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Governing interdisciplinary cooperation in Centers of Excellence

Tomas Hellström, Erik Brattström and Leila Jabrane

Department of Business Administration, Lund University, Lund, Sweden

ABSTRACT

In the past years Centers of Excellence (CoE) has risen to prominence as a funding instrument in science. The idea is that by focusing resources, people and attention within a center environment, and over a substantial time span, excellence in science can be promoted. Similarly, interdisciplinarity is often seen as an enabling condition or even necessary for frontier research. This article builds on a qualitative interview study with Swedish Centers of Excellence (CoE) directors, and asks the question: - how is interdisciplinarity governed and developed within a CoE environment, and what is its effects in terms of research processes and organization. The study presents a detailed account of a number of aspects of interdisciplinary governance, conditions and outcomes, and describes how these relate via specific mechanisms. Together the results illuminate how CoE governance creates pathways to interdisciplinarity, that allow collaboration to go beyond mere interaction, and towards integration of specialisms.

Introduction

This article uses a qualitative Small-N study to investigate how processes supporting interdisciplinary research are stimulated, created and maintained at Centers of Excellence (CoEs), and what these processes result in. In recent years CoE programs have become popular instruments of research policy across the globe. The basic idea of this way of funding science and innovation is to build substantial capacity in one or several areas of inquiry, by investing sizeable funds over a longer time period compared to traditional projects. Also, there is usually a requirement that the investment leads to the creation of a stable social milieu for research, where knowledge creation is conducted in cooperation, ‘under one roof’, in a center setting. CoEs have various aims, mostly in promoting certain areas of science and technology, and to lesser extent development (Hellström 2011; Orr, Jeager, and Wespel 2011; Aksnes et al. 2012). They also typically have a number of ‘meta-aims’ that relate to capacity to enter into and to explore emerging fields of science, to create cooperation among scholars, to professionalize academic governance, and to promote organizational capacity for governing science at the frontier (Hellström 2018).

For these reasons interdisciplinary cooperation is often a requirement in program calls, and a standard indicator in evaluations of such centers. The assumption here is that it is through cooperation between disciplines and specialisms that new discoveries are likely to happen, and that capacity for such cooperation is likely to stimulate environments of learning, within and across departments and at universities generally. CoEs are usually located at universities, and represent a type of organizational innovation there, i.e. they represent investments in growth, priority setting within the
university, and a support for sustaining academic achievement. In this regard cooperation and interdisciplinarity are qualities that ensure spill-over and integration between the center and its surroundings. For the purpose of reinforcing these structural, processual elements, CoE evaluations often look for organizational structures that promote cooperation, and leadership that supports boundary-spanning activities (Hellström 2011).

Interdisciplinarity may be conceived of on several levels. For example, one may consider various disciplinarities coming together within a singular researcher’s work; as a form of interpersonal interaction between representatives of different fields; and on larger organizational scale, as cooperation between departments and faculties (Pfirman and Martin 2017). In this article we mainly consider the last two forms, and specifically the second, since the unit of analysis is the CoE and the cooperative dynamics taking place there. We believe that an understanding on this level of integration is vital to appreciate how the university as a whole can benefit from interdisciplinarity, not only from CoEs and other units created to pursue academic goals, but also from applied interdisciplinary activities such as those involved in Grand Challenges oriented research. Combining domain expertise to solve scientific and applied problems typically involve creating routines that respect, yet challenge the disciplinary identities of participants, and that can facilitate problem extension and knowledge integration among a diversity of researchers (Hellström 2012).

Here a delimitation is in order. Since this study is focused on basic research oriented CoEs, it does not deal with transdisciplinary activities that crosses sectoral boundaries and aims to knowledge creation ‘in the context of application’ etc (Gibbons et al. 1994). That being said, in the pages that follow we will carefully outline what we mean by interdisciplinary collaboration. The article will proceed as follows: in the next section we will discuss some previous research on CoEs and interdisciplinarity, as a means of contextualizing and further delimiting our research focus. Secondly, a methods section, where we outline the approach; a non-comparative, Small-N study involving 10 Swedish CoE in the natural and social sciences, medicine and engineering. Thirdly, the results section will outline our main findings regarding the governance, supporting conditions, and outcomes of interdisciplinary work at these centers. The article ends with discussion and conclusions.

Excellence, organization and interdisciplinarity

Excellence

When discussing research excellence on the organizational level, one typically refers to environments that demonstrate high scientific quality and productivity, resource attraction and topic concentration, and that are highly visible and attractive to international talent (Orr, Jeager, and Wespel 2011; Aksnes et al. 2012; Hellström 2012; Borlaug 2016). Other evaluative dimensions include organizational matters such as leadership, organizational structure, outreach/visibility and collaboration (see Tijssen 2003). Many CoEs are expected to demonstrate some kind of interdisciplinary collaboration, at least in the broad sense of acting as platforms for interaction between specialisms and competencies. A strength in this regard supposedly lies in these organizations’ ability to provide platforms for a type of interaction; a sort of bottom-up organization of research, which is not as easily accommodated within departments and faculties (Hellström 2011; Langfeldt et al. 2015; Borlaug 2016). Gläser and Laudel (2016) refer to this as the ‘excellence turn’ in science policy. The type of funding logic implied in CoE schemes and other excellence initiatives usually works through allocating more money over longer time periods than traditional grants. Laudel and Gläser’s (2014) review of the impact of the European Research Council (ERC) grants for individual researchers identifies a number of effects from substantial, long-term flexible funding, e.g. uninterrupted research time, long time horizons, and risk- and diversity-tolerant environments.

