Cross-Sectional Processes 1
Scientific Cooperation Engineering

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1. Summary

As an interdisciplinary research network, the Cluster of Excellence (CoE) comprises of scientific disciplines ranging from mechanical engineering to computer sciences as well as finally tackling social sciences like sociology and psychology. This interdisciplinary diversity is accompanied by a structural spreading: The 25

participating organizations from five departments and around 150 scientists are allocated around the entire campus of RWTH Aachen University. Hence, many of the CoE's employees are faced with new forms of cooperation in terms of competences, knowledge, heterogeneous objectives of institutions and actors (Jooß et al. 2012). As there is a continuous staff turnover in science, a sustainable process for the integration of actors in the research network is requested.

Scientific Cooperation Engineering addresses the challenge of interdisciplinary cooperation in the CoE and aims at fostering interdisciplinarity and its synergies as a source of innovation. Therefore, the project researches means of reaching an organizational development from temporal structures to a sustainable network in production technology.

In order to achieve this aim, *Scientific Cooperation Engineering* has developed four fields of action (see Chap. 2). Within these fields of action a broad range of means has been developed and implemented. The scientific background of these means and the research results of *Scientific Cooperation Engineering* are outlined in Chap. 3: First, a requirements gathering from the perspective of the actors and tailor-made methods as well as results of cluster internal process evaluations are described (see Sect. 3.1 and 3.2), accompanied by the question on how to manage the diversity component in the CoE (see Sect. 3.3). Hereafter physical networking activities like colloquia of employees as main networking events and individualized training activities in the CoE are depicted (see Sect. 3.4). Virtual networking means are outlined in connection with the *Scientific Cooperation Portal*, as the tailored cooperation portal of the CoE (see Sect. 3.5-3.10). This includes applications for Data Analytics in cooperation management, visualization of publication data as well as project planning and management.

2. Motivation and Research Question

Interdisciplinary research and scientific cooperation take the role of an increasing driver for innovative knowledge production and "improved understanding of complex phenomena" (Lyall and Meagher 2012). In the first funding period of the CoE, the complexity and dynamics of this cooperation lead to the development of the prototype model *Application Model for Measures and Instruments of the Cross-Sectional Processes in Knowledge Intensive Organizations*. This model specifies design elements and cluster-specific measures for the management of Cross-Sectional Processes.

The initiated measures of the first funding period support the networking activities within the CoE and the efficiency of scientific working processes by focusing in particular on the detection and use of thematic synergies. The results of employee surveys and workshops led to the assumption that these measures had to be extended in various ways (e.g., virtual support measures). Furthermore, a scope of action for the management of the CoE was given: The next steps for organizational development of the CoE are derived by means of various measuring processes.

Especially in the second funding period of the Excellence Initiative, this approach has been extended towards a sustainable setup of personal and organizational structures for scientific cooperation (Cluster of Excellence 2012). Interdisciplinary integration of the scientific disciplines in the CoE represents one possibility to achieve sustainable cooperation, and can be defined as the practice of knowledge production within the interplay of sub-teams (Jahn et al. 2012). These sub-teams are brought together with all their specific knowledge, concepts and (infra) structures and thus need an integrative element (Jooß 2014). Bergmann and Schramm (2008) state that "only integration on a cognitive, but also on a social, communicative, organizational and possibly technical level leads to the capability of trans-disciplinary research to achieve good results". The central research question of Cross Sectional Processes 1 focuses on sustainability of this integration supporting the development towards a successful interlinking of people and knowledge from different disciplines:

> "Which actions are necessary to support the transfer of highly complex, dynamic and interdisciplinary research cooperation of the Cluster of Excellence into sustainable and robust structures?"

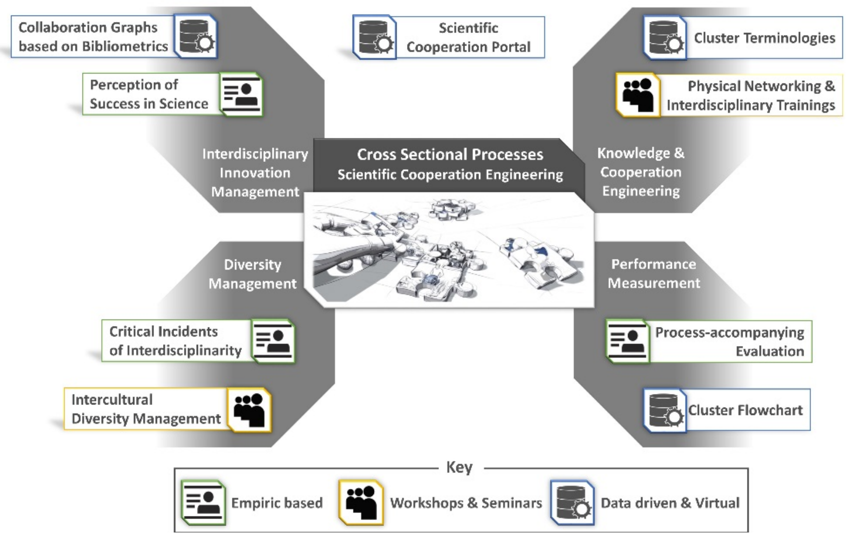

Figure 1: Fields of action and measures for *Scientific Cooperation Engineering*

This research question has been operationalized by four fields of action within *Scientific Cooperation Engineering* (see Figure 1): Performance Measurement, Diversity Management, Interdisciplinary Innovation Management and Knowledge & Cooperation Engineering.

Based on Jooß et al. (2012), the fields of action can be described as follows:

- *Performance Measurement* comprises of the contribution of the project to the steering and regulation of integrative research processes and outputs. Hence, measuring and evaluating the CoE are the main topics within this field of action. Within the Cross-Sectional Processes, tools, such as a Balanced Scorecard, have been adapted in order to derive insights into the performance of processes and the current vision and mission of the CoE on all hierarchical levels. Furthermore, project management and planning processes are supported.
- *Diversity Management* focuses on culture, age and gender aspects of the CoE. Based on the hypothesis that diversity can be seen as a source of innovation, the measurability and utilization of diversity as a competitive factor are the focus of this field of action. Within this context, culture is defined in two ways: First, culture comprises disciplinary aspects in order to elaborate necessary factors for interdisciplinary cooperation. Second, culture covers international diversity.
- *Interdisciplinary Innovation Management* aims at measuring, visualizing and managing experts from different scientific cultures and disciplines within the cluster. Therefore, the promotion of the innovative capability is fostered by means of a discipline-specific interlinking that is based on different analysis processes (e.g., bibliometrics).
- *Knowledge & Cooperation Engineering* comprises the interaction of data and knowledge on all organizational levels to support a sustainable development of the CoE. This includes physical networking, workshops and training as well as data-driven methods to support communication and exchange as a foundation for further cooperation. For instance, a cybernetic method suite supports terminologies acquisition and efforts for searching cluster-specific information via automated knowledge retrieval processes.

