AS A PRECONDITION

The problems that CITRIS has chosen to focus upon can very well be elucidated from the perspective of the individual participating disciplines. However, the understanding of the problem and the potentials for solutions are developed in collaboration between the disciplines, and it is here that better and more sophisticated solutions can emerge. Therefore, there is no advance selection of relevant disciplines or other barriers placed on who can contribute to the center's work. Nor are there limitations on which firms can be members or finance the center. The linkage occurs in specific projects where CITRIS helps link together researchers and external partners. The students can be trained for jobs in the oil industry or in an environmental advocacy organization.

BUSINESS INVOLVEMENT, ALSO IN THE START-UP PHASE

CITIRS is financed by the State of California, the University of California, and by contributions from private firms. Seventy-two percent of the financing goes to research, while the remaining 28% is used to operate the center. There are 60 affiliated firms who contribute at different levels. A small number of large firms, such as IBM, Microsoft, Ericsson, HP and Intel, helped to start CITRIS and have chosen to contribute more general funding not linked to specific projects. This allows CITRIS the possibility to allocate seed funding to promising projects. The firms give not only financial support, but also offer

possibilities to solve special problems and make available data for the students. A small number of firms donate funds and are directly linked to specific centers and projects relevant to their own business sector.

7.3.2 Stanford University – H-STAR

What happens when people encounter technology? Either the individual loses because the technology is too difficult, or the individual fully masters the technology. H-STAR takes it point of departure in the latter approach, and as it is difficult to make all the people in the world better at applying technology, it is the technology that must be made simpler.

H-STAR AS AN UMBRELLA

H-STAR is an abbreviation for the Stanford University's Human-Sciences and Technologies Advanced Research Institute. H-STAR was set up in 2005-06 and, like CITRIS, operates as an umbrella for several centers and programs. The most important centers are the Center for the Study of Language and Information (CSLI) and the Stanford Center for Innovations in Learning (SCIL).

A FORMIDABLE TASK

H-STAR has set itself a formidable task: today's technology accords fantastic possibilities for those who have access to it and can utilize it. The people who would experience the greatest change by utilizing modern technology, however, are those who, having obtained access, would not be able to utilize it. There are two ways out of this dilemma. One is to initiate a world-wide program for the dissemination of reading skills and technological skills. The other is to design technologies so that they can be used by everyone regardless of their skill level. H-START has the latter as its goal, and under this very broad purpose, H-STAR focuses on five research agendas:

- Reducing the complexity of technology so that it can be applied universally.
- Overcoming the various digital divides so that everyone, regardless of social class, race, gender, age and nationality can obtain access and learn to master technologies.
- Accelerate innovation in creating and disseminating products and services which meet people's needs.
- Solving security and trust problems within the computer, communication and information systems.
- Assuring comprehensive security and health for people through their entire lives with human-centered technology innovation.

All these agendas require a close interaction between the traditional soft sciences centered on learning, communication, etc. and the traditionally hard sciences of technological development. According to Keith Devlin, one of the founders of H-STAR, it is the firms who are seeking out this collaboration. 'In my experience, industrial partners and sponsors have been the ones who most often declare particular hard-soft collaboration as valuable.'

VISITING PARTNERSHIPS, ALSO FROM DENMARK

H-STAR attempts to optimize research by having several partners with whom they can collaborate and evolve with. Therefore, both

Link: http://www.citris-uc.org

international cooperation and inclusion of firms are important sources for developing solutions.

In order to carry out this international co-operation, H-STAR has established visiting partnerships in which H-STAR cooperates with researchers from other universities. The cooperation extends from a few weeks up to a year, where the visitor works closely with Stanford's own people, and both parties obtain the possibility to benefit from each other. The most recent international partners include the Finnish Technological Institute, TEKES, Mitsubishi Electronic Company and the Danish Government's Department of Research and Innovation. For Denmark, this has meant a possibility for exchange and cooperation between H-STAR and Danish universities.

The inclusion of firms occurs through a special partnership program, the Media-X industry partnerships program. This program contains about 25 large and strategically important firms, which can participate in seminars, workshops and annual meetings, but can also participate more directly in projects and have interaction with their own technicians and researchers around special topics.

MORE AND MORE EDUCATION

H-STAR is a pure research center, but it also contributes to several different educational programs at undergraduate, master's and doctoral levels. At the post-graduate level, a master's program is offered in Learning Design and Technology (established in 1999), whereby the students are trained to be able to teach and research in the use of technology in education. Also offered is a master of science degree in Human-Computer Interaction, which focuses on innovation and improving user-centered design through questions such as 'How do we design for users?' and 'Is a keyboard and a mouse the best we can do?'

In addition, H-STAR established, in 2002, a doctoral program in Learning Sciences and Technology Design. The education is directed toward a systematic study of design of the psychological, social and technological processes that support learning in different contexts and generations.

7.3.3 Massachusetts Institute of Technology - The Media Lab

The Media Lab at MIT should really be called the 'school for inventors'. The firms are enthusiastic about the project and have given it 100% financing. The students are also wild about the project, and they start up firms on the spot, both during and after completing their educations.

'Large firms are themselves interdisciplinary'
The Media Lab was founded at MIT in 1985. The focus was on high-tech, but practical, solutions to human everyday problems. At the Media Lab, they believe that interdisciplinarity helps to attract firms because it reflects the way in which they work.

Many firms have seen a great potential in the Media Lab, which makes it unique and has led to 100% private financing. Each year the Media Lab receives around DKK 160,000,000 in outside financing from about 60 firms. In return, these firms are integrated into several projects and management groups which conduct their work within the framework of the Media Lab.
The Media Lab has specific programs where firms can purchases different degrees of influence in the projects. There exist four

Link: http://www.stanford.edu/dept/h-star/cgi-bin/hstar.php

levels of purchase: Graduate Fellow, Consortium Sponsor, Consortium Research Sponsor and Corporate Research Sponsor. In the programs, the firm can have their employees placed in the house, obtain brainstorming days in the firm's name, utilise research staff, etc. The most expensive program costs USD 700,000 a year for a minimum of three years. At the same time, the firms achieve a part of Media Lab's right to the inventions made at the school.

