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# Using mixed methods to map vaguely defined research areas

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## Abstract

The aim of this article is to present an alternative method for science mapping, which remedies some of the classic limitations to e.g. using co-citation analysis as a mapping tool. With the emergence of new, more complex and interdisciplinary areas of research it becomes important to adjust our understandings of how to study these areas, and the argument of the present paper is that in order to provide high-resolution maps of emerging scientific areas, we need to start in the 'cognitive colleges' of the research areas themselves. To do so, a mixed methods design with co-nomination as its backbone is proposed. The potential and limitations of the alternative approach to science mapping are discussed based on an empirical example of mapping an vaguely defined research area in Denmark.

**Key words**: science mapping; complex research areas; mixed methods; co-nomination.

## Introduction

In an age of academic globalization, where knowledge is distributed, diversified, interdisciplinary and crosses boundaries to an extent never seen before, it becomes increasingly interesting and important to refine our understanding of academic disciplines, scientific fields, research areas, and their structures. New research areas emerge along with technological development and global societal challenges, and with this emergence comes challenges to both research communities and policy makers. For the research community—particularly within emerging areas—the challenges e.g. relate to the potential for collaboration and knowledge sharing, which might be obstructed by the lack of knowledge about possible partners. From a policy perspective, challenges relate to the difficulties in communicating with a scattered field, which may hinder constructive policy solutions and e.g. needed funding schemes.

In this changing context of science organization, *science mapping* can be seen as an important analytical tool for studying structures and dynamics of science and thus useful for science studies, as well as science policy studies and research evaluations (Leydesdorff, Milojević and Wright 2015). In this article, we discuss methods of science mapping, and how we might refine such methods to better suit emerging and/or complex research areas, i.e. areas that are vaguely defined and non-cohesive. We suggest a mixed-methods framework with a co-nomination backbone, as an under-explored method for science mapping and elaborates how it may complement some of the more established, yet also vulnerable methods in use. The central argument is that more elaborate and sophisticated methods for identifying and mapping out complex research areas would be of great value for the much-needed communication, both within scientific communities and between policy development and scientific knowledge. This could potentially also refine the evaluation of the performance of these research areas (measured e.g. in terms of impact, etc.).

## Scientific areas and how we map them

As mentioned, the key interest in the present paper is to present and discuss a more nuanced approach to studying scientific areas. The epistemic and relational landscapes of science are however not easily defined and with the increasing political and societal focus on cross-disciplinary challenges, we see an increasing '*diversification and specialization of knowledge that blurs traditional boundaries and challenges existing patterns of organization within science*' (Fagerberg, Fosaas and Sapprasert 2012). Adding to the complexity, we also see a plethora of concepts used to describe the organization of science, e.g. as scientific/academic fields (Bourdieu 1988; Whitley 2000), research specialties (Price 1963), or knowledge communities (Nedeva 2013). The main axis of importance across these various definitions seems to be the degree of self-organization within an area; ranging from highly institutionalized with dedicated journals, associations, conferences, etc. to the newer, interdisciplinary areas, which tend to 'latch on' to the infrastructure of the institutionalized areas, until mature enough to have developed e.g. dedicated journals of their own. Another, perhaps more overlooked dimension on this continuum are the areas which are defined from outside the science system itself, e.g. through thematic funding schemes and overarching research policy formulations.

In the present paper, the ambition is to make the case for an approach, which is tailored to the study of non-coherent and vaguely defined research areas, e.g. like research on research and innovation (RI-research), which is the empirical case in the present study. *Research area* in this study is thereby conceptually defined as a community of scholars doing research on a given topic or phenomenon. Fagerberg and Verspagen (2009) and Cole (1983) use a very similar definition in their use of a field as 'all work being done on a particular cognitive problem', but since *field* may have other connotations of organization and academic consensus, we opt for the term *research area*, since the objective here exactly is to allow the research area to construct itself, rather than imposing a fixed definition upon it, with implicit or explicit assumptions of organization, consensus and theoretical orientations.

Science mapping, i.e. the attempt to capture and delineate a specific scholarly area, is typically associated with scientometric approaches aimed at exploring structures of knowledge domains based on evidence from the scholarly literature under study (Morris and Van der Veer Martens 2008). This can be achieved by mapping various bibliographic entities such as subject terms, documents, authors or journals, mainly using co-occurrence measures such as co-citations or co-words (Morris and Van der Veer Martens 2008). Science mapping is primarily based on selective journal literatures indexed in international databases. Consequently, their main advantages are mapping of social structures as they can be realized through the institutionalized communication in these journal literatures. While such approaches have been applied successfully, they do come with general limitations, issues of construct validity, and conceptual ambiguities.

First of all, science mapping through bibliometric methods is dependent on the delineation and preselection of publication sets used for analyses (White and McCain 1997; Schneider 2010). Likewise, entities and measures used for analyses come with assumptions most notably about citing behavior and authorship norms (e.g. Nicolaisen 2007; Aksnes, Langfeldt and Wouters 2019). Citing behaviours are, however, known to be both normative and opportunistic; they tend to favour certain types of studies and are influenced by mechanisms of cumulative advantage. Similarly, authorship norms are also known to vary considerably across knowledge domains.

Second, and particularly relevant to the argument in this article, science mapping is typically restricted to formal scholarly communication mainly in journal publications. Consequently, such approaches are more appropriately applied on well-established fields with institutionalized journal communication structures and are much less appropriate for mapping important informal structures such as 'invisible colleges' (Crane 1972), areas where journal and/or international publication are less prominent, or weak structures such as emergent fields, interdisciplinary areas or weakly delineated research areas, where 'core' journals do not exist and publications are scattered over many different fields.

Finally, the conceptual ambiguities mentioned above are also very much present in science mapping studies, especially at lower analytical levels when it comes to defining, operationalizing, and delineating the constructs examined, i.e. often labeled as 'specialties', 'domains', 'knowledge communities', 'fields', or 'disciplines'. At the aggregate level, however, coarse citing behaviors seem to be sufficiently distinct to structure main fields of research in patterns recognizable with substantially different approaches (Klavans and Boyack 2009; Waltman and Van Eck 2012).