All of those fields consist of measures from different origins, as they are based on combinations of method from empirical social science and data science, as well as workshops and seminars. Empirical and data science can be seen as steps for data acquisition and analysis. Both rely on data that has been collected from the actor by means of surveys and interviews on the one hand, and data science-based publication analysis on the other. As a technical frame for all data driven approaches the Scientific Cooperation Portal has been implemented as a virtual exchange and information platform (see Sect. 3.7). Workshops and seminars fulfill a combined role.

Data can, thus, be gathered on a qualitative level (e.g., thematic accordance in project topics) and – focusing on a systemic-cybernetic perspective – feedback can be obtained on different hierarchical levels (Welter 2013).

Thus, the fundamental idea of *Scientific Cooperation Engineering* is based on an iterative cybernetic approach for the development of measures that are capable of fostering cooperation within the CoE. The projects aim at integrating scientists into this approach by various feedback loops (e.g., using cluster-wide surveys or evaluations of physical networking events). A detailed description of this approach is given in Chap. 3.1, followed with the results of the project.

3. State-of-the-Art and Results of Scientific Cooperation Engineering

3.1. Continuous Formative Evaluation

Sarah L. Müller, Thomas Thiele, Claudia Jooß, Anja Richert, Sabina Jeschke

Within the field of action *Performance Measurement*, different formative evaluation tools have been developed and implemented to facilitate the steering and regulation of the research processes and outputs. Out of these evaluations, necessary adjustments were derived to enhance the processes and the performance of the CoE.

3.1.1. State-of-the-Art

Formative evaluations examine the practical implementation of activities and the performance of an organization systematically. Due to the monitoring and analysis, the management gets ideas about how to optimize the processes of networking, the flow of information, the events etc. In this way, the effectiveness of means and the management itself can be optimized and undesirable developments may be reduced.

A special form of accompanying evaluations is the participatory evaluation which involves the actors directly in the process (Bundesministerium für Wirtschaft und Technologie 2008). In doing so, not only does the management get feedback, but the actors become obliged to reflect their own actions and learning process can be evoked as well. Without this continuous reflection and due to routines, the actors can be limited in their knowledge and actions (Giddens 1984; Sydow and Duschek 2011). Furthermore, a continuous performance management is required to evoke organizational learning processes that represent the basis for interdisciplinary cooperation and knowledge production (Jooß 2014; Liebsch 2011). The formative performance management is of particular importance for complex and dynamic processes and structures, which applies to the CoE.

3.1.2. Method

An established strategy tool for performance management is the Balanced Scorecard (BSC) originally developed by Kaplan and Norton (1992). Due to the special interdisciplinarity demands of the CoE, the BSC was adapted by Welter (2013). Like the generic basic model, the cluster-specific BSC allows looking at performance from four perspectives: internal perspective/research cooperation, learning and development perspective, output/client perspective and financial perspective.

Each perspective comprises critical success factors that were derived out of the vision, mission, and overarching goal of the CoE (DFG – Deutsche Forschungsgemeinschaft 2006). Unlike many BSCs that gather hard factors like cash flow, unit costs, or delivery times for further analysis, it is essential for the CoE to additionally consider soft performance measures from the participants' perspective. Factors like communications quality or the transparency of research contents are crucial for the participation and cooperation process – which is itself a determinant of good performance. In particular, participation induces a self-determinant, active development of the cluster that is not only driven top-down. The success factors were operationalized through questions that were evaluated by cluster participants on all hierarchical levels (research assistants, project leaders, ICD leaders, cluster management, professors).

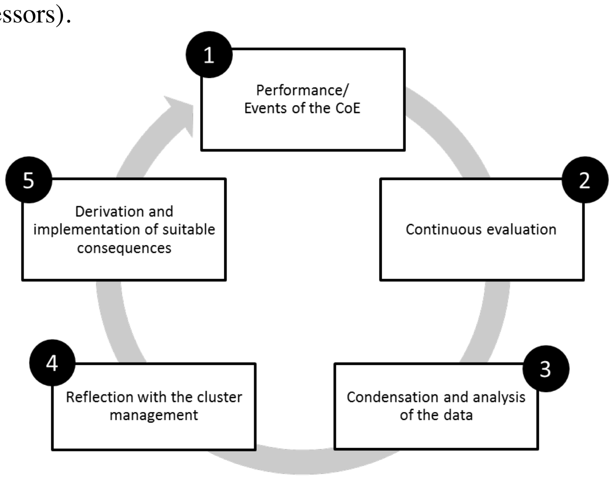

Figure 2: Iterative system of evaluation of the CoE

The formative evaluations of the CoE follow an iterative approach modeled after Jansen (2004), Horváth and Seiter (2009) and Welter et al. (2011), having been implemented to improve the cluster performance and the management itself. The iterative system starts with the evaluation itself (see Figure 2). After the condensation and analysis of the data, a content-related analysis and reflection of the results takes place. This analysis allows the derivation of recommendations for actions either for a single event or an event series – or for the entire cluster management. Through repetitive measuring, the effects of the executed consequences can be analyzed again.

3.1.3.Results and Discussion

The iterative system of evaluation is applied both for the cluster events and for the general performance of the cluster:

The regular general meetings, CoE conferences, and the colloquia of employees are evaluated with a standardized questionnaire. In this way, time series can be displayed and show alterations between single events. An example of such a time line is given in Sect. 3.4.2. The event quality can be assured and the content and format of events can be adjusted to satisfy the needs of the participants of the cluster. The content-related analysis and reflection of the events is usually conducted through the cluster management and researchers of Scientific Cooperation Engineering. One recent example of implemented results stemming from event evaluations is the implementation of microtrainings as one part of the colloquia of employees.

The performance of the CoE is evaluated with the cluster-specific BSC on an annual level. Therefore, time series can be plotted as well. Most of the time series show a constant or progressive development over time (see Figure 3). The slightly increasing curves can be interpreted as the positive effects of management actions and the continuous annual regulatory process. It is apparent that the BSC results are influenced by many known and unknown factors, whereas statements on unambiguous causes are hardly possible. Nevertheless, an analysis of causes can be done on a qualitative level to obtain results.