This corresponds well to what some observers, e.g. Heinze et al. (2009) have found, namely that extra-mural collaborations play a great role in research excellence, and that successful groups, such as CoEs, draw on larger collaborative networks, provide links between disjointed peers and
stakeholders, and work under conditions that reflect interdisciplinarity. Other organizational aspects include mechanisms supporting collaboration through sharing of laboratory or office space, maintenance of collaborative networks, and access to complementary research skills (Heinze et al. 2009). Likewise, Martin, Allwood, and Hemlin (2004), in their work on Creative Knowledge Environments (CKEs), suggest that collaboration with other groups is a robust predictor of creativity. Common observations in this literature include that organizations that generate significant research contributions typically display visionary, nurturing and integrative leadership, scientific diversity, interdisciplinarity and integration of activities (see Hollingsworth and Hollingsworth 2000; Hemlin, Allwood, and Martin 2004; Heinze et al. 2009). With these preliminary observations, we can go on to discuss insights from the literature regarding what interdisciplinarity is, how it is typically stimulated, and related challenges.

Interdisciplinarity

The traditional sense of a discipline is that of a unified, autonomous corpus of knowledge (Silliman 1974), which supports an area of instruction or expertise, that is the ‘disciplining’ of students by the profession of academic instruction and research (Guntau and Laitoko 1991). When we refer to disciplines in the context of interdisciplinarity, we talk about these broader units of inquiry, the intellectual units which ‘structure the framework in which day-to-day decisions, actions and interpretations are carried out by groups of scientists’ (Whitley 2000, 8–9). We also recognize that within the framework of interdisciplinarity, a discipline can also be understood in a more limited sense, as a specialism, e.g. molecular cell biology, which is located within a broader discipline, such as biology. As a consequence, we assume that interdisciplinarity can also be collaboration between specialisms within a broader intellectual field, where these specialisms typically have their own journals, conferences, types of methods and instrumentation, and work on distinctive theoretical problems.

The literal meaning of ‘interdiscipline’ is ‘between disciplines’ (Stember 1991), which is a space of potential, yet uncovered knowledge between two or more fields of knowledge, here taken to be disciplines, intellectual fields or specialisms, where researchers can meet to study parts of reality not yet researched. Interdisciplinarity then is a means for closing knowledge gaps between disciplines, fields and specialisms, by formulating problems and organizing research through cooperation (Karlqvist 1999). There are many and overlapping descriptions of interdisciplinarity, and at the same time a conspicuous lack of one singular, agreed-upon definition (Klein 1990; Holbrook 2013). This may be a sign that interdisciplinarity is not one distinguishable form of research at all. Rather it may simply be a way to describe of how research, especially at the forefront of inquiry, is usually conducted, in cooperation between specialisms that draw on various disciplinary sources of knowledge (results, theories, methods, etc). In fact, some argue that defining interdisciplinarity is less important than making the ‘correct appreciation of the true nature of the problem to be solved’ (Hansson 1999, 342).

So, perhaps interdisciplinarity should not be described as a particular type of knowledge, but rather in terms of a form of cooperation between areas of knowledge or specialisms in science. One way of describing such cooperation is through the notions of interaction and integration (see e.g. Lattuca 2001). The notions of interaction and integration refer to the degree of collaboration (for a comprehensive account, see Klein 2010). The first is that of interaction/communication, where cooperation is characterized by the exchange of background or contextual material between disciplines (e.g. Simon and Goode 1989). In this sense, disciplines are auxiliary or supplementary (Heckshausen 1972). The second form of interdisciplinary relationships is that of amalgamation and mixing of disciplinary perspectives and intellectual resources. Here, integration occurs when research design refines fundamental questions (Klein 2010).

Interdisciplinarity serves different strategic aims, in science and in society, and has different consequences. For example, when a problem-solving aim is pursued, one may talk about an instrumental use of interdisciplinarity. This can be a strategy to serve the needs of either the disciplines (Kann 1979), or those of the nation state as in the case of applied or strategic research (Weingart 2000). Salter and Hearn (1996) suggest that, in instrumental interdisciplinarity, institutional boarders are
typically maintained and researchers simply increase the problem-solving capacity of their own discipline by appropriating ideas and methods from another discipline. As a contrast to instrumental interdisciplinarity, Klein (2010) points to a critical use of interdisciplinarity which aims at transforming incumbent structures of knowledge, education, and politics. Similarly, Aram (2004) points out how interdisciplinarity could challenge ‘assumptions of institutional and social power embedded in disciplinary work’ (382). Klein (2010) concludes that instrumental and critical interdisciplinarity varies in degrees of interaction/integration, where the former is considered to display a lower degree compared to the latter.

