Scientific Cooperation Engineering Making Interdisciplinary Knowledge Available within Research Facilities and to External Stakeholders

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Abstract

In this paper we introduce the Scientific Cooperation Portal (SCP), a social enterprise software, and how it is integrated into our process of Scientific Cooperation Engineering. This process is applied in a large-scale interdisciplinary research cluster to ensure and manage the success of the interdisciplinary cooperation of over 180 researchers in different qualification levels. We investigate the influence of shared method competencies as an exemplary driver for collaboration. From the results we address both offline and online measures to improve interdisciplinary collaboration. We show how the knowledge generated from offline measures such as colloquia are transferred to the SCP and connected with other data available on the portal. This includes the handling of interdisciplinary terminologies, the disposability of publications and technology data sheets. The portal fosters knowledge exchange, and interdisciplinary awareness within the research cluster as well as technology dissemination both within the cluster, across the university, and into industry. The effectiveness of the approach is continuously assessed using a traditional balanced scorecard approach as well as additional qualitative measures such as interviews and focus groups.

Introduction

Dealing with complex global challenges often requires interdisciplinary research approaches to find suitable solutions (Repko 2012). Staying within disciplinary boundaries may prevent researchers to get a holistic overview of the topic at hand. Although the term interdisciplinarity lacks a unified definition (Jungert et al. 2010) it can be seen as the successful cooperation of researchers trained in the methods and conceptual approaches of different disciplines. Interdisciplinary research integrates these various methods to create new insights and methods for complex problems. Yet, actually making interdisciplinary research happen can be cumbersome because of lacking a common language, method competencies and understanding of scientific success. This problem intensifies under conditions of high staff turnover, research group size (Repko 2012), performance pressure, and increasing complexity of the research problem. How to measure interdisciplinary collaboration and finding reasons for this collaboration, and the deliberate steering of interdisciplinary groups are still largely unsolved questions. Thus active support for such collaboration requires various measures and a constant evaluation of these measures. We apply findings from bibliometrics and cybernetics to management principles of a research cluster in order support interdisciplinary collaboration and scientific success of the cluster.

Related work

Collaboration trumps solo-efforts in generating knowledge (Wuchty et al. 2007). Finding evidence of (interdisciplinary) collaboration can traditionally be done by analyzing co-authorship networks (Glänzel & Schubert 2005), although one must be careful not to mistake co-authorship for collaboration and vice versa (Melin & Persson 1996). Investigating who publishes with whom can reveal collaboration patterns and thus be used to understand interdisciplinary cooperation. Glänzel & Schubert found that geopolitical location and language are determining factors for collaboration. Collaboration decreases exponentially with physical distances (Katz 1994, Hoekman et al. 2010). Kretschmer (1999) found that similarity as well complementarity can be used to explain researchers' collaboration by analyzing co-authorship relationships. By applying this approach Kretschmer & Kretschmer (2012) could explain up to 99% of the variance for 77% of the co-authorship relationships. De Solla Price & Gürsey (1975) identified different types of authors according to their publishing behavior (i.e. continuants, transients, recruits, terminators) for which Braun et al. (2001) identified differing author productivity and collaboration patterns. Newman (2001) found patterns of small world phenomena (i.e. short paths between any two random authors). Co-author networks showed various levels of clustering and a fractal nature (e.g. self-similarity). Van Raan (2000) developed a model to determine growth of scientific literature based on the fractal nature of science. Sub-systems grow individually and can be seen as self-organizing units. This reflects in the cybernetic nature of how universities are managed (see Birnbaum & Edelson 1989). Cybernetics in this regard means that no centralized "premeditated" plan (for publications) is conceived by the management but, in the manner of a thermostat, a target output is defined and measures are taken to reach the target.

Using interviews Hara et al (2004) created a model for determining factors of collaboration in in a research center. From the interviews they found two different types of collaboration, "complementary" and "integrative" collaboration. Determining factors were compatibility (i.e. work style, priority, management style, approach to science, personality), work connections (i.e. work interests, expertise), incentives (i.e. external funding, publication, internal) and socio-technical infrastructure (i.e. awareness, communication mechanism, organization culture and structure, access to collaborators). Overall they assume personal relationships beget professional relationships and thus collaboration. They suggest that technological support could enhance the process of collaboration and that it needs further investigation.