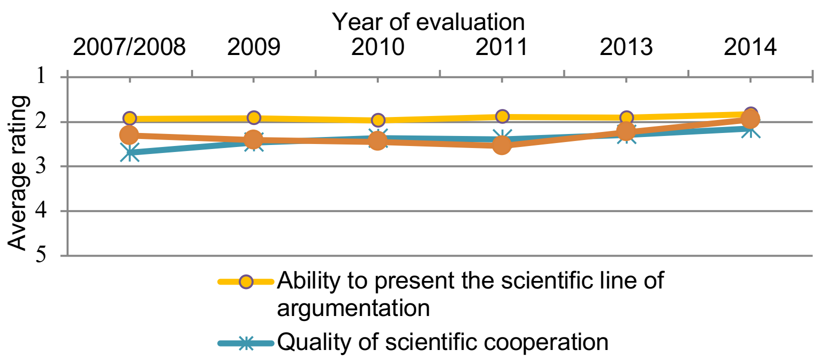

Figure 3: Exemplary results of the cluster-specific Balanced Scorecard over time (scale reaches from 1 “good rating” to 5 “bad rating”;(Müller et al. 2015)

To ensure this derivation of consequences through a back-coupling of the results of the event evaluations and of the BSC, workshops on different hierarchical levels were – and will be – conducted. The first workshop was conducted with the core team of the cluster in 2014, a second one followed in 2015. Additionally, a third workshop was carried out with the project leaders. A further workshop on the researcher level is planned on a colloquium of employees. All of these workshops aim at revealing fields of actions and a joint elaboration of recommendations for actions.

As shown, the formative evaluations and the iterative system of the CoE aim at self-optimization. *Scientific Cooperation Engineering* accompanies this process through the analysis of the evaluations and the initiation of back-coupling processes and the induction of the implementation. One example for a successful implemented measure out of the BSC is the internal newsletter that was first implemented in 2015. In this way, the transparency and the flow of information were supported.

3.1.4. Outlook

To be more transparent about the BSC survey, an online visualization of the results will be developed. This so-called virtual BSC Cockpit should be accessible by every CoE researcher through the Scientific Cooperation Portal (see Sect. 3.7). It is also expected that the participation rate of the employee survey will increase because the importance of the researchers' feedback is illustrated. Furthermore, the virtualization of results in combination with several filtering techniques allows the individual assessment of single projects. Following this idea, the BSC Cockpit represents a virtual management tool that is able to support the different hierarchical levels by fulfilling individual needs of information.

Starting with the next CoE conference, all event evaluations will be conducted online. In this way, prospective results can be displayed much faster – even a direct analysis during the event is possible. The event evaluation will also be accessible through the Scientific Cooperation Portal.

The cluster-specific BSC is well established in the CoE and can be transferred to other interdisciplinary research clusters. Furthermore, adaptions to the special needs of the concerned cluster will be necessary, and it is possible to benchmark them through the BSC. For example, through the comparison of the BSC results and the activities in different clusters it can be seen which measures are more effective. In this way the clusters can learn from each other, and conclusions about the effects of different forms of interdisciplinary cooperation or different processes, activities and structures can be drawn.

3.2. Critical Incidents of Interdisciplinary Research

Sarah L. Müller, Claudia Jooß, Anja Richert, Sabina Jeschke

Interdisciplinarity is one aspect of the field of action *Diversity Management*. Regarding the research about interdisciplinarity, there is an empirical deficit in the evaluation of the actors' perspective to interdisciplinary cooperation during the cooperation process itself in form of long-term studies (Raasch et al. 2013). For this purpose – and to support the management of the CoE – critical incidents for the success of interdisciplinary research were identified in a long-term study of Scientific Cooperation Engineering.

3.2.1. State-of-the-Art

Interdisciplinary research integrates the knowledge and methods of individuals or teams from different disciplines (National Academies U.S. 2005). Besides the acculturation (Redfield et al. 1936; Berry 1983), an integration of disciplines is expected from the involved actors (Aboelela et al. 2007; Porter and Rafols 2009) to evoke synergies (Defila and DiGiulio 1998), which heighten the complexity of cooperative processes and structures. Through the last years, interdisciplinary research increased in prevalence and it is expected that this trend will continue (Millar 2013). Therefore, it is of special importance to analyze how interdisciplinarity impacts the research process and how this process can be supported. Interdisciplinarity can have numerous forms, such as varying through the involved disciplines, the number of people or the hierarchical structures. Nevertheless, it is stated that interdisciplinary cooperation has some generalizable patterns. Thereby, communication and time are relevant factors for example (Katz and Martin 1997).

Interdisciplinary cooperation are mainly analyzed on a macro or meso-level, but the individual micro-perspective of the researchers is rarely in the limelight (Raasch et al. 2013). Thus, the involved actors in particular play a crucial role, since they are working on the direct value-adding scientific results and have to deal with the integration of the diverse methods and concepts of the different disciplines. Furthermore, there is a lack of long-term studies that display the stages of development of the cooperation process (Melin 2000). Therefore, this survey aimed at gathering detailed insights into the dynamic cooperation process already during the execution phase out of the actors' perspective.

3.2.2. Method

To analyze which phenomena are critical for the success of the CoE, a comprehensive long-term study was conducted (Jooß 2014). Therefore, a heterogeneous sample of actors across all hierarchical levels of the CoE were questioned. Using structured interviews, partly standardized employee surveys, evaluation of measures, and participatory observations qualitative data were collected over a period of five years (2009-2013).

From each set of data, phenomena of interdisciplinary cooperation were identified. Out of these phenomena critical incidents (CI) were extracted using the Critical Incidents Technique (Flanagan 1954). A phenomenon is called critical if it has a special importance for the interdisciplinary cooperation process compared to other phenomena, and if this phenomenon is the base and/or precondition for consequences or strategies. After having empirically reasoned a theoretical saturation, the CIs were clustered in generalizable patterns that provide recommendations for actions for the cluster management.

3.2.1.Results

Thirty CIs were found which are shown in Table 1 (Jooß 2014). Besides the title, they give further insight into relationships of incidental, rear and distant effects. The CIs were clustered into three patterns.

The first pattern cumulates CI in the way of *integration and allocation of time*. For a successful cooperation the interdisciplinary integration of knowledge and methods is critical. Therefore, constant communication between the participants is necessary. The researchers need to be aware of each other and the existing competences, to be sensitized for interdisciplinary cooperation, and develop a common language or rather common concepts. Furthermore, it is necessary to work out the interfaces and limits of the involved disciplines to collaborate successfully and, at best, to learn from each other. This complex negotiation process needs time and organizational support as it does not take place by itself. For this purpose, a sufficient organizationally established allocation of time is needed to foster constant exchange and should be provided. This process can be further enhanced through spatial proximity.

The second pattern *integrated knowledge management regarding the common interdisciplinary vision* points out that a common vision and a continuous knowledge management with respect to realization of the vision is needed to cooperate successfully. A common vision is the basis for the identification with and the motivation for interdisciplinary cooperation. The vision needs to be established and the researchers should be aware of it and its importance. Visualization can facilitate the localization of the researchers and their projects as well as the interfaces within the entire CoE. Therefore, it can illustrate individual contribution to the overall goal.

In terms of the vision, a continuous support of the knowledge exchange should take place. Regular networking activities should be fostered. This can be enhanced by the sub-project managers which act like key persons for networking, since they are supposed to have a content-related overview of the CoE and the interfaces between the sub-projects. Consequently, they can initiate exchanges about research findings that are crucial for further cooperation. For the exchanges, sufficient temporal freedom is crucial.