**Facilitating conditions**

The factors facilitating interdisciplinary research can be divided into two main categories: external and internal (Klein and Porter 1990). A number of studies point to institutional support for interdisciplinarity as an important contextual factor (external). Such support can range from simple intellectual openness within disciplinary departments (Lattuca 2002), to actual policies and practices such as joint appointments and special mechanisms for assessment and recruitment (Lattuca 2002; Porter et al. 2006), to the establishment of independent interdisciplinary research units (National Academies Committee 2005; Sá 2008). Among external factors, emphasis is also placed on funding conditions. The latter can have great influence over the desirability, focus, pattern, and time horizon of interdisciplinary endeavors (Boix Mansilla, Lamont, and Sato 2016; Pfirman and Martin 2017).

When it comes to internal factors, a common thread in the literature on the success of interdisciplinary teams is the importance of managing differences and creating common ground (Lattuca 2002; Öberg 2009; König et al. 2013). By definition, members of interdisciplinary teams have different backgrounds and skills, coming from different disciplines or specialisms. The extent of the desirable disciplinary distance among team members might be a matter of a trade-off (Porter et al. 2006). On the one hand, diversity may generate creative and novel outcomes; on the other hand, it may lead to disagreements and conflicts. Therefore, personal characteristics such as flexibility, willingness to learn, capacity to interact effectively with people from different backgrounds, and skilled leadership are seen as highly favorable (Klein and Porter 1990; Boix Mansilla, Lamont, and Sato 2016). Similarly, arrangements and processes facilitating interdisciplinary interaction and dialogue are also considered to be of utmost importance (National Academies Committee 2005; König et al. 2013). Beyond the organization of workshops, seminars, meetings, and training, interdisciplinary teams should develop opportunities for informal ‘collegial contact’ to develop trust and understanding and allow for ‘serendipitous connections’ (Pfirman and Martin 2017). Physical proximity is one way to ensure such informal interactions regularly (Klein and Porter 1990).

**Method**

**Case background**

The empirical focus of this study is the Linnaeus grants, a competitive CoE program for basic (and to some extent strategic) research, established by the Swedish Research Council for Environment, Agriculture and Planning (Formas) and the Swedish Research Council (VR). The grants aimed at creating strong research milieus, scientific renewal, and influence the universities’ research priorities. The application requirements outline some expectations of the centers, e.g. to promote efficient coordination, national and international collaboration, to develop purposeful organizational and leadership structures, as well as communication and dissemination strategies. Altogether 40 centers were established in 2006 and 2008, with a duration of 10 years. Each center was granted between 5–10 million SEK (ca 500,000–1 million euros) per year, with 50% co-funding from the host university. The designation of the Linnaeus centers as representing ‘excellence’ in the sense discussed above, rests partly on the highly competitive nature of the application procedure and the international evaluation
processes applied to each application. This ensured that the centers selected for funding were constituted of top-performers in their respective fields. Furthermore, subsequent bibliometric evaluations have showed that these centers together had on average a 60% higher citation rate compared to the world average (VR 2015).

**Data collection**

The study builds on a 10 center subset of the 40 CoEs. These were selected to cover the disciplines/subject areas representatively. **Table 1** provides an overview of the selected centers.

In selecting respondents, a central concern was that these should have a maximum oversight of the scientific development of the center, preferably from the beginning. Actors who filled that criterion were the founders/directors. Interviews were therefore conducted with center directors (total 10), in some cases jointly with their co-directors. Interviews were carried out in the of Spring 2016, and lasted for about 1 h in each case. The interviews were open-ended, but focused on center context, the grant’s effects on organizational development, center activities, and research processes, e.g.:

- How is the Linnaeus CoE related to research in terms of (a) organization (how research projects are run and related, teams etc. and (b) in terms of the way that knowledge is pursued in the area?
- What aspects of the CoE experience have been the most important? How has the form of funding, evaluations and other relationships (e.g. to the university) impacted on research and ways of doing research?

Interviews were conducted in an informal manner, at the respective center, and were recorded and transcribed verbatim. They were later followed up with complementary questions where it was deemed necessary. In all cases, the respondents were informed that the interviewers/research project had no connection with the funder. They were also aware that the CoE grant had come to a non-negotiable end, and that their answers had therefore no evaluative impacts in this regard.