Various forms of these collaboration support systems exist. This new emerging field of E-Science and E-Infrastructure draws on the tools and methods developed from Computer-Supported Cooperative Work (Jirotka 2012). Zheng et al. (2011) present TSEP a social platform to assist collaboration between scientists. Li et al. (2012) and Müller-Tomfelde et al. (2011) strengthen the need for shared workspaces and audio-visual support of workgroups in a health laboratory, but also tailoring to the needs of the workgroup. Alves et al. (2013) have suggested a system for finding possible collaborators in a scientific setting. Romano et al. (2011) suggest the use of wikis and ontologies along with learning environments to support researchers in the field of bioinformatics. Above all tailoring a Social-Network-Solution (SNS) to the users needs is critical, as communicative preferences may depend on user characteristics (Calero Valdez et al. 2012a).

Research Questions

In this paper we demonstrate the efforts undertaken in a research cluster to support interdisciplinary collaboration. For this purpose we look into both online and offline measures that support collaboration. We assume that shared method competencies may also be a driver of collaboration. Here we compare the shared method competencies of workgroups generated from both publication data and qualitative data collected at a member colloquium. Furthermore we show how the insights from the study are used as feedback to the researchers in the cluster. In the following sections we first describe the research cluster, the Scientific Cooperation Portal and then the analysis of methods used in the cluster.

The Scenario - The Aachen Cluster of Excellence

The challenge of keeping production industry sustainable in countries with high wages is also in interdisciplinary one. In the research cluster of excellence (CoE) "Aachen House of Integrated Production" researchers from various subfields of physics, material sciences, engineering, computer science, up to economics and social sciences are faced with the challenges of production on various levels of scale and their interfaces (i.e. from raw material properties to production processes to factory and logistics planning, with respect to human needs on all of these levels). Overcoming the stereotypic scale-scope dilemma (individualized products vs. mass production) of production (Brecher 2012) is one key goal of this research cluster. Additionally it faces the unification of the dilemma of plan- vs. value-oriented production, in conjunction called the polylemma of production. In total about 180 researchers work on this holistic view on production technology, grouped in different working areas. These researchers work in four integrated cluster domains (ICDs), which are interconnected by so called cross-sectional processes (CSPs, see Figure 1). These CSPs ensure sustainability of the research cluster in regard to human resources, advancement of scientific theory and development of technology platforms (Jooß 2012). Their research goal is to investigate, what methods work effectively to achieve said sustainability. Additionally they assist the steering committee of the cluster by providing insights on performance and recommending a course of action.

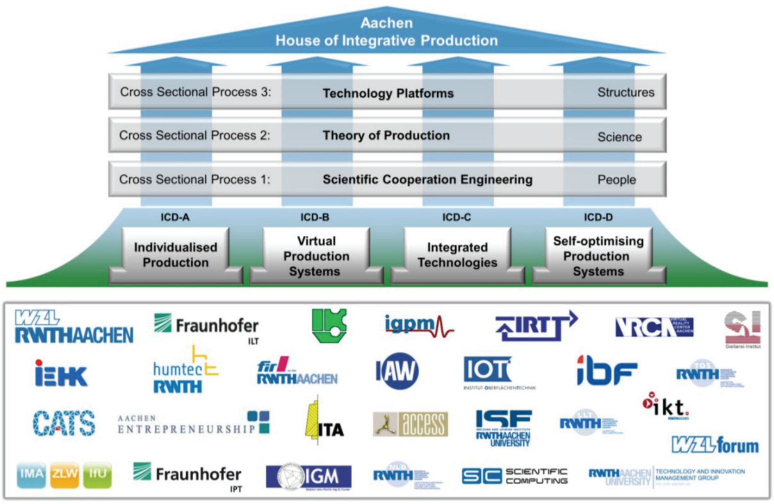

Figure 1. Research structure of the CoE, integrating institutes from five faculties of RWTH Aachen University and focusing on sustainability within the dimensions people, science and structure, incorporated within the Aachen House of Integrative Production (Brecher 2012).

Managing Collaboration

In order to ensure that the cluster works effectively key performance indicators (KPI) are established to measure performance for both internal (management) and external use (funding agency evaluation). This is done using a balanced-score-card approach (Welter 2011) with typical performance measures as (peer-reviewed) publications, patents and third-party funding, but are also contrasted by criteria like knowledge dissemination, interdisciplinarity, quality of supervision, and many more. These are used to determine how well the cluster works and where it needs improvement.

Bringing researchers from so many scientific fields together requires management of many of these success criteria in an individualized fashion. Disciplines differ in regard to what is considered successful as a publication or as advancement in theory. In order to unify the dilemma of required disciplinary diversity and the need for a unified measure of success a cybernetic management approach is applied. For example, indicators are developed that measure the transfer of knowledge within the cluster, the development of interdisciplinary methods, the coherence of the research road map, or the transfer of technology within the cluster and into industry.