The third pattern summarizes CIs in the fields of *recursive and process-related support and participation of stakeholders*. It is shown that the participation of the involved actors and a recursive and process-accompanying support are of special importance.

Table 1: Critical incidents of interdisciplinary research (Jooß 2014)

Interviews	Employee surveys	Evaluations	Observations
Exchange and terminology	Development of a common language	Exchange and networking	Iteration and participation
Co-creation of the involved researchers	Reflection of the research findings	Sensitization and tolerance towards other disciplines	Key persons for networking
Exchange of methods	Identification and visualization of interfaces	Reflection and terminologies	Identification and incentives
Key persons and networking	Exchange and temporal freedom		Virtual communication
Interdisciplinary qualification program	Interdisciplinary competences		Handling of staff turnover
Visualization of the vision	Interdisciplinary integration		Integration of external persons
Opportunity for continuous exchange	Communication and cooperation platform		Research contribution
			Temporal freedom
			Measures for further training
			Disciplinary advances in knowledge
			Personal benefit
			Public relations
			Publications

Resulting patterns		
Pattern 1: Integration and allocation of time	**Pattern 2:** Integrated knowledge management regarding the common interdisciplinary vision	**Pattern 3:** Recursive and process-related support and participation of stakeholders

This means all actors of the CoE should be involved in building the vision and scientific contents of the cluster. Furthermore, a continuous support of the interdisciplinary, communicative and team competences of the researchers is necessary and should be fostered through adequate trainings. Thereby, it should made clear that the own discipline advances through interdisciplinary integration.

It has been shown that interdisciplinary cooperation needs a process accompanying support in terms of interdisciplinary knowledge production and transfer. It is important to identify support needs and to implement appropriate measures to reflect and adjust if necessary. The critical factors clarify which aspects have to be designed from the actors' perspective. Although the CoE is highly specific, the generalizable patterns show that many aspects can be transferred to other networks and are traditional interdisciplinary research aspects (Gibbons 1994).

3.2.2. Future Studies on CIs

The CIs were collected and evaluated qualitatively for this specific CoE. To conduct further statistical analysis, test the transferability to other research networks and develop a standardized measurement the CIs have to be operationalized by means of a quantitative questionnaire. In this way, the data acquisition is also more efficient, and a greater number of people can be questioned.

The quantification comprises two different parts: The first part inquires the perceived quantitative general importance of each CI, for instance, "How important do you rate a common understanding of terminologies?" The second part gathers data about the subjective quantitative characteristics of the CIs regarding the CoE, such as, "Within the entire CoE a common understanding of terminologies was developed." Both parts are rated on a Likert-scale, respectively.

The general analysis aims at clarifying the structure of the CIs on a universal basis. Therefore, an explorative factor analysis will be conducted first. In general, a factor analysis attempts to reduce a large number of correlated manifest variables (the questions) to a small set of independent latent variables (the CIs) called factors. These factors explain as much of the variance of the manifest variables as possible. Thereafter, the interdependencies between the Cis will be analyzed using structural equation modeling. test correlative relationships between latent variables. The CoE specific analysis aims at further evaluation of the CoE to derive recommendations for action. Out of these analyses, ranked fields of actions are displayed and suitable counteractions can be evolved.

The CoE is assigned to the scientific discipline of engineering despite its interdisciplinarity. This may possibly influence the CIs and its impact on the success of cooperation. The CoEs, which are funded in the second phase by the DFG, are divided into four scientific disciplines: engineering, humanities and social sciences, natural sciences, and life sciences. By conducting the same study in other research networks, we can compare the CIs and its patterns and thus show cross-disciplinary comparisons. The results can be potential starting points for future launchings of research networks.

3.3. Intercultural Diversity Management - Age and Culture Effects in Cluster Research

Mamta Sharma, Kirsten Dahmen, Ulrich Prahl, Wolfgang Bleck

The project 'Diversity Management' seeks to find answers to some important research questions like: "Which teams perform better in a scientific work environment: homogeneous or heterogeneous?", "Which type (or types) of heterogeneity (or homogeneity) is the most important one in influencing team performance: gender diversity, age diversity, cultural diversity or diversity in disciplines?", "Which measures are necessary to manage a heterogeneous (or homogeneous) team so that its members can work together effectively in clusters, projects and facilities to become a successful research collective?"

Addressing these questions first requires a systematic examination of the aforementioned forms of diversities in different research groups in and out of the excellence cluster. The next step is to compare the work culture, work values and success (parameters to define success shall be specific to the team/to the specific study) of teams having different degrees of the above-mentioned diversities, so as to delineate the diversity (and/or leadership and management) factors that lead to the most favorable team performance. Such a comparison can often be challenging. The final step shall be to correlate *diversity* and *performance*, which shall provide methods to build new (homogeneous/heterogeneous) teams and better manage existing ones.

3.3.1. State-of-the-Art

Diversity Management is quite a new discipline emanating from the United States in the 1960s. Triandis et al. (1994) define diversity as *that a person is different from me*. For Sundstrom et al. (1990), diversity means *interdependent collection of individuals who share responsibility for specific outcomes*. Most studies on diversity and its management deal with demographic or organizational diversity. The first one is relation-orientated, considering factors like age, gender and culture. The second is task-oriented, taking education, function, job, duration of employment, etc. into account. It is relatively less complex compared with demographic diversity.

(Hoffman 1959) reported a better team performance for heterogeneous teams on cognitively complex tasks as well as those demanding multiple viewpoints since such teams tend to have a broader range of knowledge, expertise and perspectives compared with homogeneous groups. In fact, (Triandis et al. 1965) suggest that heterogeneous teams show higher creativity in problem-solving. (Bantel and Jackson 1989) also found a relation between diversity and innovation. (Caye et al. 2011) explain the many profits of diversity in business, arguing that today customers vary strongly in their behaviors, values, priorities, age, gender, etc. Therefore, a good mix of employees is necessary to cater to them. Additionally, shortage of talent makes it indispensable to recruit from diverse groups. (Wulf 2002) suggests that having a diverse workforce in science and engineering is not just a matter of impartiality and fairness but rather an ‘absolute necessity’, arguing that engineering demands creativity which could come from the different life experiences of diverse team members. He also warns that a lack of diversity could lead to opportunity costs, which are the costs incurred because of using a ‘‘non-elegant’’ solution to an engineering problem resulting from lack of diversity. Different barriers and benefits of having diverse teams have been discussed by (Cox 1993) and (Gebert 2004). For example, as (Gebert 2004) describes that such advantages of diversity over team homogeneity as higher productivity, effectiveness, innovative capacity and creativity, sometimes there could also be more conflicts and stress and less communication, group stability and work satisfaction. On similar lines, (Bassett-Jones 2005) introduces the concept of the ‘paradox of diversity management, innovation and creativity’. He identifies that although diversity can be a source of creativity and innovation, leading to competitive advantage, it could also cause misunderstanding, suspicion and conflicts in workplace, resulting in absenteeism, poor quality, low morale and loss of competitiveness. These are two conflicting aspects and thus necessitate effective ‘Diversity Management’.