**Data analysis**

The analysis utilized what Thomas (2006) refers to as ‘the general inductive approach’, where interview protocols are carefully read in order to elicit general commonalities and categories in the material, taking the point of departure in a research question. The procedure followed a standard

**Table 1. Overview of the centers.**

<table>
<thead>
<tr>
<th>Center</th>
<th>Year</th>
<th>University</th>
<th>Subject area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linnaeus Center on Engineered Quantum Systems (LINNEQS)</td>
<td>2006</td>
<td>Chalmers</td>
<td>Physical Sciences and Engineering</td>
</tr>
<tr>
<td>Learning, Interaction and Mediated Communication in Contemporary Society (LinCS)</td>
<td>2006</td>
<td>University of Gothenburg</td>
<td>Humanities, Social Sciences and Educational Sciences</td>
</tr>
<tr>
<td>Center for Studies on the Therapeutic and Prognostic Potential of Mesenchymal Cells of the Tumor Stroma(STARGET)</td>
<td>2006</td>
<td>Karolinska Institutet</td>
<td>Medicine</td>
</tr>
<tr>
<td>Hemato-Linné</td>
<td>2006</td>
<td>Lund University</td>
<td>Medicine</td>
</tr>
<tr>
<td>Organising Molecular Matter (OMM)</td>
<td>2006</td>
<td>Lund University</td>
<td>Natural Sciences</td>
</tr>
<tr>
<td>Innovation, Entrepreneurship and Knowledge Creation: Dynamics in Globalizing Learning Economies (CIRCLE)</td>
<td>2006</td>
<td>Lund University</td>
<td>Humanities, social sciences and educational sciences</td>
</tr>
<tr>
<td>Lund University Center of Excellence for Integration of Social and Natural Dimensions of Sustainability (LUCID) –</td>
<td>2008</td>
<td>Lund University</td>
<td>Humanities, social sciences and educational sciences</td>
</tr>
<tr>
<td>Center for Marine Evolutionary Biology (CeMEB) –</td>
<td>2008</td>
<td>University of Gothenburg</td>
<td>Natural Sciences</td>
</tr>
<tr>
<td>Lund Center for Control of Complex Engineering Systems (LCCC) –</td>
<td>2008</td>
<td>Lund University</td>
<td>Physical Sciences and Engineering</td>
</tr>
<tr>
<td>Uppsala Center of Evolution and Genomics (UCEG) –</td>
<td>2008</td>
<td>Uppsala University</td>
<td>Natural Sciences</td>
</tr>
</tbody>
</table>
method of first going through the interview transcripts in detail, identifying accounts which denoted activities explicitly or implicitly relating to the research question. These statements may be referred to as ‘meaning units’ following Giorgi (1997), and they are taken to represent ascriptions regarding, in this case, how the center conditions affected interdisciplinary collaboration. Meaning units were captured by assigning codes in the form of short descriptive labels to statements. Codes were clustered based on commonalities identified relating to the research question. Using these codes, the themes were broken down into lower level categories according to the same method of identifying similarities in meaning units. The dimensions captured in this way are presented in the next section together with explanations and illustrating quotes. The authors have selected the most representative quotes with respect to content across disciplines, and those that were most illustrative of the overall results.

Results

This section is divided into three main categories derived from the data: governance, conditions and outcomes. The logic behind this overarching division is obviously the simplicity of sequence, where typically governance actions are expected to facilitate conditions which in turn generate outcomes. Although these categories are certainly analytically separable and also correspond to the empirical pattern found in the data, they are not fully analytically and empirically distinct. For example, the conditions for interdisciplinary research reported by the respondents may be more or less in line with the governance measures taken to facilitate interdisciplinarity. Also to some extent conditions overlap with outcomes, since some outcomes of governance have to do with facilitating conditions. Nevertheless, governance, conditions and outcomes can be separated by their sequence, circumstances, and by the intentions that bring them about, as expressed by the respondents. They are also fruitful in ordering the subcategories into a structure, which is logical as well as corresponds to the content of responses found in the material.

Governance

This heading covers typical interventions performed in order to facilitate cross-field and cross-specialism cooperation. These consist of training/nurturing of juniors, developing organizational structure and processes, and finally supporting an informal epistemic environment.

Training/nurturing

This activity involves enabling early career and doctoral researchers in cooperative, cross-border activities through various means. One of these is joint supervision and funding of juniors, e.g.

We have joint supervision of PhD students where the supervisors are from the different fields that participate in the center. (OMM)

And:

One post-doc was funded by two different Linnaeus centers at two different faculties, the natural science and the medical faculty. (OMM)

There is also evidence of integration activities on the junior level, for example intellectual meeting places such as the cross-departmental seminar:

[we] also now have this across department community where PhD students and post docs meet on monthly seminars and annual retreats. And I think this has broadened their perspectives and made them better prepared for future work. (TARGET)

An important instantiation of this pertains to nurturing connections between basic and applied (clinical) perspectives already early in the career, this amounting to an often overlooked but central form of cross-boundary interaction:
The third thing is probably also that we have somehow succeeded in the ambition to create a training environ-
ment for younger scientists who are [now] better prepared to do what is called translational research. They have
grown up in an environment where basic scientists and clinical scientists interact. \( \text{STARGET} \)

**Organizational structure**
The centers are often placed within faculties, and build on cooperation between departments there. The composition
and structure of a center is thus heavily influenced by the structure of the faculty. In some cases, there is more of a cross-boundary
department structure at the faculty, which helped facilitate interdisciplinarity at the center, e.g.