Despite its limitations, science mapping based on journal literatures is a useful exploratory tool for many policy and evaluation tasks. Different conceptions of constructs, however, would require different entities and measures for mapping and some constructs or tasks would require entities and/or approaches beyond journal literatures. Therefore, and also due to the limitations described above, recent years have seen a rise in new ways of mapping scientific fields (e.g. Merkx and Van den Besselaar 2008; Lepori and Probst 2009; Minguillo 2010), and refining established methods to do so (e.g. Chavalarias and Cointet 2008).

The present article continues the work of developing and refining science mapping techniques for policy and evaluation contexts, where traditional approaches are limited. Specifically, the aim of the article is to present and discuss an approach, which was used for mapping non-cohesive and vaguely defined research activities of policy interest. It is argued that this method could be usefully applied in other science mapping attempts, where 'traditional' methods are less useful.

## Mapping a non-cohesive research area – The case of Danish RI-research

The point of departure of the study presented in this article was a special policy request to map Danish 'research on research and innovation' (RI-research). Denmark, like many other countries, is witnessing an increased political commitment to acting strategically in research and innovation policy, and to ensuring that decision-making within these policy areas takes expert advice and research-based knowledge into account. The perceived importance and complexity of research and innovation policy has led, in turn, to a growing demand for RI-research and efforts to create linkages between RI-researchers and policy-makers.

Many communities and scholars study science, research and innovation, but it is difficult to identify and delineate an institutionalized field of RI-research, either nationally or internationally, and no systematic attempts have been made to examine or explicate the scope and coherency of this area of research in Denmark. At a glance, the area hardly seems to constitute a community, but rather a set of disconnected activities spread across a limited number of small environments and individual researchers from different research institutions. Against this backdrop, the Ministry of Higher Education and Science commissioned the authors of this paper to perform a mapping of Danish RI-research. The explicit aim was to provide a high-resolution picture of Danish RI-research landscape including active environments and individual researchers, the scope and organization of the research area, the thematic orientations, and the cognitive and practical cooperation patterns of the researchers within this research area (Degn, Mejlgaard and Schneider 2015). The task of mapping such an area of research thus demanded a novel approach, as no initial formal structures can be expected and, correspondingly, no obvious point of departure exists. RI-research is a not a manifest field of its own, with formal communication structures such as core journals and conferences. Moreover, research interests in RI-research is spread over many areas with limited interaction and communication among such areas. This task provided an opportunity to experiment with a mixed-methods approach to mapping an interdisciplinary research area such as RI-research.

An initial assumption is that potentially relevant research activities can be identified in areas of the social sciences and humanities, where research practices and publication profiles deviate substantially from international journal publication. Consequently, we are not able to reliably predefine a selection of core international journals, which can be assumed to be representative for RI-research, let alone capture the specific Danish interests examined, as is needed for the point of departure with traditional mapping approaches.

Hence, what was needed was a different unit of analysis as journal publications could not be the starting point for mapping the structure of RI-research, neither in Denmark, nor internationally. We argue that the characteristics of this specific science mapping study might be similar to many other studies of vaguely defined scientific areas, particularly interdisciplinary and highly thematic ones, like e.g. innovation studies or the newer branches of climate research. These are, as mentioned, difficult to study empirically as their structures, dynamics, and internal workings are not necessarily solidified and institutionalized. The argument of the present paper is that in order to provide 'high-resolution' maps of emerging research areas, we need to move beyond the view of publication or literature as the unquestionable starting point, and start in the research areas themselves. To do this, a mixed methods design is needed to accommodate the need for breadth as well as depth, and to ensure that the limitations of individual methods are balanced by strengths of others.

In the sections below, we outline a research design based on a variety of methods, which attempts to capture the complexity of an emerging research area, while at the same time mapping it out. Additionally, the design aims at capturing the potentialities of the mapped research area by combining a focus on the cognitive patterns (perceptions of relevance) and the actual cooperation patterns.

## The mapping design

There are multitude of ways to conduct mixed methods research, ranging from not actually mixing to fully mixing (Leech and Onwuegbuzie 2009). Naturally, there are a number of caveats and complexities related to mixed methods research, which primarily relate to the paradigmatic premises connected with qualitative and quantitative methods. Mixed methods proponents tend to move beyond these challenges by claiming a pragmatic standpoint between the positivistic and interpretive paradigms, and emphasize that the value in combining the methods outweighs the potential difficulties. Additionally, a central argument in this pragmatic stance is that much *actual* research does not fall within the 'purist' versions of quantitative and qualitative research. As Johnson and Onwuegbuzie (2004) mention: '[m]ixed methods research offers great promise for practicing researchers who would like to see methodologists describe and develop techniques that are closer to what researchers actually use in practice'.

In the following sections a mixed methods design is outlined which attempts to utilize a variety of methods to capture and investigate the complexities and dynamics of a research area, while at the same time assessing its impact and structures. Subsequently the applicability of the framework for mapping vaguely defined research areas is discussed, potential caveats are highlighted, and further avenues for research are presented.

### The co-nomination backbone

The backbone of the mapping framework presented in this article is the co-nomination method. Co-nomination can be perceived both as a method for gathering data and as an analytical tool used to analyze the data gathered, despite the fact that it is most often referred to as co-nomination *analysis*. Co-nomination analysis is claimed to have been constructed by Georghiou and colleagues in 1988 in their attempt to map scientific fields in the UK (Giusti and Georghiou 1988) and is highlighted as particularly relevant in areas where bibliometric analyses are not applicable or possible. In fact, however, the method was already used in the early 1980s e.g. by Blaivas et al. (1982) and Lenk (1983), to map scientific fields, and subsequently compared to co-citation analyses of the same fields to determine its relevance and applicability. Other uses of the co-nomination method, is seen e.g. in Nedeva et al. (1996), where it is used to identify experts within a specific area. All these studies demonstrate that co-nomination can be a valuable tool for mapping or identifying patterns that might otherwise be difficult to detect.