AN INNOVATIVE CULTURE CREATES INNOVATIVE STUDENTS

The interaction with the business community is achieved not only through the firm's involvement in various research projects. The Media Lab is itself a breeding ground for new innovative talent. It is oriented toward establishing spin-off firms and likes to point to a series of new firms started by current or former students. They have also achieved more than 100 patents, with another 100 patents under review.

The research effort is divided into 30 groups, each group being led by a senior researcher. The groups participate in different research projects which are again divided into different consortia, where firms, other MIT departments and foreign universities take part. A research group typically participates in more than one consortium, and this is one way to assure a high degree of interdisciplinarity. In total, there are more than 300 research projects.

THREE STEPS IN THE DEVELOPMENT OF THE MEDIA LAB

Since its founding in 1985, research at the Media Lab has moved over three major themes:

- In the first decade, focus was directed toward technologies which could make possible the digital revolution and promote the possibilities to express oneself digitally. Work was carried out on topics ranging from cognition and learning to electronic music and holography.

- In the next decade, focus was directed toward integrating the computer into the physical world. Work was carried out with many different topics such as wearable computing and wireless communication, thinking machines and new forms of artistic expression, and new approaches to understanding how children learn.

- And in this current decade, focus is on 'adaptation to people'. This is done through projects ranging from managing conditions such as Alzheimer's and depression, to social robots which can monitor the health condition of children and the elderly to the development of smart prostheses which can imitate or perhaps even surpass the ability of human limbs.

THE WORKSHOP APPROACH, AND 'WHAT IF...?'

Even though Media Lab is very research oriented, it also contains, in contrast to other such laboratories at MIT, a sizable teaching program at the master's level. The program in Media Arts and Sciences (MAS) has 70 students and a doctoral program with 65 students. In addition, there are various opportunities available to bachelor's level students to be involved in project work or participate in lectures, and there are about

150 bachelor's students in the program. Considerable resources are used in the teaching program, and as such, there are about 40 teachers and 70 administrative employees linked to the Media Lab, which gives it a much higher teacher/student ratio; this is a reflection of the priority on disseminating knowledge to the students.

In the teaching, great emphasis is placed on 'What if...?' and 'How do we...?', while the classroom work takes the form of workshops, with an emphasis on breaking down traditional disciplinary boundaries. At the same time, emphasis is placed on recruiting staff who do not fit in under the traditional disciplinary boundaries. To fall outside or between traditional disciplinary boundaries is viewed by the Media Lab as a positive attribute. The greatest strengths of working interdisciplinarily are the genuine innovation which emerges by accepting and being excited by ideas which come from unexpected places. It gives the capacity to be able to tackle problems which cannot be solved within the traditionally defined disciplines.

The Media Lab is located in a single building, where students, teachers and researchers have access to high-tech equipment such as 3-D printing, electronic manufacture and quantum computers. This is all connected by a gigabit-net which enables easier access to the different parts of the school and its technologies.

7.3.4 University of British Columbia - The Media and Graphics Interdisciplinary Centre

Where, how and when and for whom is technology an appropriate solution? These are the questions that MAGIC in Canada seeks to answer. In this innovative center, advanced theories about human beings come together with cutting-edge technology from the media world and computers.

Human/computer interaction and multimedia MAGIC is an interdisciplinary center at the University of British Columbia (UBC) in Canada. The center functions as a contact point for ideas, at the interface between the human/computer interaction and multimedia. It brings together researchers from both the soft humanities areas and the hard technical areas. The reason for this is that it is necessary to have knowledge of human perception, cognition and behaviour, as well as knowledge about technical design, usefulness in science and industrial processes.

PROJECT ORGANIZATION LIMITS THE NUMBER OF STAFF

When a project starts up, the network is used to recruit the best people and bring in the most appropriate facilities. The projects can thus be anchored in different places at the university, all according to the project's requirements for equipment. This project organisation enables MAGIC to operate with only nine permanent staff, while 40 affiliated researchers are brought in according to need in the specific projects that are initiated. The center has 12 ongoing projects, of which one of the most interesting and comprehensive is 'Visual Analytics'. Visual Analytics deals with possibilities to produce better information through a linkage of humans' visual intelligence and computer tools. Visual analysts utilize a broad range of computer techniques and models to produce prompt, defensible and understandable assessments of complex situations which can function as bases for decision-making for relevant decision-makers.

Link: http://www.media.mit.edu/

NATIONAL EFFORT AND FIRMS THAT CAN PURCHASE INFLUENCE

The project is part of a larger national initiative to build up Visual Analytics as a Canadian field of strength. In this connection, the Canadian Network of Visualization and Analytics Centers (http://cnvac.ca) has been established, in which MAGIC and the University of British Columbia play a key role.
The project requires participation from researchers from several academic disciplines, covering both the hard and the soft sciences. More specifically, it involves researchers from the following disciplines: applied mathematics, graphic computer design, information visualization, cognitive science, humancentered information management and computer science.

MAGIC cooperate with industrial partners on research and development initiatives. The firms are involved at several levels. The center assists primarily with identifying and bringing together industrial research projects and academic experts. In addition, MAGIC helps administer research projects and secure grants from relevant government programs. The firms and individuals can increase their influence on MAGIC's programs and methods by joining MAGIC's board. This can be done by entering into a more long-term sponsor arrangement. MAGIC also encourages its industrial partners to participate in the center's 'Researcher in Residence' program, where the firms can have one of their employees linked to research activities in MAGIC for up to a year. There are a total of 8 major firms attached to MAGIC.

ENTREPRENEURSHIP AND INNOVATION

MAGIC has a clear focus on entrepreneurship and on procuring licenses for new products. UBC's resources are also applied in this area, with the University-Industry Liason Office (UILO) seeking to ensure effective, rapid processing. UILO is a contact point for firms seeking to get into contact with relevant researchers and laboratories. In addition, MAGIC also takes responsibility for the commercialization of research.

MAGIC has thus been involved in the creation of several new firms or new products within existing firms. In addition, small and middle-sized firms in the media sector located in the province of British Columbia have received offers to enter into cooperation arrangements with MAGIC on developing ideas, proof-of-concept prototypes or implementation of development projects in their later development stages. This is all financed by a state program for entrepreneurs and therefore constitutes only a minimal burden on the firms.

MAGIC's educational programs are at the post-graduate level in entrepreneurship and technological design. In addition to a normal post-graduate program, a supplementary program is offered with a specialization in Human-Computer Interaction, an interdisciplinary field of study that studies human behaviour in technology-rich environments with the purpose of helping to design and test new technologies.