Measuring performance in an interdisciplinary context is not a trivial task, but beyond that, steering performance is even harder. The cybernetic management approach incorporates various measures to both measure and steer performance.

A mix of offline and online measures is used to reach a maximum of potential cluster members. As offline steering measures the CSPs conduct member colloquia, cluster conferences, general assemblies, seminars, and workshops. In the member colloquia all partaking researchers spend a whole day dealing with topics that overarch the ICD-structure of the cluster, such as interdisciplinary communication skills (e.g. presenting research to non-experts), finding research partners (e.g. scientific speed dating) and developing a common research road map. On dedicated cluster conferences researchers present the results of their individual scientific research to the other members. In general assemblies principle investigators (PI) present the meta-level of research from their institutional point of view connecting the theory behind partaking institutes. These measures foster the interdisciplinary awareness, cooperation, communication and method skills. Some topics are addressed in seminars or workshop to address individual and sub-project based needs. For example a seminar on interdisciplinary publishing addresses the participants perception of the publishing process form their disciplinary perspective. Best-practices in cluster-typical cooperation are discussed and shared with the participants. An online method to enrich these offline approaches is the Scientific Cooperation Portal presented in this paper.

All measures are all evaluated in regard to the KPIs quantitatively (using a questionnaire method) but they are also addressed in interviews and focus groups with the researchers to ensure validity of the measurements.

The Scientific Cooperation Portal

As an online measure the CSPs introduced the Scientific Cooperation Portal (SCP) in 2013 (Vaegs 2014). The SCP is a social portal system used as a centralized knowledge storage system and was introduced to face the aspect of transparency of communication, which appeared in several evaluations. Voluntary access to the SCP is limited to cluster members and PIs exclusively (yet).

The SCP provides user profiles, yellow pages, a cluster based news feed, calendar and event system, and a centralized file storage system. Required forms for typical needs (e.g. travel expense forms) are available from this centralized storage system. All data on the SCP can be tagged and thus interconnected with each other. As specific features designed to match the cluster specific needs measured by the BSC, interviews, and focus groups, applications are built to address the challenges of interdisciplinary use of terminology, interdisciplinary publications, and technology transfer.

User Profiles

Members profiles can be found through the yellow page system and contain information about disciplinary background, method competencies, expertise in technology, publications, and participation on terminology definitions. Furthermore typical contact information is available.

Terminologies

One critical aspect mention in many evaluations is the lack of a unified language/terminology. Since different disciplines use terminology differently the approach of the CSPs is not to unify terminology, but to enhance awareness of disciplinary differences. For this purpose an application is developed that portrays the differing definitions of frequently used terms from the various perspectives, highlighting differences in understanding. Definitions are connected to their authors, publications in which they are used, and their technology data.

Publication Relationship Analysis

Publications are a peculiar aspect of scientific work, as they disseminate knowledge gain to the scientific community. They are often (wrongly) used as sole performance indicators overvaluing quantity above quality. The SCP uses publications to establish researcher profiles. This allows the CSPs to understand (and measure by proxy) the collaboration in the CoE. Furthermore we will use visualization and graph based approaches to understand and communicate publishing efforts of the CoE to its members (Calero Valdez 2012b). User profile pages will be connected with their co-authors, but also with topics stemming for publications keywords. Furthermore used technology and terminology from publications are connected with their respective technology data sheets and terminology pages.

Technology Transfer

Technology developed in the CoE should be disseminated both within and to industry partners to be useful to a possible consumer of the technology. In order to simplify communication of advances, a technology transfer portal is integrated into the SCP (Schuh 2013). Here technology data sheets present key advantages of developed technology and contact information of the provider of the technology (see Figure 2). They are also connected to their provider users as well as publications that relate to the technology. Technology data sheets can be customized to be viewable by external partners (e.g. industry) once they have achieved a sufficient level of stability.