The co-nomination method is based on asking key individuals, e.g. central researchers, to nominate persons they find relevant and important to their research area. These nominees are then probed the same way and the process continues (ideally) until redundancy is achieved. The method thereby resembles 'snowball sampling', which is used to explore and determine hard-to-reach or hidden populations (Biernacki and Waldorf 1981). A key strength of the co-nomination method is that it 'explicates the structure of the invisible colleges' and that '(t)he resulting map reflects the researchers' collective visualization of their scientific specialty' (Lenk 1983). Co-nomination thus provides a map of the cognitive networks or cognitive colleges, i.e. the network of people that researchers find relevant and significant to their specific area. However, co-nomination also opens itself up to various other uses and can thereby be used to explore both the actual cooperation pattern of the area, the journals that the researchers themselves deem relevant (and/or publish in), their funding sources, etc.

As described by Lenk (1983) co-nomination provides roughly similar results as co-citation analyses would in areas where sufficient data is available, but the aim of the paper was, as mentioned, to provide a framework for high-resolution mapping of vaguely defined and non-cohesive research areas. We therefore argue, that co-nomination could fruitfully be supplemented by other methods; to both validate and elaborate on the results, but also to make the best possible use of the data generated by the method in itself. As mentioned earlier, co-nomination explicates invisible or cognitive colleges by asking the researchers to define their own research areas through nominations, but it also provides valuable data, which can be explored further through both qualitative and quantitative studies.

### Design and data collection

To achieve the aims stated above the study was designed as a mixed methods study, so that both the breadth (the scope and the overall patterns) but also the depth of the research area (the thematic orientations, priorities, and challenges) were explored. In the visualization below, the research design is illustrated. The co-nomination analysis constitutes the backbone of the study and as the figure demonstrates, it feeds into the complementary parts of the study. In the following, the design and analysis phases of the project are presented, in order to arrive at discussion of an overall mixed methods

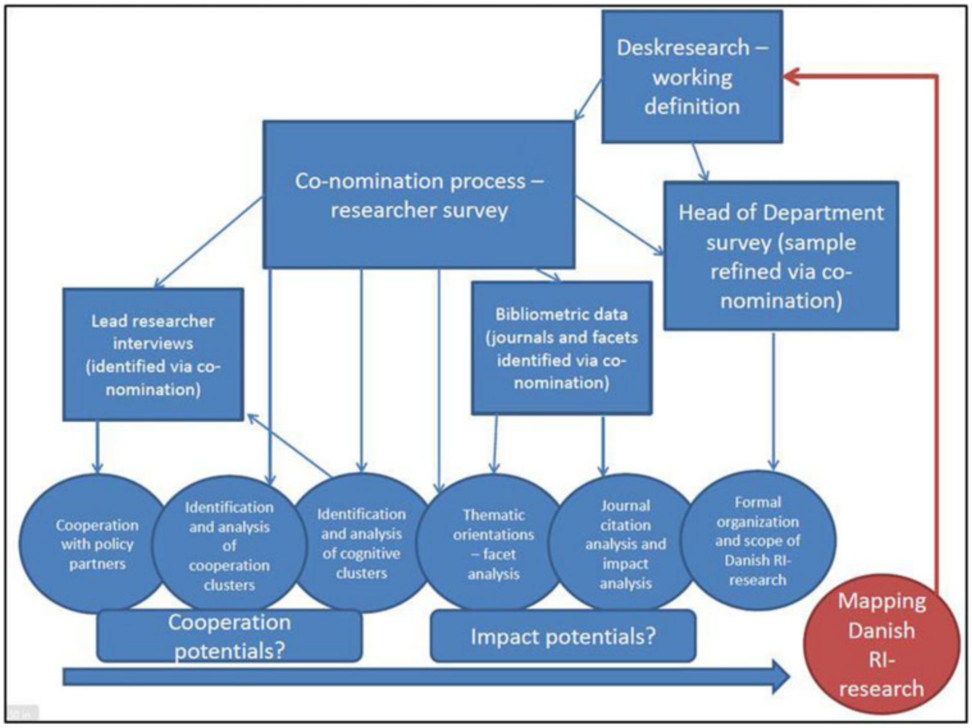


**Figure 1.** Study design.

framework for mapping and understanding vaguely defined and non-cohesive research areas (Figure 1).

The initial phase of the study was a desk research process, which primarily focused on existing studies of both science mapping in order to qualify and verify the methodic framework, but also on the RI-research area in particular, to provide a working definition of RI-research to be used in the co-nomination analysis.

A key part of this desk research was thereby the development of a working definition, which was both aimed at being specific enough to provide a starting point of the co-nomination process and broad enough to encompass the multitude of variations within a non-cohesive research area. This development of a working definition is naturally a crucial and potentially perilous point in the process, as the overall ambition as mentioned was to let the research area 'define itself'. A starting point is however needed to allow key individuals to be selected from which the co-nomination can begin. The choice was made to base this working definition on very broad descriptions of the two key substantial components of the thematic area, namely *research* (described in the Frascati-manual (OECD 2002) and *innovation* (described in the Oslo manual (OECD 2005)). This follows the assumption mentioned above that a research area is a community of scholars doing research on a given topic or phenomenon, and we are thereby basing our working definition on the core elements of this topic. The working definition of RI-research was then formulated as follows: *research which deals with the production of knowledge and the implementation, consumption, and application of knowledge, which creates/facilitates improvements in businesses, society, and policy*.

Importantly, this working definition was constructed with the explicit purpose of being revised continually in the co-nomination process, but provided an important point of departure, from which the iterative mapping could commence. The working definition allowed for categorizations of research orientations and potential sub-research areas, from which key individual researchers were selected by the authors. The selection of these initial respondents is naturally crucial, as it can potentially bias the process. The broad working definition and the subsequent categorization of potential sub-areas, however, allowed for a broad 'baseline', and the co-nomination process in itself was seen as a potential validation or rejection/modification of this working definition.