7.3.5 Stanford University - d.school

Creation of a culture of cooperation, design thinking, innovation, etc. On first sight, it sounds like what we have heard before, but at Stanford they have gone all the way and have established an entire institute that works on the basis of this philosophy.
Every scientific area is increasing the per-

centage of those who gradudate Stanford University's 'd.school' is a new design institute characterized by a cooperation between several schools and faculties, including medicine, business, engineering and the humanities. Inasmuch as it contains representatives from both the soft and hard sciences, there is cooperation across distantly related academic disciplines, and hence, interdisciplinarity in the broadest sense.

There is a desire to have very different academic tendencies cooperate with the help of design thinking, which is a specifically creative procedure where ideas can flow freely. The expectation is that innovation will arise when strongly interdisciplinary groups create a culture of cooperation so that different points of view can meet each other on an equal footing and with mutual respect.

The interdisciplinary groups at the d. school must work in an intersection where three disciplinary fields meet. The three areas are technology, business and the humanities, where the technology contributes knowledge about the project's execution, business provides information about sustainability and applicability, and the humanities contribute ideas about usefulness and desirability. Hence, the individual project groups are characterized by a unique mixture of different disciplines, and they must have as much freedom and autonomy as possible. In this way, they obtain innovative solutions in the best possible conditions.

BOOT CAMP, CLASSES AND LABORATORIES

The d.school is also special, offering a varied and different program of instruction which includes training camps, classes and laboratories. The training camps are courses which can last between one day and ten weeks. The goal is to give the students experiences in design thinking, introduce basic concepts of innovation and establish connections and empathies across academic disciplines.

The classes at d.school are advanced-level offerings to Stanford students. They give them the opportunity to apply design thinking to projects from the real world. The classes typically last 10-20 weeks and contain 20-40 students taught by 2-5 instructors, executives and partners from industry and non-profit organizations. Two to five classes are offered by the d.school each semester. They are loosely organized around themes or initiatives and are organized to give the students competencies in relation to design thinking in practice, multidisciplinary cooperation and innovation processes.

As for the laboratories, the d. school is now constructing their first laboratory, which should give the possibility for a practical implementation of the subjects already being taught. In other words, the d. school laboratories must be places where design thinking is applied to projects from the real world, the goal being to add new and valuable knowledge.

The educational activities do not award any academic degree but should be seen as an extra involvement over and above the normal requirements. Students who participate in d.school come from all parts of the Stanford University system, with the analytical skills which their home departments have given them. At d. school, they supplement these analytical skills with skills in design thinking and interdisciplinary work.

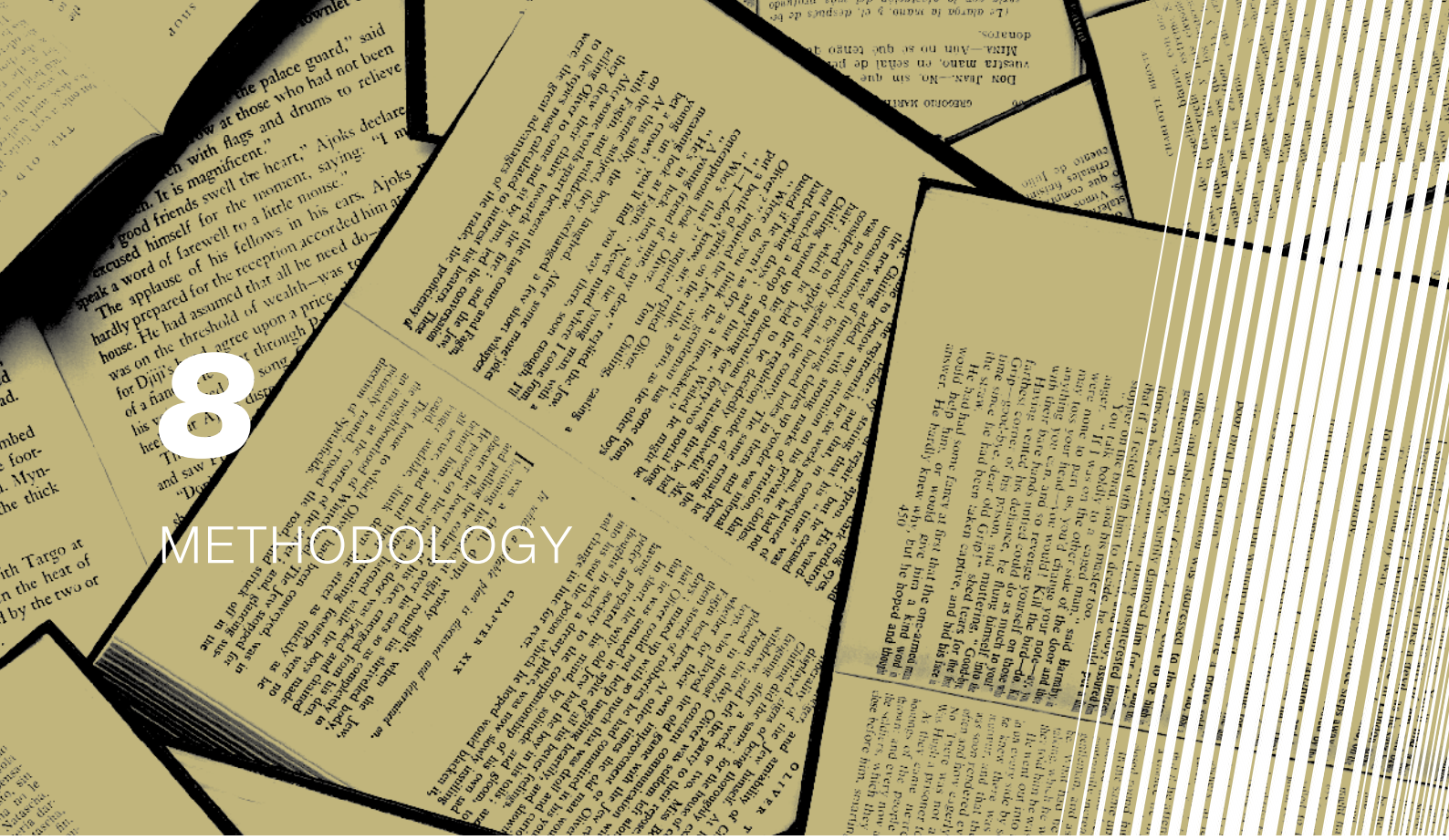
Link:http://www.magic.ubc.ca/

STAFF FROM ALL OVER

The d.school staff contain primarily a core group composed of representatives from the schools of Computer Science, Mechanical Engineering, Management Science and Engineering and the Graduate School of Business. In addition, the d.school has a consulting teaching staff, additional personnel and the d.school Association, an association of academics from various Stanford faculties who have completed their supplementary training and should now lead the way in design thinking and innovation. The association operates on a yearly basis and overlaps with the academic year. The d.school is directed to the students at Stanford. The interaction with the firms appears in the individual projects which are implemented in class and depends on the themes which are taken up. Hence, there are no formally established cooperative arrangements with a group of firms.