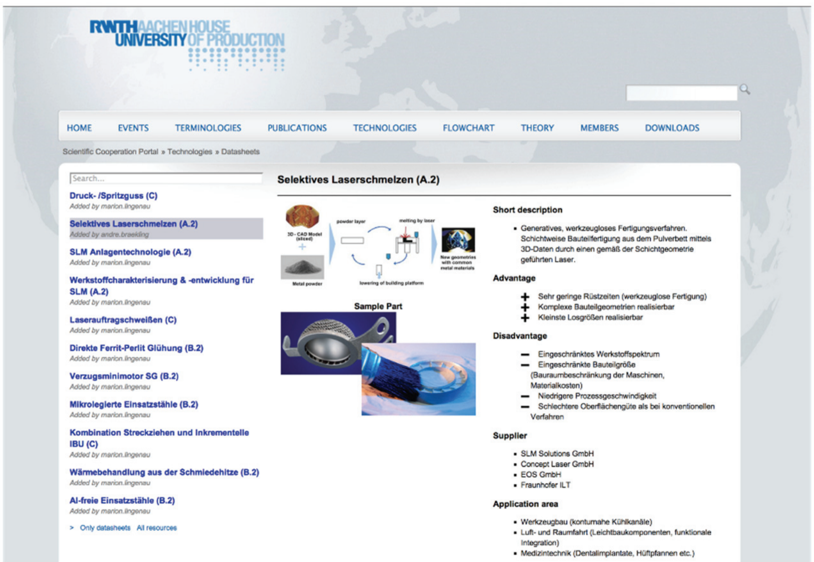

Figure 2. Example technology data sheet on the SCP.

Methodology – Assessing Method Competencies

In order to find out what methods are used in the cluster we approach that topic from two directions. First we pick full-text data from the cluster and manually scan the methodology sections of these papers for named-entities that refer to method-names. We then perform manual deletion of duplicates on synonyms on the data. We create a method graph connecting each workgroup with its methods. Since classical database coverage of engineering sciences is subpar (Harzing & Van der Wal 2007), we collect publication data manually by requiring researchers to submit their work in order collect funding for travel expenses for instance.

In a second step, conducted during a member colloquium, we asked all workgroups to brainstorm on the methods that they used on a daily basis (see Figure 3). The time frame for this task was about 90 minutes, and instructions were given to collect methods that are both used in publications and methods that are available but have not been used yet. As a working definition what constitutes a method several definitions were given (US patent definition, a definition derived from philosophy of science, a definition from Computer Science) to heighten awareness of disciplinary differences in the meaning of the term “method”. Methods are then again cleared for duplicates and synonyms. Another method graph is constructed. Both method graphs are then compared an evaluated in regard to graph statistics.

Not addressed in this paper are the workshops that address in a similar fashion the topics of interdisciplinary terminologies and technology data sheets.

Figure 3. Exemplary results of a method workshop in a subproject.

Results and Interpretation

At this current timeframe full-text publications were available for 7 of 12 sub-projects. From over 500 publications 76 were selected (availability and containing a clear method section) and manually scanned for methods. Form these, 222 named-entities were recognized and reduced to 195 unique methods. The constructed method graph (see Figure 4) showed a graph density of *.006*. Community detection (Blondel et al. 2008) revealed 7 communities and a modularity of *.773*.

The method collection from the member colloquia surprisingly also resulted in a sum of 195 methods (after deletion of duplicates and synonyms). The graph (see Figure 4) showed a graph density of *.005* and also revealed 7 communities. Modularity of the graph was determined at *.766*.

Interestingly the nodes connecting most sub-projects in both graphs are nodes that relate to “modelling”, “FEM” and “Software Development”. Method overlap in both cases is sparse, meaning that either shared methods are sparse, remain unmentioned (in both verbal an written communication) or that no unified terminology exists regarding applied methods. Both graphs show a structural symmetry between each other.

As a side note is worth mentioning that even the term “method” is far from having a shared understanding. During the member colloquium the need for clarification arose, in particular in regard to discerning it from the term “technology”. In the various fields of engineering, clear differentiation is not always possible. One develops a technology that is used by others as a method. Discussions regarding this took substantial time off of brainstorming times.