As mentioned, the co-nomination method was perceived to be not just a method for mapping relations and cognitive colleges (perceptions of relevant peers within a specific research area), but also as an opportunity for exploring the social, collaborative structures of the research area (actual cooperation patterns), thematic orientations (using keywords), and the material manifestations of these (the preferred journals of the nominees), as seen by the nominees.

In the design phase, the co-nomination survey was thus constructed to collect data on all these parameters. The survey asked for nomination of (up to 10) Danish and (up to 10) international researchers that the nominator perceived to be relevant and important *to his/her own RI-research*, nomination of (up to 10) Danish and (up to 10) international researchers that the nominator had direct collaborations with *in his/her RI-research*, a prioritized list of journals that the nominator found to be important and recognized within his/her RI-research area, and (up to 20) keywords or word-strings, which the nominator found covered his/her RI-research area. The survey was distributed to the first round respondents and as the nominations came in, further rounds were administered (see Table 1 below). Reminders were administered twice per respondent after approximately 2 and 4 weeks.

Simultaneously, a survey was distributed initially to the heads of all social science departments (where RI-research was assumed to be

**Table 1.** Summary table of respondents and response rates in the co-nomination survey

| Survey distribution round | Number of recipients | Number of respondents | Response rate |
|---|---|---|---|
| 1 (nominated by project team) | 36 | 26 | 72% |
| 2 | 86 | 72 | 84% |
| 3 | 132 | 85 | 64% |
| 4 | 119 | 82 | 69% |
| 5 | 172 | 102 | 59% |
| 6 (English version) | 76 | 38 | 50% |
| Total | 621 | 405 | 65% |

predominantly carried out) and subsequently to any non-social science department identified in the co-nomination procedure, in order to investigate the formal organization of the RI-research area, e.g. in terms of funding, prioritization, and types of activity. The sample of department heads was expanded by the co-nomination process as new nominations came in, which made the survey an ongoing validation of the co-nomination method and an important illuminator of potential dark spots in the co-nomination.

Based on the findings in the co-nomination process, 10 informants were selected for interviews, which aimed at shedding light on the perception of opportunities and challenges in the Danish RI-research area. The selected informants all had a high number of direct nominations and represented different sub-areas as well as differing institutional affiliations.

Finally, based on the co-nomination survey responses concerning journals and keywords, the study included bibliometric analyses of publication patterns and academic impact of the Danish RI-researchers. In combination, these multiple components of the study provided a detailed understanding and delineation of this interdisciplinary area of research.

## Analyses and selected results

The different types of data that these processes yielded, lend themselves to a number of different analyses and provide complex answers to complex questions. The section below summarizes the main findings emerging from each of the individual components of the study, and highlights the complementarity and hence the benefits of the mixed-methods approach to mapping RI-research in Denmark.

### Cognitive networks

First, the 'cognitive networks' were analyzed by constructing symmetric matrices for each pair of nominated individuals and performing a frequency distribution analysis to assess the strength of the co-nomination. 'Cognitive networks' are understood as the networks that arise from the questions about relevant researchers to one's own RI-research area, i.e. relevance networks. A threshold of two independent co-nominations was enacted to avoid idiosyncratic nominations. Cluster analyses and visualizations were performed using Vosviewer (van Eck and Waltman 2009). Such a visualization is seen in Figure 2, where the overall map of the cognitive networks of Danish RI-research is shown.

The dynamic of the map is that the more co-nominations, i.e. the more times two individuals are nominated together, the closer they will be in the map. The size of the circles indicate the number of nominations. The map can therefore illustrate both clusters, signifying 'sub-areas', but also clusters that are adjacent which signifies relations between sub-areas. Second, the analysis reveals 'hot spots', i.e. individuals or environments that are central in specific areas.

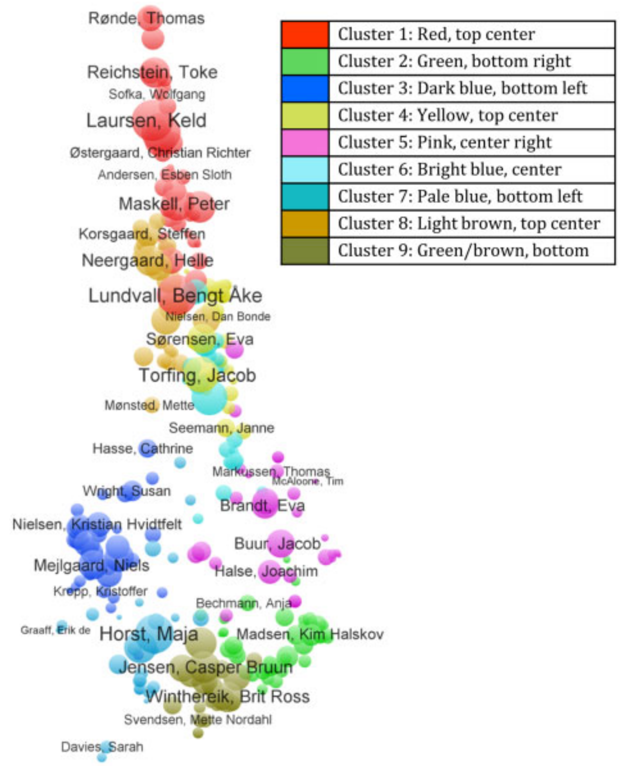


**Figure 2.** Cognitive network—Danish RI-research.

The clustering presented above is based on Danish nominees only, since the purpose of the study was to explore Danish RI-research. The co-nomination analysis provides an image of a fairly heterogeneous research area in Denmark, with several, but small, environments with a few core individual researchers and a broader population of researchers in the periphery. Most of the nine identified cognitive networks have one or a few centrally located individuals who received numerous individual nominations.