If you go to a university abroad most often those competences would not be in a single department, instead there
would be people spread out in computer science, in electrical engineering and mechanical engineering, and
mathematics. But in [university], there is already an organisation, a department structure which is quite well
aligned with the needs of the centre. \( \text{LCCC} \)

Attracting and keeping people from different disciplines in the centers may be a matter of having
permeable organizational boundaries, but also being clear about direction.

Several of the guys that we didn’t invite from the start, because of lack of information, are now key persons. So, we
have an organisation where you don’t really say this is we and no one is allowed to come, but we have it per-
meable so people can come and go. […] If you are clear on what your expectations are on the people that
join, and you are clear on what the benefits will be […] then there is no problem. \( \text{CeMEB} \)

One way of steering the center to more cross-boundary cooperation, given the in
flux of personnel from different fields, is by means of maintaining an interdisciplinary meeting processes, e.g.

Because even if we are a lot of people we spent at least half of the time of the meetings in group discussions. We
have presentations but they are fairly short, […] and we divide up in small groups and discuss the same topic.
Sitting 20 people around the table is no point. Disciplines are mixed in the groups. \( \text{CeMEB} \)

**Informal epistemic environment**
Informality, or slack, in the environment makes it more conducive to cooperation, since it means less
of a risk to engage in uncertain partnerships. The long-term perspective of excellence funding is one
important facilitator here:

[…].Building these bridges between disciplines has been really fun and rewarding. That is something with a long-
term perspective. You won’t deliver anything during the first couple of years but later you can deliver something
that is really new and very interesting. \( \text{CeMEB} \)

The long-term perspective makes it possible to maintain an open-ended line of inquiry, which allows
new connections to be made beyond the discipline, e.g.

[…]this money was not really generated to fund a particular line of investigation. \( \text{Hemato-Linné} \)

Yet, the informality of the environment makes it necessary to maintain energy and collaboration once
cooperation has been initiated:

It is very easy to lose focus. I think you have to work to stay together, to collaborate and to maintain the energy.
\( \text{LinCS} \)

Finally, an important aspect of governing collaboration in an informal research environment is to be
able to select and maintain focus on issues that requires complementary disciplines, while not
departing from spontaneity:

The whole idea of the centre is this collaboration and synergy that you get when you meet and talk to people and
come up with, well, when you find the issues that different competences can help solving. When you are com-
patible but also complementary. \( \text{CeMEB} \)
**Conditions**

The conditions category refers to the circumstances that are perceived to facilitate interdisciplinarity in the center environment, rather than to direct interventions. Conditions include time availability and core funding, and the presence of shared interests and complementary expertise.

**Time availability**

Having the time to cooperate and the discretion to allocate the funds freely seem to be important factors. Typical statements to this effect are:

I can verify a very common statement about interdisciplinarity: it takes time. That is something I can really verify. So, the most positive is that we had 10 years of research without any [predefined] deliverables, so complete freedom over 10 years. (LUCID)

And that;

It was important that it is such a long term grant. And also that it, sort of, not forced but stimulated people to work together in constellations that we did not do before. And in a way these two aspects are connected because if you have a ten-year period you dare to collaborate with people that are not that close to you in terms of the field they work in. So I think it stimulated some really new things. (UCEG)

Cooperation hinges on time in at least two respects. Firstly, it takes time to decide on a direction between specialisms, and how to forge that path to mutual satisfaction, e.g.

Yes, it is always a challenge when you work together […]. The end result is always much better but it takes more time to agree upon exactly what should be done, etc. So it’s like a time lag before you get started […].to understand each other when you come from slightly different disciplines within a discipline like biology. (UCEG)

In this case the respondent refers to cooperation within a broad field, biology, where one may speak of cooperation between sub-disciplinarities or specialisms which are not typically integrated. Secondly, mutual respect between epistemic orientations, such as basic and applied, is something that develops over time:

There have of course been some cases where the more basic scientist would think that the clinical questions are somehow trivial, and the clinical scientist would think that some of the basic questions are irrelevant. But I think as time went along, mutual respect increased. That has been very nice to see. (STARGET)

**Shared interests and complementary expertise**

Center researchers typically agree on a shared set of intellectual problems and opportunities, to which they find reasons to direct their resources. Such agreement is perceived to facilitate cross-specialism cooperation. An illustrative quote:

You have to have new people who are not the same as those already there but who share some kind of interest that can latch onto the interests that are really there. (LinCS)

Facing a practical challenge, which cannot be resolved from within disciplinary perspectives helps motivate the inclusion of another field in the process of inquiry. Practical challenges may require complementary disciplines to join forces, e.g.