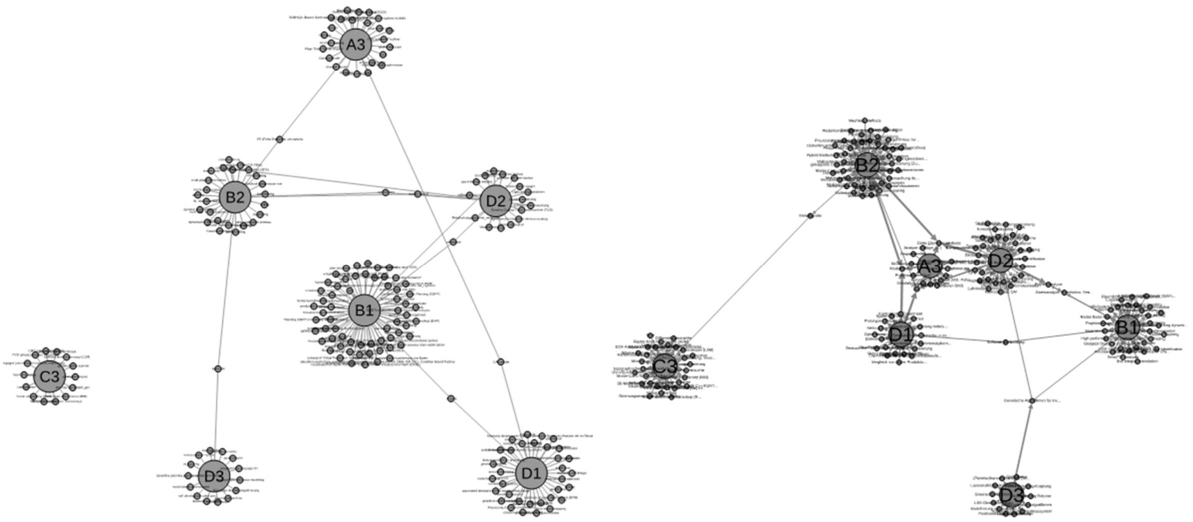

Figure 4. Method graphs constructed from member colloquium data (left) and from method sections of publications (right)

Conclusion

The differences in terminology, in particular in regard to the term “method” itself, further underline the need for support in an interdisciplinary setting. As mentioned by Hara et al. (2003) compatibility is essential for scientific collaboration.

Applying the approach from Alves et al. (2013), we enrich researcher’s profiles with method competencies to enable finding researchers within the cluster that share research interests. The terminology application must respect disciplinary differences in understanding of methods (that can also be technologies) and can be seen as a measure to broaden understanding of method competencies across disciplinary boarders. Furthermore technology transfer must be performed not only to external stakeholders but also within a research cluster. The findings from the member colloquium confirm the need for social software that integrates terminology, methodology, technology, and publications as an online support measure to our research cluster. This means when a user opens another user’s profile, he will see a list of methods used by this researcher, which hyperlinks to an ontology-based wiki and also full-text publications (when available) that contain these methods. Furthermore technology used by a researcher is hyperlinked to technology data sheets, which in turn are linked to publications and terminology.

In the future, we are able to better understand interdisciplinary cooperation by following the individual as well as the work groups' usage behavior of information of the Portal. Both, the genesis of a novel cooperation can be retraced and related to the respective genesis conditions as well as the growing density of the collaboration's network in order to see growing novel topics or methodologies within and across work groups. Also, looking from the industry side and the analysis of industry's interest and search for information behavior can be also a promising approach for emerging topics and research fields.

Limitations

The procedures to generate graphs rely heavily on manual correction and synonym detection. We must assume that further unnoticed synonyms exist in the data as the author is no expert in all of the found methods. This limitation also applies to the manual named-entity search in the papers. Furthermore only a fraction of the actual publication output was used, due to availability of full texts.

The similarity of the graph could to a large extend be caused by the method of construction. For both graphs first workgroup nodes are created and then connected to their method nodes. This would in many cases lead to similar graphs, if methods were unrelated.

The presented approach was used as a starting point into the data. In the future users of the portal may choose to add their own synonyms to method definitions to enhance the analysis process in future iterations. The approach also only reflects collaboration of the similarity type. Complementary or integrative collaboration should in essence not contain the same set of methods. Nonetheless an overlap that enables communication should be found.

Furthermore we have not looked into interrelations between both graphs yet, as the methods are not in a single language. Finding adequate translations should also be a user driven task as well.

Summary and Outlook

In this paper we presented the scientific cooperation portal a social portal to support interdisciplinary collaboration in research clusters. The features of the portal were developed from systematic evaluation of researchers needs using both qualitative and quantitative methods (Schaar 2013). Content for the portal is generated by both the users and the CSPS from at various events. Furthermore we looked into shared method competencies as a driver for collaboration by investigating the methods used in the sub-projects both from verbal and written evidence. We found low overlap between sub-projects in methods, but high similarity for both approaches. Interestingly when comparing the method overlap with actual collaboration from publication data (Calero Valdez et al. 2012b), we find a similar graph density (.005) but a higher level of clustering (27 communities, modularity .844). Further evaluation (e.g. graph isomorphism) will reveal whether this accurately reflects similarity between the different graphs. Furthermore looking into references and citation data could prove useful. Researchers sharing the same methodology should cite similar work. The hypothesis that ones technology is another's method could also be verified by looking into citations in method sections. From these findings we derive the need for collaboration support and underline the selection of features of the Scientific Cooperation Portal as well as conducting member colloquia which bring researchers together on a personal level and foster communication between sub-projects and across disciplinary boarders.

Connecting both offline with online measures has improved KPIs for scientific collaboration, which was established by a BSC-approach.

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