As the visualization illustrates, this allows for an analysis of the closeness of the various clusters, e.g. as can be illustrated by the connectedness of clusters 1, 8, 4, and 6, which seem to be closely linked. To explore further the thematic orientation of these clusters, a facet analysis (see e.g. Hjørland 2013) was performed via the keywords provided in the co-nomination analysis (see below). This analysis revealed that these cognitive networks are all concerned with different aspects of innovation studies, such as innovation policy and funding, innovation systems, innovation networks and clusters

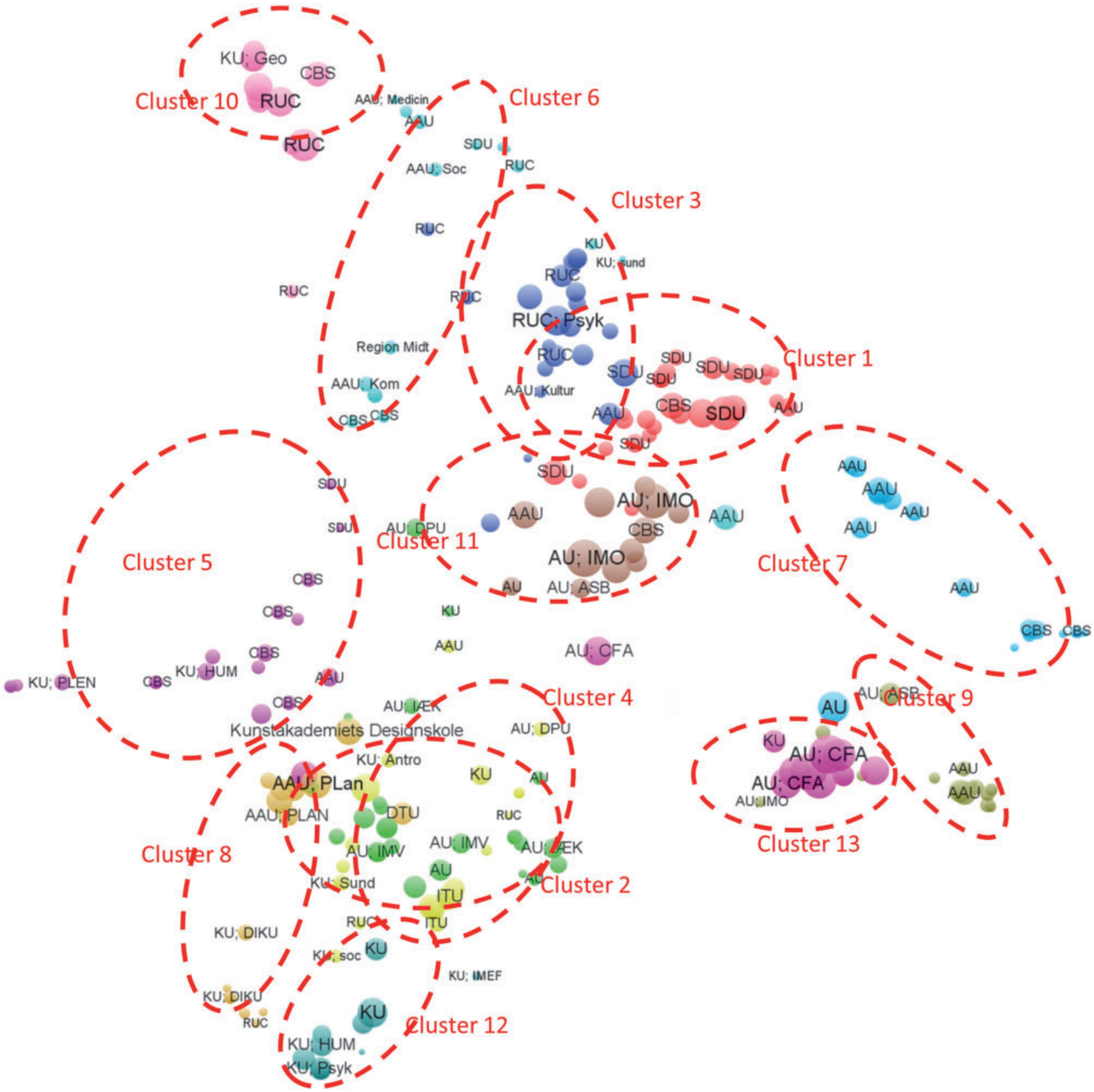


**Figure 3**. Cooperation network clusters with institutional affiliation labels.

(Cluster 1), public innovation and innovation management (Cluster 4), user driven innovation, design and creativity (Cluster 6), entrepreneurship (Cluster 8), and design in and as innovation (Cluster 5).

## Cooperation networks

Interestingly, even if the cognitive networks tended to also reflect institutional affiliation, the clusters also transgressed institutional borders in the sense that a variety of institutions were represented within each separate cluster. Comparing the structure of the cognitive networks with the cooperation networks offered an opportunity to examine whether Danish RI-researchers in fact interact with the individuals and environments that they consider most relevant to their own work. Cluster analysis based on cooperation data showed that collaboration closely reflect institutional patterns, and that RI-researchers tend to cooperate with colleagues from their own institution. In Figure 3 below, the institutional affiliation labels are added to the cooperation clusters, and the figure clearly shows how the patterns of cooperation tend to revolve around institutional affiliation.

The discrepancy between cognitive and cooperation clusters point to a possible, but unrealized, potential for collaboration in Danish RI-research. As a small community compared to e.g. the UK or the USA, operating in geographical proximity and within a national system that does not significantly hamper cross-institutional cooperation, Danish RI-researchers could easily extend their collaborative patterns to make them align better with the underlying