Trying to solve large and complex problems. The projects at d.school are directed toward complex and difficult social problems. Examples of the social problems are stopping drunken driving, building better primary schools or ensuring a sustainable environment, while business problems could be how to make it more fun to stand in line or how to prepare the design of software so that it helps people and organisations even more. The solutions to these problems, and hence the product which the d. school offers, will typically be objects, software, experiences, implementations or organisations.

Link: http://www.stanford.edu/group/dschool/



8 METHODOLOGY

8.1 ANALYSIS OF THE RESEARCH COUNCILS

The analysis of the research councils is based on an analysis of the individual project grants awarded by the councils. Analysis of the project grants is carried out on the basis of the six main scientific branches. The data consist of applications and awarded grants for the period 2005-2007. A total of 400 applications were reviewed, covering great differences in the number of applications from each research council.

There are several differences among the different research councils. The Danish National Research Foundation (the fund supporting basic research)distinguishes itself from the other councils by not allocating funding on an annual basis, but instead every second or third year. Funds are not given for individual projects but in the form of larger grants for the establishment of centers of excellence which are to function for five to ten years. Since its establishment in 1991, funding has been given to 68 such centers.

The Danish Council for Strategic Research and the Councils for Independent Research are significantly larger in both the number of grants awarded and in the size of total grant pool. These research councils award a large number of very small project grants, which can distort the total funding picture. Hence, our analysis limits itself to those grants over a certain amount. The reason for this is that genuine interdisciplinarity can be achieved only by including persons from several different research environments, and that the inclusion of more than one researcher in the project requires a certain level of resources. In our analysis, we have determined this minimum funding level to be DKK 3,000,000. For the Danish National Research Agency and the National Advanced Technology Foundation, all their grants exceed this minimum amount.[12]

For all the grant-giving councils and foundations that form part of this study, we have undertaken a manual review of all available applications for projects where funds have been awarded. The assessment of the project's degree of interdisciplinarity is based on two factors:

12) From 2008, the National Advanced Technology Foundation has adjusted its instruments so that it is now possible to apply for a grant of DKK 2.5-15 million for an advanced technology project.

1. Which persons from the public and private sectors are listed as participants in the project, and what is their background? Projects with the participation of many persons with very different scientific backgrounds and employmen will be assessed as 'strongly interdisciplinary'.

2. The project description, which often states which scientific disciplines are to be included. Inclusion of many different disciplines in the project application entails that the application is assessed as 'strongly interdisciplinary'.

Table 8.1 shows the percentages of the total number of project grants reviewed for this study.

Table 8.1 Proportion of the total number of funded projects reviewed in this analysis.

	Number of applications reviewed 2005-2007	Of which: number of grants exceed-ing DKK 3,000,000, 2005-2007.	Proportion of grants over DKK 3,000,000 as percentage of total grants awarded
The Danish National Research Foundation	24	24	100
The Danish National Advanced Technology Foundation	51	52	100
The Danish Councils for Independent Research	213	232	92
The Danish Council for Strategic Research	109	187	58
Total	397	495	80

Source: DAMVAD, 'Thinking across disciplines - interdisciplinarity in research and education

For the National Research Agency (DNRA) and the Advanced Technology Foundation, we have reviewed all the project grants, but for the DNRA, the type of grant is different (centers of excellence), which means that the analysis of these is based on publicly available documents. For the Councils for Independent Research and the Council for Strategic Research, we have not reviewed all the grants, as only a part of them are publicly accessible. This is the reason why only 58% of the total possible number of projects from the Council for Strategic Research were reviewed. As there is nothing to prevent us from utilizing the same categories of methodological procedures in the analysis of the different research councils' applications, we have used the same methodology for all four research councils, even though the type of project grants differs from council to council. A thorough review of all the projects and their implementation provides insight into how the different disciplines interact in research. However, an investigation of interdisciplinarity in projects which have received public research support in Denmark cannot take account of all the uncertainty factors.

In the tabulation, the individual application is used as a basis for assessment of interdisciplinarity. Hence, a project's subsequent inclusion of elements of interdisciplinarity

that have not been described in the application or in the original list of participants will not be included. In this study, it is not possible to conduct a follow-up review of the projects in order to investigate whether they interdisciplinary elements entered later in the process.

In this review of the different project grants, we have examined only those applications that have received DKK 3,000,000 or more; we have not analyzed the size of the grants in relation to their potential degree of interdisciplinarity. If the analysis had had this point of departure, the results would probably be a greater emphasis on interdisciplinarity in those projects with larger grants, as interdisciplinary projects tend to be more costly due to the larger number of participants in the project.

8.2 ANALYSIS OF EDUCATION

The analysis consists of a calculation of interdisciplinarity in existing higher education programs and a calculation of interdisciplinarity in the newly established higher education programs in the period 2005-2007. In the calculation, the focus has been on whether there is an explicitly formulation of strategic objectives for interdisciplinarity in the educational program, and an analysis of the disciplines described as a part of the program.