3.3.2. Method

An online questionnaire study named ‘Criteria for Scientific Success’ was conducted by the Steel Institute (Institut fuer Eisenhuettenkunde, IEHK) together with the Human Computer Interaction Center (HCIC) of the RWTH Aachen in the latter half of 2014. The survey begins with questions asking for the general information of the participant like age, gender, nationality, native language, country of origin, and the kind of environment (city, town or countryside) in which the person grew up. Additionally, the subjects were also asked for their educational qualification, academic discipline, work or academic position, experience or tenure, prior work experience elsewhere, and if their current field of work matches with or is identical with that in which they received their education. Whenever a question involved multiple choices in the form of statements, the participants were asked to display their agreement (or disagreement) with that given statement on a 6-level Likert scale, where rating 1 stands for *totally disagree* and 6 means *totally agree*.

The Steel Institute aimed to ascertain whether and how culture, age, experience, gender and academic discipline influence the scientific success of researchers, as measured by the number of their publications. Three research groups of the RWTH Aachen (Cluster of Excellence, CoE; Collaborative Research Group, SFB 761; one of the materials engineering departments, MED) were chosen for the survey for the primary reason that these groups show varying degrees of the aforementioned diversities.

3.3.3. Results

Based on the responses of the survey participants, different forms of diversity were evaluated, and an attempt has been made to identify and understand the correlation between *diversity* and *scientific success*.

Diversity in the three research groups

Gender diversity has been quantified in terms of the fraction of female team members (see Figure 4a). Cultural diversity has been described by the proportion of non-German researchers (Figure 4b), who in this case belong to countries like Belgium, China, Croatia, India, Poland, Russia, South Korea, Sweden, Thailand and Turkey. Other forms of diversity – namely, diversity in age, experience, qualification and academic discipline – have been summarized in Figure 6.

Success in science in terms of number of publications

The results of the first part of the questionnaire study by HCIC led to the conclusion that researchers rate 'publications' as the most important factor for scientific success. Hence, the number of publications was compared for the three groups. Figure 7 shows that the members of SFB have published the largest number of articles, followed by those of CoE. The number of articles published is the smallest for MED among the three groups. The publishing trends of SFB and MED differ considerably, in that more than 30 % members of SFB have published in excess of 30 papers, whereas over 40 % researchers in MED have just started publishing (0-1 articles). CoE lies in between, where 25 % members have published 5-9 papers and about 27 %, 2-4 papers. The number of beginners (0-1 papers) is also relatively small (~12.5 %).

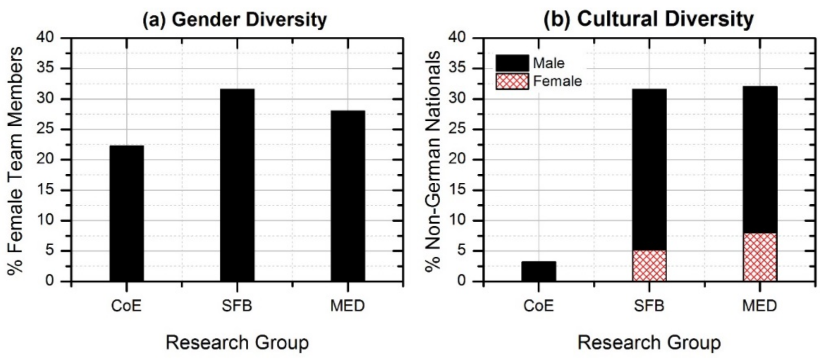

Figure 4: (a) Gender and (b) cultural diversity in the three research groups

Only considering the data in Figure 5 and Figure 6, it seems reasonable to conclude that the most diverse group in all respects, the SFB, is also the most successful group. CoE is the second most successful group. It has only a limited gender and cultural diversity, but a higher age diversity and higher interdisciplinarity compared to MED. The mono-disciplinary, young group MED which intermediate gender and cultural diversity has only limited success in terms of publications so far. However, a detailed look into the results points out that the scientific success (or its absence) cannot be completely attributed to the presence or absence of gender and cultural diversity, because although CoE is less culturally and gender diverse, it is more successful than MED, which has gender and cultural diversity.

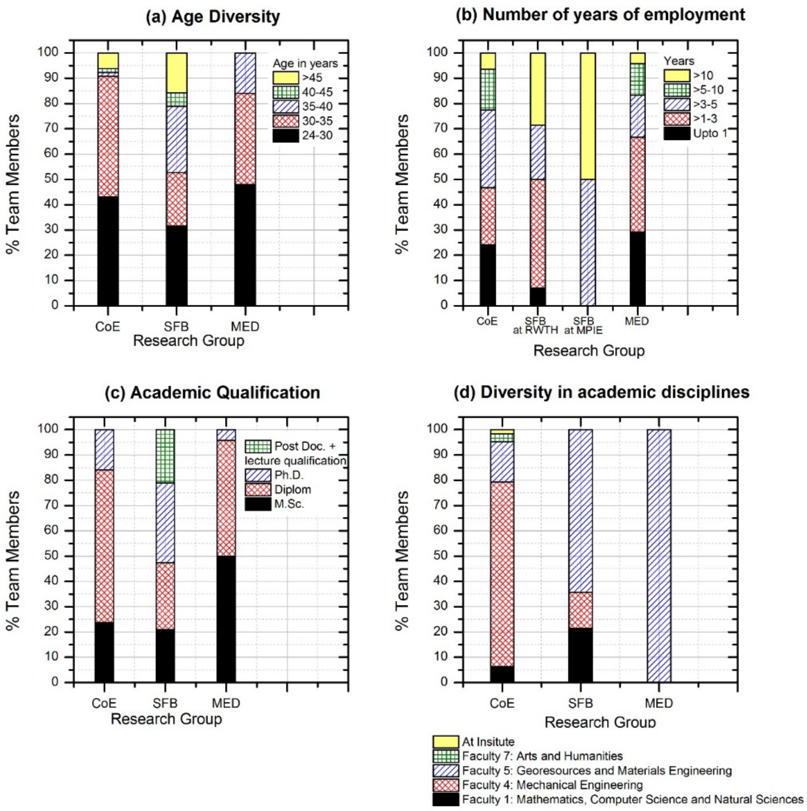

Figure 5: (a) Age, (b) Experience, (c) Qualification and (d) Academic discipline diversity in the three research groups

The scientific success can nevertheless be correlated to interdisciplinarity since the least disciplinarily diverse group (MED) also has the smallest number of publications. Interdisciplinarity is still not the sole reason for scientific achievement because although the members of CoE belong to more diverse faculties than SFB, SFB has higher number of publications than CoE. We found that age and work experience were positively correlated, $\rho(86) = .818$; $p < .01$ and therefore in this discussion, age and experience are synonymous! Based on this work, a strong association between age or work experience and scientific accomplishment in terms of publishing can be concluded. This has also been observed by (Baer et al. 2007), who attribute the benefits of tenure or educational diversity to the accompanying informational diversity, which has a positive effect on team performance due to wider range of informational resources available to the team.