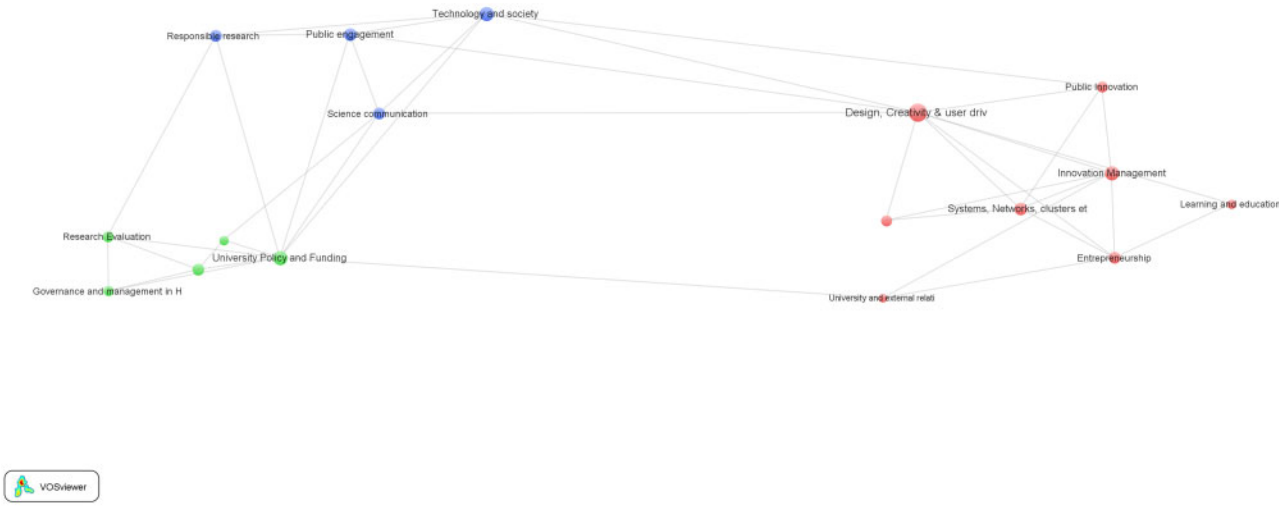


**Figure 4.** Co-nominated facet map.


**Figure 5.** Cognitive colleges with facet attribution.

cognitive networks. This observation was very strongly reinforced during the qualitative interviews with key researchers, who also unanimously spoke of a certain degree of fragmentation and disconnect in the Danish RI-research.

## Thematic orientations

As mentioned earlier, the co-nomination survey asked respondents to provide keywords describing their primary research interests in the RI-research area. These were collated, interpreted, and reduced to 17 'facets' representing broad categories of thematic orientation in RI-research. The facets were developed via a triple coding process, where the project team first coded all keywords into more generalized categories, and subsequently discussed overlaps and differentiations. This process reduced the 1400 keywords obtained via the co-nomination process to 17 distinct facets. Each respondent was subsequently assigned one or more facets depending on the keywords he/she provided via a dual coding process. Figure 4 illustrates the relationship among facets, and points to a clustering of 'innovation' oriented themes (dots to the right), 'science, technology, and society' themes (top left dots), and 'policy and evaluation' oriented themes (bottom left dots).

Returning to the map of cognitive networks, attributing facets to the clusters corroborate the structure of the map. The nine cognitive networks clearly have diverse research interests and describe their own research using keywords that vary significantly across clusters and very modestly within clusters. Figure 5 below shows that in addition to the innovation-oriented clusters, we have one cluster (Green, bottom right) focused on design, participatory design, and user-driven innovation, but also other issues related to technology in society. Adjacent is another cluster (Brown/green, bottom) which focuses on responsible research and issues related to the interaction of technology and society. The light blue cluster, which has a very clear individual centre of gravity at University of Copenhagen, focuses on issues of science communication and public engagement, and would likely be considered an Science-Technology-Society (STS) studies cluster, while the final cluster (Dark blue, bottom left) is oriented towards higher education governance, funding, research policy, and research evaluation.

Interviews with 10 key nominees was used as a way of validating the 'hot spots' and elaborating on the results achieved through the mapping components of the study. This qualitative part of the study was used to gain a deeper understanding of potential reasons behind the discrepancy between cognitive and cooperation networks and for understanding the apparent dominance of the innovation-oriented research activities within the broader Danish area of RI-research. The informants e.g. pointed to significantly more successful development of institutional support structures for innovation studies, such as the DRUID network, and also highlighted the lack of national funding opportunities as part of the reason for the modest volume of research policy studies in the Danish context. Furthermore, the informants stressed the (cognitive as well as project-related) interdependencies between Danish and foreign research groups as one of the reasons that development of national collaborative networks have not been given high priority in research policy studies.

### Journal and impact analysis

To elaborate on the thematic analyses which emerged from the facets described above, and to position the national area of research within an international setting, the final stage in the research process was to perform bibliometric analyses of the publication patterns of the research area and the impact of the specific sub-areas.

In the co-nomination process, the nominees were asked to indicate up to 10 journals that they found relevant for their RI-research area. This part of the data collection allowed the project team to map the domains of the Danish RI-research in a much more nuanced and empirically sensitive way, than it would have been possible with a pre-determined journal 'universe'. The construction of the network of journals was based on a search of the recent mutual cross-citation activity in the Web of Science database between the nominated journals, and a threshold of two nominations were enacted to avoid skewedness in the data.

When using cross-citation activity to explore and map the relevant domains of RI-research, we are able to visually depict the core and scatter for a specific data set, in this case nominated journals. These journals naturally both represent journals which are read by the nominees as well ones in which they actually (aim to) publish. The core journals emerging from this co-citation analysis however, represent those assumed to contain a significantly larger proportion of the RI-research articles (Figure 6).

Identifying the core journals of the national research area in this way, allows for the analysis of e.g. research impact of the national research area within the broader international research community. The core journals were clustered and a few of the clusters were excluded from the analysis based on the well-known core-scatter phenomenon (Bradford 1934) which in this case is very explicit. The impact analyses were performed using data from CWTS' CI-Web of Science database and the results can be seen in Table 2 below.

For the purpose of the present paper, the interpretation of the results is less relevant, but it can be mentioned that the publication activity of the nominated authors in the different clusters were also analyzed to verify the research area clusters, to examine the correspondence between nominations and the derived research areas, and importantly also to determine whether Danish researchers are actually publishing within these areas from 2005 to 2011. The results confirm these assumptions and thus confirms both the nominations and the actual clusters.