The following institutions are included in the analysis:

- Universities
- Business Colleges and other middle-term educational institutions.
- Academies of Professional Higher Education and other short-term educational institutions.
- The educational institutions under the Ministry of Culture

A review has been carried out of all existing higher education programs in order to obtain a current picture of the number of interdisciplinary educations in Denmark[13] and the degree of interdisciplinarity in 2008. According to the national coordinated system for admission to higher education (KOT), there are about 350 higher education programs in Denmark. In addition, there are continuing and in-service educations (VVU), certificate programs and master's programs, where according to the Ministry of Education data base of all public adult and in-service educations (VIDAR), there exist an additional 170 educational programs.[14]

Applications to new educational programs, both conventional and continu-ing/in-service programs in the period 2005-2007, are assessed on the basis of the intention to provide a picture of developments in interdisciplinarity in recent years in these educational programs. This part of the analysis is compared to the analysis of the framework conditions and how they interact with the new programs that are certified.

A special analysis has been carried out of both standard educational pro-grams and continuing/in-service educations. We have done this in order to investigate the thesis that the degree of interdisciplinarity is greater in the continuing/in-service educations than in the standard programs, in that the latter have been developed with a point of departure in the client's needs.
A description of interdisciplinarity in Danish

13) The national system for application to higher education (KOT) lists only bachelor programs from the universities and not the master's-level programs, as one cannot apply to these programs the KOT system.

14)This does not include the many subgroups, such as the pedagogical certificate program. These are not included because they are assumed not to be interdisciplinary. They all belong under the same main group and are therefore not of interest in the context of this report.

educational programs brings with it several challenges. It is difficult to determine when an educational program goes from being interdisciplinary to being recognized as a unique discipline. An example is political science, which emerged as a discipline combining law and economics; or architecture and design, which are such new research areas that they do not have their own affiliated theoretical domains. Instead, they draw on research from fields such as sociology, engineering and aesthetics.

Specifically, it means that for several of the educational programs, it is a matter of judgment as to whether the educational program is to be placed in the category 'mono-disciplinary', 'interdisciplinary within a branch' or perhaps even as 'interdisciplinary within closely related fields'. This applies, among other things, to the language and commercial programs and to IT programs, which are relatively new educational disciplines that have interdisciplinary roots. The educational programs under the Ministry of Culture are also classified as monodisciplinary, but in reality many of these programs draw on a wide range of fields in order to create their own.

Beyond the type of interdisciplinarity is applied in this study, it is also important to be aware of the type of interdisciplinarity which is not intended or integrated into the organisation of a given program, but which the individual student can set up by combining their courses from different programs. To an increasing degree, students in many higher educational programs have the possibility to integrate optional elements as a part of their education. In certain long-term education programs, students are even required to study a number of courses outside their own main field. In many cases, this gives the student the possibility to select subjects and courses in entirely different areas and educational institutions than their home institution. In addition, the increased internationalization means increased freedom of choice and thereby more and more mixed educational profiles.

In other words, students have the possibility to themselves direct their educational program. What is basically a mono-disciplinary education can, by virtue of the optional elements, be made interdisciplinary, e.g., by supplementing a university bachelor education in German with an optional module in mathematics.

This kind of interdisciplinarity, when seen from the perspective of the in-stitutions, is unintended and a consequences of the student's choice of study. It is difficult to obtain an overview of this type of interdisciplinarity, as it would require a review of all students' and graduates' optional courses, credit transfer records and periods of study abroad.

8.3 THE INDEX OF INTERDISCIPLINARITY

The purpose of this section is to describe how the Index of Interdisciplinarity is constructed, the raw data used, and the index's key findings and correlations. The Index of Interdisciplinarity takes its point of departure in Shannon's measures of diversity (Shannon and Weaver 1962 and Stirling, 2007).[15] It expands upon this with a measure of distance from interdisciplinarity. The index is used in research and development institutions which are part of the Research Statis-

15) C.E. Shannon and W. Weaver (1962), The Mathematical Theory of Communication (Urbana: University of Illinois Press); A. Stirling (2007), 'A General Framework of Analyzing Diversity in Science, Technology and Society'. SPRU SEWPS 156.

tics for the Public Sector 2005 as registered by the Danish Centre for Studies in Research and Research Policy (Center for Forskningsanslyse/CFA).

8.3.1 The empirical data on Danish research and development institutions

The survey covers 665 active research and development institutions as registered in the research statistical database for the public sector in 2005. The basic statistical research unit is usually the smallest administrative unit within the individual institution. For universities, it is typically the individual department (the Danish terms being either 'afdeling' or 'institut'), while for hospitals and sector research institutions it is the individual department or unit. Table 8.2 provides an overview of the total number of units and institutions in the research statistics, and information on the number of institutions active in research and development work and therefore forms the basis for the study.

Table 8.2 Number of research and development institutions in the survey

	Total number of units	Total number of institutions	Of which: with research and development activities
Higher education institutions	50	272	256
• Universities, other institutions of higher education • University hospitals	18	348	292
Total number of higher education institutions.	68	620	548
Public research institutions			
• Sector research institutions • Other public research institutions	15 84	47 98	36 73
Total public research institutions Private non-business institutions	99 8	145 9	109 8
Total	177	774	665

Source: CFA

The overall response rate for registration in the research statistical data-base is very close to 100%, but from a few institutions the quality of certain parts of the responses is relatively poor. Certain institutions have not indicated several areas for their research and development activity, even though they present themselves as interdisciplinary on their home pages. This has a negative effect on their interdisciplinarity score in the index. In this study, we have not sought to correct for this.

The 665 research and development institutions carry out their research activities within six main research areas; these branches of science can in turn be subdivided into several subfields, as indicated by the research statistical database for the public sector. Table 8.3 shows the number of research and development institutions that belong to the individual subject areas.

Table 8.3 R&D institutions grouped by main area

Area	Number of R&D institutions
Natural sciences	57
Technical sciences	38
Health sciences	353
Agriculture and veterinary sciences	23
Social sciences	83
Humanities	111
Total	665

Source: Damvad and CFA

8.3.2 The Index of Interdisciplinarity

The Index of Interdisciplinarity used here is newly developed, but it is based on a very much used measure of diversity developed by Shannon and described in Shannon and Weaver (1962).[16] The Shannon Index measures both the variation in the number of disciplines and the balance between these (cf. Stirling, 2007).

The analysis of interdisciplinarity carried out here seeks to measure the difference or degree of interdisciplinarity between an institution's main scientific field and other fields of science. For this purpose, the Shannon Index has been expanded with a weight that is linked to each category. The weight gives a value to the category, which is determined by whether the scientific area is closely related to the main scientific area, linked to the same soft/hard scientific areas, or cuts across the soft/hard areas which are defined by, respectively, the first four and the two last areas in table 8.3.