However, they do not attribute this benefit to 'age diversity'. SFB, with the highest average age (35.5 years) and highest number of experienced researchers (>45 years old), also has the highest percentage of researchers (35 %) with more than 30 research papers. This result is also true for CoE and MED. CoE with a higher average member age and experience than MED also has published more articles than MED. This leads to the conclusion that the higher the diversity in age or experience of the group members, the higher the likelihood of the group being successful.

Group control and project structure

It should be pointed out that there are some differences in the way these three research groups are financed and in the way they are controlled. MED works both on industrial projects and publicly-funded projects. In case of industrial projects, there are sometimes restrictions in publishing when the results should be kept confidential. This could also be one of the reasons why the number of publications is not as high as for the other two groups. The group SFB on the other hand is more focused on fundamental research. There are no restrictions on publishing as such: In fact, publishing is an important criterion to obtain funding for the next research period. The CoE is a part of the Excellence Initiative of the German federal and state governments. The German Research Foundation (DFG) was given responsibility for implementing the initiative together with the German Science Council. Thus, in this case making the research results public is very necessary.

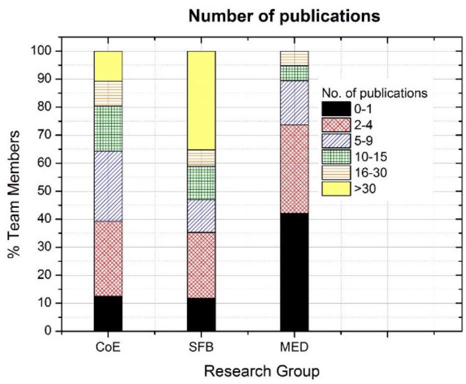

Figure 6: Number of research publications by the members in each of the three research groups

3.4. Physical Networking and Tailor-made Trainings as Means for Cluster Development

Thomas Thiele, Sarah L. Müller, Andre Calero Valdez, Anne Kathrin Schaar, Claudia Jooß, Anja Richert, Sabina Jeschke, Martina Ziefle

Physical networking processes are demanded especially by the actors and focus on interdisciplinary and scholarly exchange (Jooß 2014). In order to realize this demand, measures like networking events can be conducted. Moreover, interdisciplinary trainings serve not only as further education, but also as a platform of exchange and, therefore, are a part of the knowledge and cooperation engineering activities of the Scientific Cooperation Engineering project. This chapter depicts the design of networking events and interdisciplinary trainings as key elements for the interdisciplinary integration within the CoE.

3.4.1. State-of-the-Art

As a possible approach to forming an interdisciplinary cooperation, disciplines may consequently participate in an integration process that supports the stabilization and efficiency of scientific working processes. The integration process is mainly based on the ability of all actors in the cluster to communicate effectively despite their different terminologies (e.g., with respect to methods or technologies). According to Jahn (2008), communication should be accompanied by social & organizational, technical and cognitive perspectives in order to combine various scientific disciplines into one consortium. Aiming at an added value of interdisciplinary research and following Vaegs et al. (2013b), the definition of these perspectives is outlined in this chapter, followed by the results in the subsequent chapters.

The *social & organizational perspective* addresses the definition and relation of different interests and activities between involved projects and organizational institutions: Different research interests and topics have to be exchanged and matched. With regard to interdisciplinary networking and training events, the main aim of the social & organizational perspective is the initiation of negotiation processes between the actors in the CoE.

In the context of interdisciplinary networking and training, the *technical perspective* allows a sustainable knowledge transfer and aims at supporting idea generation and dissemination in physical events. Therefore, a technical system has to be integrated into daily workflows and should not provide any interruption from usual routines (Jahn 2008).

The *communicative perspective* focuses on the linkage of discipline-specific linguistic expressions and communicative practices (Vaegs et al. 2013b). The negotiation process of a common language is a vital element for knowledge generation and communication. The aim can be seen in the achievement of an integrative understanding without dismissing the terminology of the own scientific discipline.

The *cognitive perspective* comprises the distinction of different discipline-specific knowledge domains and the connection of scientific as well as practical aspects within this knowledge (Bullinger et al. 2009). The goal is to gain deeper insights into methods and concepts that originate from different disciplines. Merging an interdisciplinary group can be achieved by fostering mutual understanding and integrating knowledge into a combined research effort.

Following Bergmann and Schramm (2008), the coverage of these perspectives supports the development of an interdisciplinary group towards an integrative work process as a consortium. How this approach is implemented in the CoE using physical networking events and interdisciplinary trainings is depicted by two examples in the next chapters.

3.4.2. Method: Design of Colloquia of Employees

Since 2008, Colloquia of Employees are part of the networking strategy of the CoE. As a forum for so-called *networking services* (Sydow and Zeichhardt 2009) and meetings on the level of the researchers, the Colloquia aim at the promotion of cluster-internal cooperation and the transfer of knowledge. Furthermore, an increasing transparency and development of a mutual comprehension between the cooperating disciplines is addressed. Jooß (2014) stated that it is of particular importance for the quality of the cooperation that all participants of an interdisciplinary research cluster are integrated in the bottom-up development of scientific contents and aims.

In order to support these aims, the Colloquia are designed as a mixture of workshops and provide a communication platform. They take place twice annually and are not defined in terms of topics, concepts and agenda. The design and implementation of the Colloquia are based on two sources: First, results of the formative event evaluation are used in order to derive useful topics from the actor's perspective (see Chapt. 3.1); and second, the concepts and topics are determined in close cooperation with the Cluster Management and the Cross-Sectional Processes.

The first source illustrates the participative character of the Colloquia of Employees. As demonstrated in Welter et al. (2012), individual feedback of the participants is evaluated and used to improve or redesign previous topics. The second source arises from superior aims of the cluster, such as the necessity to develop sustainable future concepts for the CoE. Based on the hypothesis that a group "is capable of producing ideas that are more novel than the ideas that they begin with" (Nickerson and Sakamoto 2010), the Colloquia gather the employees (among others) for idea generation.

3.4.3. Results: Developmental Stages and Evaluation

Within the topics and concepts of the Colloquia, different developmental stages can be clustered. These stages show a strong connection to the typical development phases of networks (Müller et al. 2015).

Initiation: The first Colloquia were conducted at the beginning of the first funding phase of the CoE. Therefore, main aims can be seen in the creation of a common purpose regarding a joint vision and mission of the line of research, primarily supporting cognitive & communicative perspectives.

Interfaces: As a next step, highlighting interfaces between the different disciplines and projects became a major element in the concepts of the Colloquia. In order to improve interdisciplinary communication, synergies and ideas for new cooperation should be raised. The focus of this step can be seen in cognitive and communicative aspects as interface highlighting results in ongoing exchanges and visualizations. Subsequently, the results were disseminated on a technical perspective via the Scientific Cooperation Portal.