## Discussion and conclusions

The purpose of presenting the design and analyses of the mapping of Danish RI-research was, as mentioned, to illustrate how a comprehensive, mixed-methods research design can contribute to the mapping of complex scientific research areas—a task which is arguably beneficial both to the research- and policy communities, as well as to scholars studying research and research evaluation. In the following, we will discuss more broadly the benefits and potential caveats of the suggested approach, and its contribution to literature on science mapping. Finally, we will briefly discuss how the suggested framework might also contribute to the ongoing development of mixed methods as a valuable approach in research studies and evaluation.

As mentioned in the introduction, many studies of scientific areas have been 'hampered' by the lack of available data, e.g. bibliometric data in the social sciences and humanities (Hicks 2004; Nederhof 2006). The approach outlined in the present article does not solve the problem of availability of publication data, but offers another view on, and way into the research areas, which may yield some of the same insights that co-citation analyses offer on other fields with more detectable publication patterns. An example could be the cooperation networks analyzed above. These networks can be validated by co-citation analyses, but the co-citation analyses alone would, we argue, have yielded a different and less nuanced picture, as it would have been limited by both a predefined, and thus potentially skewed or biased, sample of journals and the limited indexation of these journals. Together, however, these analyses provide a detailed picture of the publication patterns within a cross-disciplinary field, which is traditionally hard to capture. The data collection through co-nomination thereby paves the way for a more solid empirical base of 'classical' bibliometric analyses. By asking the nominees to indicate relevant journals, the base of citation analysis becomes more empirically relevant and sensitive to the research area. The co-nomination method thus also shows potential in relation to the scientometric field, where it would be relevant to explore the potential for methodological refinement further.

The analyses above has also demonstrated that allowing the community to 'self-define', i.e. to draw the borders around their own research area rather than attempting to draw these borders a priori, not only helps us to map the area; it also revealed 'sub-areas' that were not initially entailed in the 'sub-areas' that emerged from the desk research. The co-nomination analysis thus enriched the working definition of the research area and helped uncover niche-areas.

Another key contribution of the presented framework is the combination of the focus on the cognitive networks, which maps the reputational structure of the research area, and the collaboration networks, which maps the social structure of the research area. By combining and comparing the two, we gain detailed insight into the potentials of the research area, the uncultivated ground for collaboration and knowledge sharing, and thus valuable information both for the communities themselves, and for policy-makers. As one informant in the Danish study mentions:

'We do research on things that you also find internationally, but we don't have the resources to "fill the field" in the same way that you find in other countries. It becomes a bit fragmented, because it also depends on the other things that people do, and which cooperation partners and resources that just happens to be available. (. . .)'

Studies such as the presented one may help identify and qualify the knowledge 'that happens to be available' and thus strengthen the knowledge base of emerging research areas. From a science policy perspective, the combination of the two foci is relevant, as it highlights both the differentiation within a specific research area, and the potential for supporting and cultivating the collaboration within and between sub-areas. The importance of such support is highlighted by Hambrick and Chen, who note that 'a new academic field will ascend not only, or even primarily, because of its intellectual advances, but also because of its sociopolitical context and undertakings' (Hambrick and Chen 2008).

As argued above, a mixed methods, bottom up research design seems to capture many of the nuances and complexities of interdisciplinary and composite research areas. However, a respondent-based method of data collection such as the co-nomination method also has several limitations, which should be addressed. Being