*16) The Shannon index is defined as SH = ∑pi*log(pi) , i=1, … , N, where pi is the proportion in category i, N is the number of categories and ∑pi=1.*

Table 8.4 Examples of the variation in the index values

		Example no.			Ex. 0 %	Ex.1 %	Ex. 2 %	Ex. 3 %	Ex. 4 %	Ex.5 %
	ID number of field	Name of field	Percent	Weight						
1	504	Business economics	20	0	100	80	50	20	20	30
2	506	Sociology	20	1			20	20	20	
3	509	Technology assessment	10	1		20	10		10	10
4	612	Psychology	10	2			10	15	10	
5	605	Linguistics and philology	10	2					10	
6	613	Other humanities disciplines	10	2			10		10	
7	303	Social medicine	5	4				15	5	10
8	410	Human nutrition	5	4				15	5	20
9	105	Biochemistry	5	4				15	5	20
10	208	Environmental technology and pollution control	5	4					5	10
	Total		100	-	100	100	100	100	100	100
Shannon index					0	0,50	1,36	1,78	2,16	1,70
The index of interdisciplinarity					**0**	**0,32**	**1,47**	**4,31**	**4,33**	**4,65**

Note: The grey area is filled out by the institutions in their response to the data requested by the sur-vey of research statistics. The institutions fill in at least the first line but can indicate up to 10 different areas from the disciplinary classifications table. If the institution fills in only the first line with 100%, then it is considered 'mono-disciplinary' (example 0). Example 1 shows 'little diversity', example 2 'middle diversity', while examples 4, 5, and 6 are cases of 'great diversity'

If the institution indicates one a single sub-area with 100%, this contribution obtains a weight of zero and the index gets the value of zero. These institutions are labelled 'mono-disciplinary'.
This expanded Shannon index, here called the Index of Interdisciplinarity, is thus USH = ∑pi*log(pi) * vj , i=1, ... , N; j=0,1,2,4. Table 8.4 provides examples of the values entered on the Index of Interdisciplinarity.

Table 8.5 shows the distribution of institutions by discipline and interdisciplinarity. Of those institutions active in research and development, 51% are monodisciplinary, 25% interdisciplinary within one main field, 13% interdisciplinary across closely related fields and 11% interdisciplinary across distantly related fields. As concerns the degree of interdisciplinarity, the calculations show that interdisciplinarity is least common within health sciences, while most common for institutions within technical sciences.

The number of employees is lower among the 337 (51%) of mono-disciplinary institutions than among the 328 interdisciplinary institutions. Hence, table 8.6 shows that 72% of all full-time research and development employees work within interdisciplinary institutions.

Table 8.5 Distribution of institutions by field and degree of interdisciplinarity.

Field	Mono-disciplinary	Percent classed as Interdisciplinary		
		Within a single field	Across closely related fields	Across distantly related fields
	..... %			
Natural science	28	21	42	9
Technical sciences	5	45	18	32
Health sciences	66	22	6	6
Agricultural and veterinary sciences	22	35	26	17
Social sciences	43	19	18	19
Humanities	40	32	14	14
Total	51	25	13	11

Source: Damvad and CFA

Table 8.6 Distribution of research and development employees (one person/yr.) at mono- and interdisciplinary institutions

Field	Mono-disciplinary	Percent classed as Interdisciplinary		
		Interdisciplinary	Total	Proportion of full-time R&D positions at interdisci-plinary institutions
	---------- Number of R&D positions--			--- Percent ------
Natural science	750	2554	3304	77
Technical sciences	58	1603	1661	97
Health sciences	2137	2863	5001	57
Agricultural and veterinary sciences	243	1195	1438	83
Social Sciences	641	1097	1738	63
Humanities	398	1600	1998	80
Total	4226	10913	15139	72

Source: Damvad and CFA

8.3.3 Statistical calculations

The association of interdisciplinarity with the specific characteristics of in-stitutions, such as size, cooperation or type of research, can be measured using a simple coefficient of correlation or in a more complex way, with a logistic or Tobit regression, where the index value is the dependent variable.[17] The conclusions in table 6 are based upon the group average, coefficients of correlation, Tobit and OLS regressions.

The findings can be divided into two parts: those which concern the degree of interdisciplinarity in all institutions, and those which concern the degree of interdisciplinarity within the interdisciplinary institutions. The results, shown in the two columns in table 8.7, vary between the two divisions along certain dimensions. It can be seen that there is an association between the Index of Interdisciplinarity and the size of the institutions when all institutions are considered. This is due primarily to the fact that the larger institutions are often interdisciplinary. If we focus only on the interdisciplinary institutions, however, there is a weak association between the size of the institutions and the value of the index, in that there is a weak tendency for larger interdisciplinary institutions to be more interdisciplinary than smaller interdisciplinary institutions.

Table 8.7 also shows that the institutions' distribution of research into ba-sic research, applied research and development work does not covary with the institutions' interdisciplinarity. However, there is a negative association for basic research among the interdisciplinary institutions, such that the interdisciplinary institutions are less interdisciplinary as the share of basic research in their profile increases.

Table 8.7 also shows that interdisciplinary institutions often cooperate with others about their research and development, and that the degree of interdisciplinarity is greater when they cooperate with others. The findings show that institutions with outside financing of their research and development are more interdisciplinary but that outside financing largely co-varies with the interdisciplinary institutions' degree of interdisciplinarity.

Finally, the results show that the Centers for Higher Education (CVUs), the sector research institutions and the universities (in that order) have higher than average scores on the interdisciplinarity index, while the hospital units lie below the average. Similarly, there is a significant variation between institutions which state, in their responses to the research statistical survey, that they carry out research and development within various strategic areas. The variation follows the type of institution, such that institutions with strategic areas in the field of health, for example, typically lie below the average, while the converse is true for the other fields, similar to the pattern shown in table 8.5.

17) The logistical regression is estimated based on either the probability for interdisciplinarity (0,1) or on the degree of interdisciplinarity (0,1,2,4, compare table 4). A Tobit regression is estimated simultaneously from the probability for interdisciplinarity (0,1) and the index value, given that the institution is interdisciplinary. The OLS regression is used only for interdisciplinary institutions alone (index value>0).