Learning: The third period of Colloquia focused on interdisciplinary mutual learning. This concept was promoted by means of presentations in so-called micro-trainings. These can be seen as a method for supporting an enhanced knowledge transfer in a daily working environment (Lukosch et al. 2009). The typical training duration has been adapted towards the needs of the participants in the CoE, ranging from 20 minutes to 90 minutes. The presentations contain information on the methods and contents of the diverse disciplines. All aspects mentioned in Sect. 3.4.1 are tackled in this step, since learning comprises of cognitive, social, communicative, and technical perspectives.

Sustainability: Despite the end of the second funding period in two years, the ongoing Colloquia aim at developing visions for the future. Therefore, deduced synergies were evaluated in order to set up networking sessions on the project level. As a next step, these synergies were used to develop future topics for the CoE.

All of these topics and concepts have mostly been accompanied by an informal part in order to support further professional networking on a personal level. Following Gratton and Erickson (2007), this kind of networking encourages the success of team work and in particular addresses social and organizational dimensions.

Focusing on the participants' perspective regarding the Colloquia, a descriptive analysis of the evaluation in a time series can give some hints for the importance of these networking events. Figure 7 displays three exemplary questions of the evaluation survey. All questions are answered on a four-point Likert scale, in which "4" represents disagreement and "1" agreement.

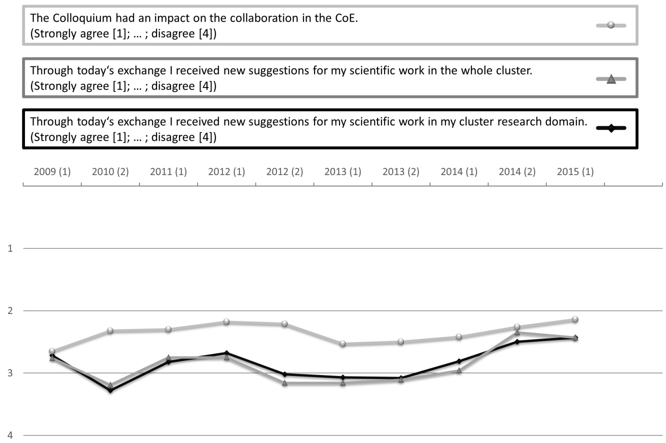

Figure 7: Exemplary colloquia evaluation results in a time series

In the second founding period of the CoE, all three graphs show an increasing development that exemplifies the approval of the depicted topics and concepts. The impact of the collaboration especially develops from an average rating of $M = 2.5$, $SD = 0.73$ in 2013 to $M = 2.1$, $SD = 0.81$ in 2015 (1). This can be interpreted as an ongoing acceptance of the Colloquia as a cooperation-fostering measure. The other two graphs show slightly more volatile behavior – depending on the topic: Whereas topics like economic assessment of demonstrators receives $M = 3.0$, $SD = 0.90$ in 2014 (1), idea generation on future research topics seems to be more suitable ($M = 2.4$, $SD = 0.90$ in 2014 (2)) in terms of suggestions for personal scientific work. As a whole, the Colloquia are perceived as vital means for the cluster development in terms of physical networking, knowledge transfer and sustainability.

3.4.4. Interdisciplinary Training and Next-Level Learning Concepts

Scientific Cooperation Engineering comprises of a tailor-made training program that was developed for training necessary skills for the interdisciplinary research environment of the CoE. In addition, Jooß (2014) attested to the importance of qualification programs in the context of interdisciplinary cooperation, demanding “an offer of classical and superordinate, interdisciplinary qualification measures”. Thus, the training program is based on two pillars.

As a first pillar, interdisciplinary trainings have been developed that support the further integration and comprehension of scientific disciplines by focusing on a cognitive dimension in particular. In close cooperation with Cluster Management, *Scientific Cooperation Engineering* coordinates learning activities with the aim of establishing subject-specific seminars in the field of production technology.

Interdisciplinary training are cluster-specific seminars that were developed in order to support the integration of experts from different scientific disciplines and to foster the perception of synergies among the actors in the CoE (Jooß et al. 2012). The training sessions were implemented towards the vision of an interdisciplinary school of methods (see Figure 8) that consists of various seminar offers aiming at a useful skill set for cooperation in the CoE.

On average, the evaluations of the seminars[1] show a broad acceptance – especially regarding the publication workshop. In 2015 for instance, 43 % of the participants voted "strongly agree", while 57 % "agreed" that "the topics of the seminar contributed to a better understanding of interdisciplinary cooperation" (M=1.67, SD=0.51). The seminar "Fundamentals and techniques of management cybernetics" takes on a special role, as one of the elemental CoE approaches of cybernetics is depicted in the seminar and practical guidance is given by this approach. The evaluation showed a clear contribution of this seminar towards a common understanding of cybernetic principles (M = 1.88, SD = 0.83). The feedback gained from this evaluation is used to optimize the seminars towards the needs and aims of the CoE.

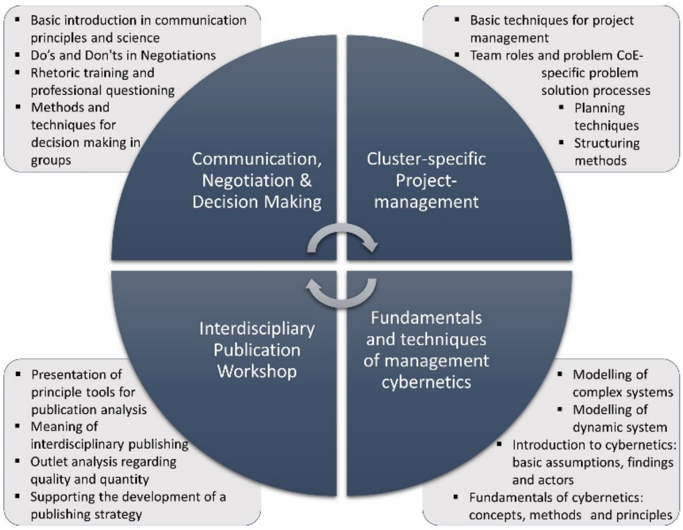

Figure 8: Interdisciplinary school of methods

[1] All questions are answered on a four-point Likert scale, in which "4" represents disagreement ("disagree") and "1" agreement ("strongly agree").

As the second pillar, Next-Generation Learning Concepts are adapted for the CoE and focus, on the one hand, on seminars in a special format: As illustrated in Sect. 3.4.2, microtraining sessions were conducted as short seminars during the Colloquia of Employees. The presenters of these seminars are members of the CoE itself. On the other hand, *Scientific Cooperation Engineering* currently works on a broader approach for the integration of CoE's topics into learning activities in cooperation with the Cluster Management. First concepts were created in order to develop a broader transfer of CoE content into social networks, e.g. via constant posts and explanation videos for CoE topics.