We have a spin-off project which is called BAMBI (conservation in the Baltic Sea). In that project we have social scientists on board and that is really interesting. […] The reason to invite them there was that there was an urgent need to deal with management in conservation. There was a need to understand more about how management dealt with genetic biodiversity. (CeMEB)

The engineering disciplines have a natural tendency to combine and synthesize disciplinary knowledge for the purpose of solving problems, as is illustrated in the following quote:

A complex engineering system could be many things. It could be control of a factory, an airplane, but it could also be large-scale infrastructure network, like the power network of Scandinavia or the power network of Europe, or
the traffic network of a city. [...] So it is many different applications areas but there is a common knowledge base that we are building, and common principles, and sometimes you can transfer experiences from one area to another area in a very useful way. That is the motivation why we keep all these different kinds of applications under the same umbrella. (LCCC)

This illustrates how a shared knowledge base may be host to a diversity of applications if it is already applied in its orientation. However, outside of the applied disciplines a shared knowledge base may not come as naturally. One reason is the continued reliance on the disciplines to produce the researchers that go into interdisciplinary environments. This may require a balancing act. An interdisciplinary environment that succeeds in maintaining its ties to the disciplines must balance between a strong center identity and good relationships to the disciplines (in this case departments), e.g.

So, we said we are going to have a centre where we sort of maintain strong and dual dialogue with the departments. [but] which has its own identity; its own interdisciplinary identity. It is strong in itself but it exists based upon solid and good relationships with the departments that created it. (LUCID)

The strength of disciplinary identities that make up an interdisciplinary environment is a crucial factor when it comes to integration of perspectives. In this sense not all disciplines have the same potential, e.g.

Generally, I think it is easier to work with disciplines with not so strong identities. So geographers, they have no strong identity. You never hear somebody say I am a geographer therefore blabla, but we hear quite often I am a political scientist so therefore blabla. (LUCID)

As was seen under the governance heading above it may fall upon the younger researchers to make the connection between disciplines:

The junior researchers are very important because they are the ones who are most open-minded and see the connections between different types of groups. [...] post docs act as glue between the different research groups. Typically, they would be involved in collaborative projects. (UCEG)

**Outcomes**

Interdisciplinary outcomes were of a widespread character and covered the closing of disciplinary distances among center participants, the facilitation of discovery and verification processes in ongoing research, as well as transfer of results and models from one field to another.

**Closing disciplinary distances**

An important outcome of an interdisciplinary center is of course the enabling of fruitful interdisciplinary encounters. One such is illustrated in the quote below:

One of our members is a professor in clinical oncology, basically treating breast cancer patients and identifying new treatments. At the other end is a person who is very much into development of novel methods to analyze biology. He has developed new methods to characterize cells at much higher resolutions. These two people would not have met without this network but they now met long before this work started to be public. (STARGET)

A requirement for this is of course that the participating researchers already are in a state of mind that supports them in identifying disciplinary similarities and complementarities. One outcome in this regard has to do with how the center environment affects a collaborative mindset, e.g.

All of the researchers in the center are biologists. Biology is a broad field. So the center is very broad. That was a problem in the beginning [...] because we came from different parts of biology. But once we started to understand each other we saw the parallels. It was kind of cool. (UCEG)

Rather than just transferring knowledge, the closing of disciplinary distances may offer new perspectives one’s own discipline, this of course being part of a more general interdisciplinary learning process that will later facilitate the more tangible integration, e.g.
Yes, just listening to and trying to understand people that have deep knowledge in other disciplines is of course really rewarding. Listening to these physicists, sometimes they just ask what are really silly questions in biology. But then you have to answer and you have to think deeply about your own discipline. And of course, looking at the problems from a completely new perspective is extremely educating. (CeMEB)

**Discovery and verification**

The change of mindset has several effects that pertain to interdisciplinary work processes. One of these is the identification of ‘problem spaces’ between the disciplines that become intellectual niches for new research:

There has not been an expansion because we started very broadly. It’s more like we have created new niches in between the different fields, that we were not aware of before. We have found more connections between them. (UCEG)

The proximity and network effects between different specialisms also facilitate this integrative process, and speeds up new initiatives:

The cross-disciplinary nature of the network has allowed people to take new initiatives more rapidly […] I think it has increased the speed of the progress and the readiness to try new things. It reduced the threshold for starting novel projects, because of the personal vicinity. (TARGET)

An example of such an integrative outcome is when one research area draws verification for some research from another field, e.g.

We have had a lot of collaboration with the group that is [using] electron microscopy on material and devices. They have spent a lot of time analysing the devices we made. And this is now starting to be very valuable, but it has taken a long time. (LINNEQS)

**Results transfer**

One way of transferring results is when method developed in a basic discipline is adopted by clinicians. The following quote illustrates how this process can be facilitated by proximity:

These two people started collaboration around this new method. […] Normally the basic science people would stay where they are and talk to some mouse people, and then eventually the mouse people maybe will need clinicians. But here we have this emerging methodology being reported in […] seminars where this clinician was present. This is an example of sort of rapid integration of new methodology for clinical studies. (TARGET)

In order to facilitate this kind of transfer results must be of cross- and interdisciplinary relevance. That is, they have to facilitate insight and discovery for some group outside the areas of inquiry (3.9), e.g.