Table 8.7 Association between interdisciplinarity and institutional characteristics for all institutions and for interdisciplinary institutions only

Institution's characteristics	Association with interdisciplinarity	
	All institutions	Of which: only the interdisciplinary institutions
Size (full time R&D staff)	+	+/0
Main area	+/- jf. tabel 4	+/- jf. tabel 4
Type of research (proportions of R&D staff doing basic research, applied research and development work)	0	-(gf)/0
Cooperation with others on R&D	+	+
Cooperation with Danish partners	+	+/0
Cooperation with foreign partners	+	+
Cooperation with private firms	+	+
Cooperation with institutions of higher education	+	+
Outside funding total	+	0
Outside funding from public sources	+	0
Proportion outside funding from public sources	+	0
Outside funding from research councils, etc.	0	0
Proportion outside funding from research councils, etc.	+	-/0
Additional outside funding from ministries	+	+
Proportion of additional outside funding from ministries	+	+
Outside funding from private firms	-/0	0
Proportion outside funding from private firms	-	-/0
Outside funding from abroad	0	0
Proportion outside funding from abroad	+	+/0
Type of institution		
Universities, sector research institutions and centers of higher education	> gns.	> gns.
Hospitals, and others	< gns.	< gns.
R&D within selected strategic areas	+/- ift. gns.	+/- ift. gns.

Source: Damvad and CFA.

8.3.4 Changes as a link in the merging of institutions

In Chapter 3, a calculation is presented of the research communities which score the maximum points on the Index of Interdisciplinarity. The figures in the calculation are from the public research statistic database from 2005 and therefore predate the merging of universities and sector research institutions that took place in 2006/2007. All research communities in the calculation still exist today, but part of the institutions in the calculation may have changed names or have been fused into new organizational structures as part of the consolidation of higher education and research institutions. Table 8.8 contains information about the individual departments and institutions as they appeared in 2005, and as they appear after the mergers.

Table 8.8 Institutional changes for research communities in the Index of Interdisciplinarity as part of the mergers of universities and sector research institutions

Top five Institutes/departments	Institution	Institutional change after merger
Natural science		
Institute for Sport	Univ. of Copenhagen	
IT University in Copenhagen	IT University in Copenhagen	
National Space Research Center	National Space Research Center	On 1 January 2007, The National Space Research Center merged with the Technical University of Denmark (DTU).
BiC, BioCentrum incl. Center for Food Research	Technical University of Denmark	The Biocentrum remains under the Technical University of Denmark, but has now become DTU Biosys or Institute for System biology.
Department for Biosystems	National Laboratory for Sustainable Energy, Risø	On 1 January 2007, the National Laboratory for Sustainable Energy was amalgamated with the Technical University of Denmark, Center for Food Research, Fisheries Research Unit, Center for Space Research and Transport Research Unit.
Technical sciences		
Department for Systems Analysis	National Laboratory for Sustainable Energy, Risø	On 1 January 2007, the Department for Systems Analysis became part of the Danish Environmental Survey, and is now part of Aarhus University.
Herning Business and Engineering College	Aarhus University	On 1 August 2006, Herning Business and Engineering College merged with Aarhus University, after which the name was changed to Aarhus University, Business and Engineering College (AU-HIH).
Mads Clausen Institute	University of Southern Denmark	
Center for Communications, Optics and Materials	Technical University of Denmark	
National Institute for Building Research		On 1 January 2007, the National Institute for Building Research merged with Aalborg University.

Table 8.8.1 Institutional changes for research communities in the Index of Interdisciplinarity as part of the mergers of universities and sector research institutions.

Top five Institutes/departments	Institution	Institutional change after merger
Health Sciences		
Center for Rehabilitation and research on Victims of Torture	University of Southern Denmark	
Institute for Sports and Biomechanics	University of Southern Denmark	
Institute for Research in Health Services	National Hospital (Rigshospitalet)	
Neurocenter – Neurology		
UNI*C Danish IT Center for Education and Research		
Agriculture and Veterinary Sciences		
Center for Forests, Landscape and Planning	Royal Veterinary and Agricultural University	On 1 January 2007, The Royal Veterinary and Agricultural University merged with the Pharmaceutical University of Denmark and then changed its name to the Faculty of Life Sciences At the same time, the Faculty was subordinated to the University of Copenhagen.
Research Center for Ecological Agriculture (FØJO)	Danish Agricultural Research Center	
Institute for Veterinary Pathobiology	Royal Veterinary and Agricultural University	On 1 January 2007, The Royal Veterinary and Agricultural University merged with the Pharmaceutical University of Denmark and then changed its name to the Faculty of Life Sciences. At the same time, the Faculty was subordinated to the University of Copenhagen.
Institute for Production Animals and Horses	Royal Veterinary and Agricultural University	On 1 January 2007, The Royal Veterinary and Agricultural University merged with the Pharmaceutical University of Denmark and then changed its name to the Faculty of Life Sciences. The Faculty was then subordinated to the University of Copenhagen.
Institute for Basic Domestic Animals and Veterinary Science	Royal Veterinary and Agricultural University	On 1 January 2007, The Royal Veterinary and Agricultural University merged with the Pharmaceutical University of Denmark and then changed its name to the Faculty of Life Science. At the same time, the Faculty was subordinated to the University of Copenhagen.

Tabel 8.8.2 Institutional changes for research communities in the Index of Interdisciplinarity as part of the mergers of universities and sector research institutions.

Top five Institutes/departments	Institution	Institutional change after merger
Social sciences		
Institute for Environment, Technology and Society	Roskilde University	On 1 September 2006, the Institute for Environment, Technology and Society became part of the new Institute for Environment, Society and Spatial Change (ENSPAC).
Institute for Informatics	Copenhagen Business School	
Institute for Social Development and Planning	Aalborg University	
Vitus Bering Center for Higher Education	Roskilde University	On 1 January 2008, the Vitus Bering Center for Higher Education changed its name to VIA University College.
Roskilde University Library		
Humanities		
Institute for Architecture and Design	Aalborg University	
Aarhus School of Architecture	Aarhus School of Architecture	
School of Architecture	Royal Danish Academy of Fine Arts	
Center for Higher Education Vita		
Jutland Center for Higher Education		Since January 2008, the Jutland Center for Higher Education has become part of VIA University College. VIA is a merger of the Vita Center for Higher Education, CVU Vita, Vitus Bering Danmark, the Mid-West Center for Higher Education, Alpha Center for Higher Education and the Jutland Center for Higher Education, CVU Midt-Vest.