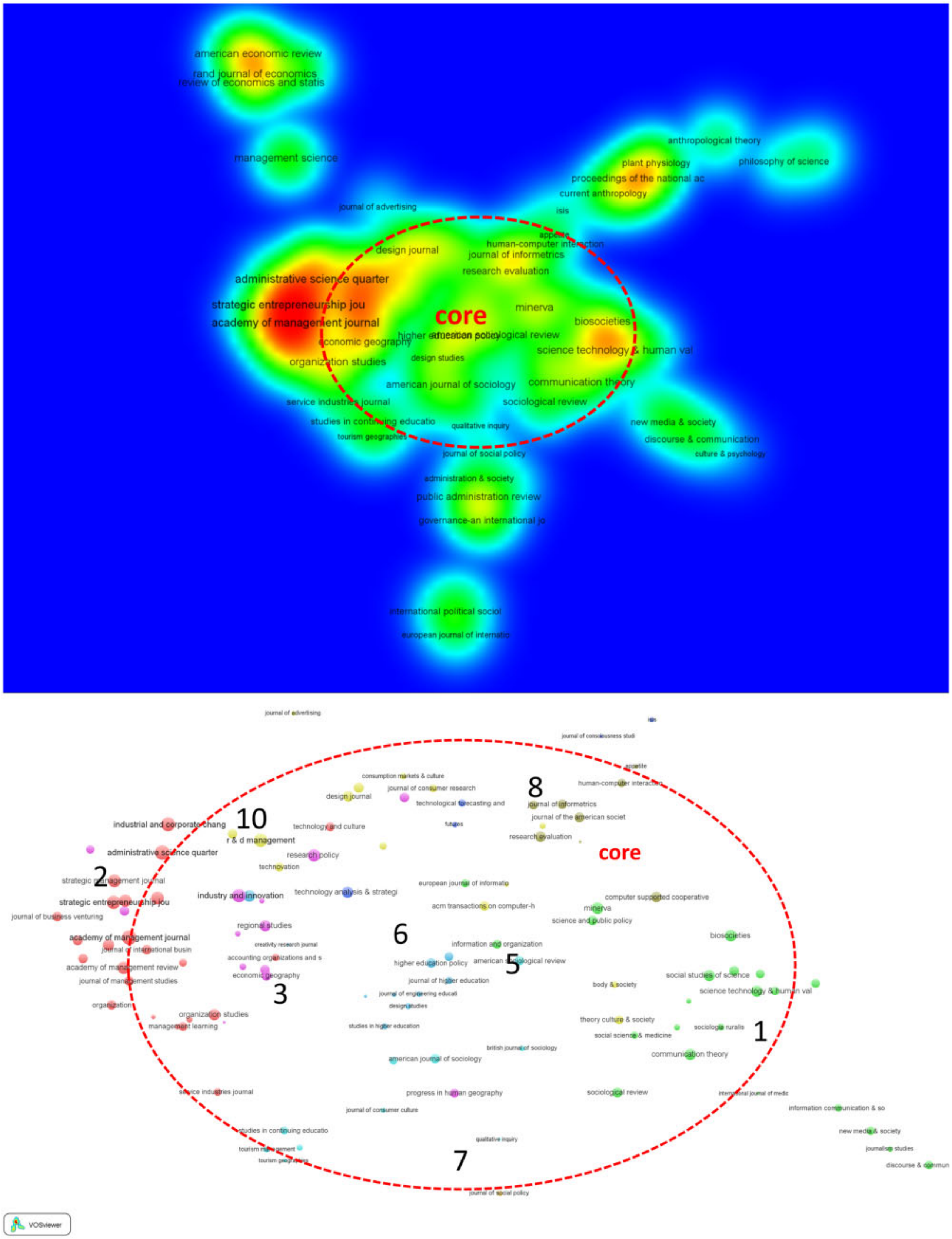


Figure 6. Citing relations of journals related to RI-research—heat map showing core and periphery (top) and zooming in on the core showing clustered journals (bottom).

**Table 2.** Standard citation indicators calculated for Danish articles published in journals assigned to the included clusters (see Appendix E) in the period 2005–2011. Indicators are based on CWTS' CI-Web of Science database and comparable to the ones used in the Leiden Ranking (http://www.leidenranking.com/) (Authors 2015)

| Publications (P) | % of total P | Mean normalized citation score (MNCS) | Proportion of highly cited articles (PPtop10%) | Normalized proportion of highly cited articles (NPPtop10%) | Cluster no. | Subject areas[c] |
|---|---|---|---|---|---|---|
| 170 | 23% | 1.44 | 13.4% | 1.34 | 1[a] | Science studies, sociology and communication |
| 159 | 22% | 2.07 | 24.7% | 2.47 | 2[b] | Management and organization |
| 87 | 12% | 1.64 | 17.2% | 1.72 | 3 | Planning and development |
| 56 | 8% | 1.33 | 14.6% | 1.46 | 5 | Consumption, behaviour and management |
| 35 | 5% | 1.97 | 10.2% | 1.02 | 6 | Higher education |
| 62 | 8% | 1.28 | 12.4% | 1.24 | 7[b] | Public administration |
| 86 | 12% | 1.62 | 18.9% | 1.89 | 8 | Information science |
| 76 | 10% | 1.32 | 15.3% | 1.53 | 10 | Research policy, technology and innovation |
| 731 | | | | | | |

[a]The cluster composition is mixed; there are highly relevant specific RI-journals but also journals which can be considered marginally relevant.

[b]Clusters on the fringe of the core; here we should expect that the majority of the Danish articles are not on RI-topics.

[c]Subject areas are based on the journal subject categories in the Web of Science; notice individual researchers and particular clusters, as depicted in the cognitive map in Figure 5, may publish in different journals belonging to two or more subject areas. In the present analysis, we have not identified the portfolio of journal articles linked to the different clusters in Figure 5 and subsequently mapped these articles to the subject areas outlined in the present table with indicators.

exactly respondent-dependent means that the method is sensitive to response bias and non-responses. The power and autonomy of the respondents is high in directing the distribution and given the fact that the boundaries of the research area is unknown, it is hard to detect skewedness in the data. One potential caveat here is that if no researchers in a specific sub-area choses the answer the distributed survey, this sub-area will be 'invisible' in the mapping. This would however require that this sub-area was also not acknowledged by adjoining sub-areas, but nonetheless it is a possibility, which should be considered.

Another potential problem with the co-nomination method, which was encountered to some degree in the reported study, is the potential for digression into research areas, which are not related to the area which is being mapped. When this problem arose in the present study, indicated particularly by responses in the keyword section, an initial screening question was inserted in the survey, where respondents were given the opportunity to indicate whether or not they saw themselves as part of the RI-research area. Several indicated in the subsequent distribution rounds that they did not, which indicated that the 'perimeter' of the area had been reached.

A final limitation of the presented framework naturally concerns the scope and pragmatics of such a method. The approach could be argued to be most relevant to map smaller, interdisciplinary areas, and are perhaps also most relevant in national contexts. It would, however, be highly interesting to investigate the scope of the method, e.g. by attempting to automate the distribution processes and the processing of data.

## Avenues for further research

Despite the limitations discussed above, we argue that the example demonstrates that the mixed methods approach to science mapping could prove a valuable framework in future research. The example has demonstrated that the individual analyses not only validate each other, but also refine the results of one another, which provides a more solid and nuanced picture of an otherwise opaque research area, such as the Danish RI-area. It would, however, also be relevant to further refine the framework with other data collection methods and analyses. One potential avenue to pursue could be to combine the co-nomination approach with the focus on academic curriculum vitaes (CVs) as Lepori and Probst (2009) have attempted. The academic CVs were used by Lepori and Probst to analyze the geographical mobility, the educational background and the publication patterns of researchers within a (national) specific area of research. One could argue that in combination with the co-nomination approach the selection of CVs could be refined, and the analyses thus be more robust.

A final contribution—and perhaps starting point for further studies—is that the framework outlined in the present paper contributes with an example of how a mixed methods research design might capitalize on the advantages of the various methods in all stages of the study. An explicit aspiration of the study of Danish RI-research has been to bring together qualitative and quantitative methods in both the design phase, the data collection phase and in the analysis, thus aiming for what Leech and Onwuegbuzie call a fully mixed methods design (Leech and Onwuegbuzie 2009). Where many mixed methods designs are used in separate phases of the research process (partially mixed and sequential), the outlined design aims at bringing in the combination of methods at all stages in the process, i.e. in both design, data collection and analysis. In further studies of complex research areas, such a design could be even further refined by strengthening the qualitative aspect of the quantitative elements, e.g. by allowing for more open questions in the co-nomination survey.

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