When we had the first preliminary sequence DNA from this snail, we asked a medical researcher who work with Alzheimer’s disease to look into the sequences. And he immediately found five of the genes that are involved in Alzheimer in humans […] What is interesting for medicine is of course understanding what these genes are doing in a completely different organism. In humans, we know them because they produce this disease. But what do they do in snails? What do they do in fish etc.? (CeMEB)

A more radical form of interdisciplinarity is created when in such cases as the above, results are transferred from one domain to another and starts affecting the processes of inquiry as well as the explanatory models there:

So now when we are working with marine organisms we will actually present completely new models for medical research, explaining existing models and how these are land related. These [results] are important in order to understand the human and how things work on the cellular, genetic level. (CeMEB)

This concludes the results section of this article. Table 2 summarizes the main results, as well as key phrases that capture the content of the derived categories. In what follows we will look closer at what insights can be derived from this in terms of governing interdisciplinary research at CoEs.
Discussion and conclusions

A central aim of the Linnaeus Grant was to create organizational structures for sustaining cross-cutting research on a high international level. As we saw in the research overview, previous studies agree on the connection between excellence and interdisciplinarity (e.g. Martin, Allwood, and Hemlin 2004; Heizne et al. 2009; Hellström 2011; Langfeldt et al. 2015; Borlaug 2016; Gläser and Laudel 2016). The two central assumptions guiding this aim are that (i) certain intellectual issues are too complex for single disciplines to solve on their own, and that (ii) epistemic governance can facilitate the interdisciplinary capacities and outcomes necessary to achieve excellence (here understood as new scientific advances). In the research overview, we also observed that studies converge on a set of contextual precursors to interdisciplinary outcomes. First, continuity in funding is considered important for engaging in interdisciplinarity (e.g. Pfirman and Martin 2017). Second, independent, interdisciplinary research units are the preferred organizational form for pursuing interdisciplinary research (e.g. National Academies Committee 2005; Sá 2008). Third, institutional support from the immediate academic setting to interdisciplinary endeavors can be a determinant of their success (e.g. Lattuca 2002; Porter et al. 2006).

While such factors certainly were present in the respondents’ accounts, and perceived as important precursors to interdisciplinary outcomes, our results also put the focus on how the internal governance of the centers promote such effects. Some previous studies emphasize the connection between leadership activities, or broadly governance, in collaborative research environments, and significant research contributions (Hollingsworth and Hollingsworth 2000; Hemlin, Allwood, and Martin 2004; Heinze et al. 2009). In the present study, we find that the governance of CoEs is largely about creating and ensuring that certain conditions and processes are present in the research environment, the idea being that these conditions will eventually lead to interdisciplinary outcomes. Center directors seem to be of the mind that one should stimulate and not force interdisciplinary

Table 2. Overview of results.

<table>
<thead>
<tr>
<th>Factors and categories</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governance Training/nurturing</td>
<td>Joint supervision and funding of juniors. Integration activities on the junior level. Nurturing connections between basic and applied perspectives.</td>
</tr>
<tr>
<td>Organizational structure</td>
<td>Cross-boundary department structure. Permeable but distinct organizational boundaries. Interdisciplinary meeting structure.</td>
</tr>
<tr>
<td>Conditions Time availability</td>
<td>Time to cooperate. Time to decide on direction between specialisms. Develop respect between epistemic orientations over time.</td>
</tr>
<tr>
<td>Shared interests and complementary expertise</td>
<td>Researchers share sets of intellectual problems and opportunities Practical challenges that require complementary disciplines. Shared knowledge base for a diversity of applications. Balance strong center identity and good relationship to the disciplines. Strength of disciplinary identities. Younger researchers to make the connection between disciplines.</td>
</tr>
<tr>
<td>Outcomes Closing disciplinary distances</td>
<td>Fruitful interdisciplinary encounters. Identifying disciplinary similarities and complementarities.</td>
</tr>
<tr>
<td>Discovery and verification</td>
<td>New perspectives on own discipline. Identification of ‘problem spaces’ between the disciplines. Proximity and network effects between different specialisms speed up new initiatives. Verification of research from another field.</td>
</tr>
<tr>
<td>Results transfer</td>
<td>Method developed in a basic discipline adopted by clinicians. Results of cross- and interdisciplinary relevance. Results transferred from one domain to another.</td>
</tr>
</tbody>
</table>
outcomes. This is represented in the empirical accounts by the tripartite division between governance, conditions and outcomes. The challenge for the analysis is to identify the pathways from governance to outcomes via mediating conditions. Luckily, the results offer accounts of several such pathways, which we will now discuss in the light of some of the literature. Table 3 is an attempt to summarize/illustrate these pathways/mechanisms.

**Governance of a network of specialisms**

The result section outlined three areas of typical governance interventions, perceived by the respondents to support conditions for interdisciplinarity. These were training/nurturing, organizational structure, and informal epistemic environment (Table 2 offers some examples of each). A general observation is that all of the governance interventions seem to relate, largely, to managing a network of specialisms. In fact, the idea of network governance is a reoccurring theme in the respondents' accounts. Three such general network promoting activities appear to support conditions for interdisciplinarity. These are activities that: (i) ensure and nurture a base of cross-cutting specialisms in the CoE’s network, (ii) create proximity and promote slack, and (iii) encourage open-ended lines of inquiry. The first refers to activities related to organizational structure. They include recruiting from different specialisms and building on cooperation between departments. Related to this are training/nurturing activities, aimed at vitalizing the network. Here, setting up joint-supervision and socializing junior researchers into interdisciplinarity, were important in bridging between different specialisms (cf. National Academies Committee 2005). Younger researchers typically played that role.