8.4 QUESTIONNAIRE SURVEY ON INTERDISCIPLI-NARITY

As part of the survey of interdisciplinarity in research and higher education, DAMVAD carried out an internet-based questionnaire survey in which 120 relevant decision-makers within research, education and business participated. The survey had three main objectives:

• The survey should contribute to describing the knowledge about interdisciplinary communities within research and education in Denmark and abroad.

• The survey should point out potentials for interdisciplinarity. In this connection, the respondents should answer questions about their attitude toward the eventual benefits and advantages of interdisciplinarity for business and the possibilities to strengthen interdisciplinarity.

• The survey should describe the attitudes

toward and barriers to interdisciplinarity within education and research. Here the respondents should answer specific questions regarding barriers to interdisciplinarity in the research councils and the research granting system, at the universities and in the research institutions, in the education system and in the ministries' funding of research.

In accord with this study, the survey of decision-makers takes its point of departure in a definition of interdisciplinarity where a distinction is made between three different types of interdisciplinarity (cf. Chapter 2 on 'What is Interdisciplinarity?'). The respondents were presented with this definition at the start of the questionnaire before they began to answer the questions. They were also made aware that the survey had a special focus on research and education with interdisciplinarity across distantly related scientific fields.

The framework for questions consists of 13 general questions, containing both closed and open-ended questions. The closed questions were used especially in connection with questions regarding the barriers to interdisciplinarity, where several possible barriers are listed and the respondents having to select an answer with which they agree or disagree. The open questions have the intention of identifying the respondents' knowledge of interdisciplinary communities and their attitudes toward potentials for interdisciplinarity. In these cases, the open questions are an advantage, as it is difficult to construct exhaustive response categories for current fields, and because the use of closed questions runs the risk of overlooking new approaches to issues or key knowledge that the respondents might possess.

The survey was conducted as an internet-based survey using the questionnaire and analytical tool Enalayzer, where the questionnaire is sent to the respondents via their e-mail address. The questionnaire was administered during the period January-March 2008.

8.4.1 The survey population

The sample used in the questionnaire survey consists of three different groups of actors. First, there are actors within the research community, which include universities and other research institutions, from the research council system and Danish Certified Technological Service Institutes (GTSs). The second group includes actors from the educational institutions offering short and middlecycle programs, including professional schools and engineering colleges. The third group consists of actors from the business sector.

The respondents from the survey population were selected through two phases:

- In the first phase, the questionnaire was sent out to the respon-dents, who are influential actors within their fields. The respondents from the individual research and education institutions are thus key resource persons, e.g., university heads, deans, heads of institutes or departments at universities and research institutions. In the selection of respondents within the business community, the aim was to go after influential firms which have a strong interaction with the research community and are represented, for example, in the research councils and boards of the public research system.

- In the second phase, the questions were sent out to respondents lo-cated with the help of the snowball method. The essence of

this method is that the respondents from the first phase, in connection with their answering of the questionnaire, designate other important actors who are far ahead in terms of interdisciplinarity. This method helped us to find 20 new respondents in the survey. The advantage of the snowball method is that it ensures that relevant actors within interdisciplinary communities are identified. In this way, it becomes possible to delve more deeply into the different perspectives and problems of interdisciplinarity.

The respondents are not selected in a random manner, and the survey is therefore not representative for all Danish research and educational institutions or the Danish business community. However, emphasis is placed on establishing a group of respondents which consists of influential decision-makers within the three sectors.
Table 8.9 shows an overview of the three actor groups and the number of respondents from each group. Over half the respondents are from the universities and research institutions, and this actor group is therefore overrepresented in comparison to the two others. By comparison, just under a fourth of the respondents come from institutions offering shorter and medium-length educations, while about a fifth of the respondents come from the business community.

Table 8.9 Survey population and number of respondents from each group

Respondents coming from:	Antal respondenter
Universities and other research institutions	71 (61 pct.)
Institutions offering short- and medium-cycle educations	21 (18 pct.)
Business sector	25 (21 pct.)

Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

There is a skewing in the number of respondents from the different fields within the educational and research community, in that nearly half the respondents have stated that they have a higher education within the field of social science. Table 8.10 shows the proportion of the respondents who indicated that they have a higher education within the individual field. The total response rate becomes larger than 100% because some of the respondents have a higher education within more than one field.

Table 8.10 Distribution of survey respondents by field of study

Field of study	Number (per cent)
Natural science	20 (17 pct.)
Technical science	16 (14 pct.)
Health sciences	11 (9 pct.)
Social sciences	52 (45 pct.)
Agricultural and veterinary science	4 (3 pct.)
Humanities	35 (30 pct.)
Other	16 (14 pct.)

Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

8.4.2 Response rate and drop out

Table 8.11 shows the response rates and drop outs for those respondents coming from universities and other research institutions, those from short- and medium-cycle educations, and those from the business sector. More specifically, the table indicates, for each of the three actor groups, the number of questionnaires distributed, the total number of responses, the number of complete and incomplete responses and the percentage of answers.

Table 8.11 Response rate for the questionnaire survey

Institutional 'home' of respondent	Number of questionnaires distributed	Number of respondents answering	Number of completed questionnaires	Number of incomplete questionnaires	Percentage responding
Universities and other research institutions	135	71	49	22	53
Short and medium-term educational institutions	34	21	16	5	62
Business sector	56	25	19	6	45
Total	225	117	84	33	52

Source: DAMVAD, Questionnaire survey on interdisciplinarity, 2008.

For all three groups, the response rate is about 50%, though somewhat less for the private business respondents and a bit higher for those coming from institutions offering short- and medium-cycle educations. The high response rate shows that there was a significant interest in participating in the survey. It can also be concluded that it is not a case of a distorted drop out rate, as there is an even distribution of responses across the three groups. This is a strength for the survey.

Nevertheless, there is a characteristic difference in the answers of the different groups to the questionnaire's closed questions, as the number of 'don't know' responses is much higher among the group of private sector respondents than among those with a base in the higher educational institutions. The questions to which the firms respond with 'don't know' are those which require an intimate knowledge of the research and educational system in Denmark, and are therefore directed especially to the universities.

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