The second governance activity, termed ‘creating proximity and promoting slack’ relates to informal encounters between the specialisms. In order to encourage this, directors made organizational choices such as promoting permeable center boundaries. They were nevertheless clear to members about the general direction and expectations, and institutionalized physical platforms for interaction (e.g. seminars, coffee meetings, colloquia, etc.). The platforms served to promote collaboration towards these ends. Slack and proximate meeting places certainly served to facilitate informal interactions (cf. Pfiorman and Martin 2017). However, the final aspect of network governance, ‘encouraging open-ended lines of inquiry’, seems to be the main driver of an informal epistemic environment. Activities here were described in terms of maintaining long-term research perspectives, flexible fund allocation across the network, and maintaining energy within the network by balancing focus and spontaneity. The result was a risk-tolerant environment that mitigated the higher transaction costs associated with interdisciplinarity (van Rijnsoever and Hessels 2011).

In the next two sections, we will first discuss how the respondents linked these three governance activities to conditions for interdisciplinary research. We will then move on to showing how conditions were perceived by the respondents to yield certain epistemic outcomes.

**Conditions for interdisciplinary research**

Shared interests/complementary expertise and time availability were the two main conditions directors perceived as facilitating interdisciplinary outcomes. Some of the most emphasized aspects of these conditions were: ‘shared interests/complementary expertise’, which in turn can be seen as
supporting ‘collaborative mindsets’, and ‘lower thresholds to start collaborations’. According to the interviews, shared interests/complementary expertise resulted from governance activities promoting cross-specialisms and slack (cf. Pfirman and Martin 2017). For instance, the accounts show that complementary expertise was discovered when researchers from different backgrounds met on unconditional terms. Shared interests were developed when intellectual problems were discussed. Researchers started to understand each other, see parallels between their specialisms, and reflect about their own specialisms.

Time availability supported these initial, collaborative steps. Governance that promoted open-ended lines of inquiry gave members time and space to agree on epistemic problems (cf. the notion of ‘creating common ground’, Lattuca 2002; Öberg 2009; König et al. 2013). While these conditions depended on slack and time, they also depended on favorable access between the specialisms. The respondents linked such access or proximity to lower thresholds for turning interactions into actual collaboration. This observation is supported by Klein and Porter (1990), who suggest that physical proximity is an important facilitator of informal interactions.

In the next section, we look at the outcomes of these conditions.

**Epistemic outcomes**

From the narratives, we derived three main categories of outcomes: closing disciplinary boundaries, discovery and verification, and result transfers. In this final section, we focus on the latter two. Closing disciplinary boundaries is an epistemic outcome that refers to decreasing the cognitive distance between specialisms. However, unlike the other categories, it can also be framed as a process that begets more interdisciplinary effects downstream. From this perspective, one may want to consider it an epistemic condition as much as an interdisciplinary outcome. Discovery seems to be mainly associated with the condition of shared interests/complementary expertise. In the interview accounts, we find that developing shared interests and discovering complementary skills led to the discovery of new problem areas. Such discoveries laid the ground for developing new niches and new lines of inquiry. Similarly, the respondents related verification and transfer of results to lower collaboration thresholds. The latter seems to have prompted a faster transfer and integration of results and instruments between specialisms. In some cases, such transfers were expected to open new lines of inquiry in their new adoptive disciplines/specialisms.

The identified epistemic outcomes mirror the variations of interdisciplinarity identified in the literature. For instance, the establishment of new niches resonates with the notion that interdisciplinarity serves to cover knowledge areas unaddressed by established disciplines (cf. Stember 1991). Verification and results transfer evoke the instrumental aspects of interdisciplinarity raised by Salter and Hearn (1996). According to their take on instrumental interdisciplinarity, ideas and methods are borrowed from one discipline or specialism into another to improve their problem-solving capacity, while the boundaries between disciplines tend to be maintained. In our case however, we find that disciplinary borders can be crossed: the transfer from one discipline or specialism can affect processes of inquiry and explanatory models in others.

This is most likely due to a number of factors found in the governance and conditions columns in Figure 3, which specifically relate to qualities of the CoE funding instrument, such as long-term proximity of specialisms, and slack from base funding. The present study shows how these can sustainably foster the types of novel intellectual encounters that interdisciplinarity is associated with. By providing a detailed qualitative account of interdisciplinary governance, conditions and outcomes in CoE settings, we have been able to analyze some of the mechanisms that support interdisciplinary cooperation. In this study we have illustrated how the CoE setting can enable researchers to move beyond a merely interactive, borrowing epistemic relationships, to integrative relationships, where new cross-cutting specialisms develop. We believe that the above account can aid in understanding organizational/social correlates for interdisciplinary research, as well as contributing insight to academic leadership in these contexts.
Disclosure statement

No potential conflict of interest was reported by the authors.

References