3.5. Interdisciplinary Innovation Management

André Calero Valdez, Anne Kathrin Schaar, Martina Ziefle

Interdisciplinary collaboration is widely considered to be a solution for complex problems that surpass the competencies of individual disciplines. But where disciplines have developed methods and communicative patterns that enable fruitful collaboration between its researchers, interdisciplinary collaboration lacks these patterns. This brings forward challenges in interdisciplinary collaboration. In order to tackle these challenges and reap the benefits of interdisciplinary collaboration, a cybernetic management approach is applied in the CoE to ensure innovative processes.

3.5.1. State-of-the-Art

No widely accepted definition of interdisciplinarity exists, although a definition should be taken seriously (Repko et al. 2013). Interdisciplinarity comes in qualitatively different modes of collaboration and research. Depending on the definition, distinct or continuous outcomes can be considered interdisciplinary (Aboelela et al. 2007). For the sake of a common denominator, we consider any collaboration between two researchers from different fields as interdisciplinary. A simple exchange of ideas, complex method integration, and an integration of theories are all considered as interdisciplinary; given the common aim of solving a problem or optimizing research (Lattuca 2002; Deinhammer et al. 2003). Under this assumption, we outline benefits and barriers of interdisciplinary collaboration and assume different degrees of applicability and severity.

Experts agree that topics like climate change, demographic change, hunger, and energy are too complex to be solved by single disciplines. To face these challenges, a vision of interdisciplinary research is needed (Deinhammer et al. 2003; Repko 2008; Aram 2004; Jungert et al. 2013). This is because often-mentioned benefits of interdisciplinary collaboration are the *creative breakthroughs* (Nissani 1997; Repko

2008; Lyall et al. 2011) enabled by the *fertilization (Hübenthal 1991)* of new collaborations. The *widening of horizon* (Repko 2008) leads to new questions and insights that let researchers overcome the tunnel vision, which is needed to see the bigger context. This bigger context might be necessary when *dead ends* occur (Lattuca 2002) in dealing with the aforementioned global challenges.

3.5.2. Methods: Benefits and Barriers of Interdisciplinary Collaboration in the Cluster of Excellence

Aside from necessity, *personal benefits* come into play, motivating researchers to conduct interdisciplinary research as well. Interdisciplinary work is described as *exciting, interesting* and *satisfying* by scientists (Lyall et al. (2011). Interdisciplinary work may be intrinsically motivating, but must receive organizational support. Oskam (2009) even says that researchers must have interdisciplinary training to cooperate well in interdisciplinary settings. They need to have thorough disciplinary training and interdisciplinary connections to enable innovation processes. Where and how this training should be applied depends on the perception of the benefits and barriers of the researchers.

Managing a research cluster like the Aachen House of Production requires addressing these benefits and barriers in order to leverage their outcome to the fullest. Individual differences on how these should be addressed can only be derived from empirical social research. Understanding how the benefits affect performance and how barriers hinder performance should be examined by interviewing partaking researchers as well as their perception of those factors. Since every research endeavor might be unique (i.e., new combination of people and institutions) it is also necessary to identify new factors that affect interdisciplinary collaboration and performance. Qualitative research can help understand the connections and the pivotal points where these factors become effective. In order to ensure transferability of qualitative results, quantitative methods should be used to complete the picture.

For these reasons, we assessed the perceived benefits and barriers in the Cluster of Excellence in a qualitative interview study. The results from this study were then verified by a quantitative questionnaire study. This triangulation allowed us to identify new benefits and barriers as well as quantify their importance as perceived by the members of the CoE. Furthermore, we could identify how these benefits and barriers can be addressed with individual features of the Scientific Cooperation Portal.

Six semi-structured interviews were conducted face to face at the participants' workplaces. The main questions were focused on the experience of the researchers regarding interdisciplinary collaboration in the CoE. Interviews took between 16 and 43 minutes, and were recorded and fully transcribed for content analysis according to Mayring (2013). In a follow-up study the identified categories were then evaluated for their perceived importance by questionnaire (*N = 45*). Each benefit or barrier should be rated according to its importance (1 = least important, 4 = most important).

3.5.3. Results from the Benefits and Barriers of Interdisciplinary Collaboration Study

The categorization of the transcription lead to ten categories regarding perceived barriers of interdisciplinary work and eight categories being listed as benefits. As barriers, the strongest and most often-mentioned categories were *language* and *missing depth* (five mentions each). *Language* refers back to the problems of communication across disciplinary boundaries. Disciplinary *languages* differ and may use terminology differently – unbeknownst to the communication partner. Often, this becomes apparent later in the interaction when details are worked out. The category *missing depth* refers to the feeling of only performing superficial research, when interdisciplinary collaboration is conducted. Three other categories were mentioned four times each – namely: *missing points of intersection, no idea of disciplinary potential,* and *time*. Missing points of intersection addresses the interdisciplinary collaboration directly. Researchers felt unable to identify points where their research overlapped specifically and collaboration would be fruitful. The next category *no idea of disciplinary potential* also addressed the inability of knowing how the other discipline could serve them without being reduced to a mere service and not a research endeavor on its own. *Time* refers to the lack of time researchers felt anyways, amplified by the additional requirements from interdisciplinary collaboration. Other barriers mentioned were the sheer *size of the cluster* (three mentions), organizational barriers (three mentions) and different aims (two mentions). As minor barriers, *different approaches* and challenges in *publishing* were identified.

The most-mentioned benefit was the *intrinsic motivation* (six mentions) of researchers. Researchers reported that interdisciplinary collaboration sparked their interest and that the interdisciplinary scope itself was the strongest benefit to them. They perceived the *widening of their own horizon* (five mentions) as a strong motivation to take part in interdisciplinary collaboration. Besides these personal aspects more general benefits in interdisciplinary collaboration were mentioned. Four researchers each mentioned that the *combination of knowledge* in interdisciplinary collaboration harbors *innovation potential* and the potential to *cover the complexity of the world*. *Leveraging the knowledge network* and its *new opportunities* were also mentioned by researchers (two mentions each). One researcher also mentioned *getting to know their own discipline* through the mirror of other disciplines.

The quantitative evaluation of the benefits and barriers led to similar results. The strongest barriers were: *different approaches* (M = 2.77), *language* (M = 2.65)*, size* *of cluster* ($M = 2.65$). The weakest barriers were *different aims* ($M = 2.47$), *publishing* ($M = 2.42$), and *organizational barriers* ($M = 2.11$). The other barriers fell in between these evaluations. Standard deviations for all barriers ranged between $SD = 0.63$ and $SD = 0.95$. These numbers denote that all barriers are, on average, perceived to be existent but are not so strong. A different picture appeared when looking into the quantitative evaluation of the benefits. Here the difference between the strongest benefits (*widening of own horizon*, $M = 3.23$) and the weakest benefit (*new opportunities,* $M = 2.3$) were more pronounced. Standard deviations were also smaller (*SD* range: 0.64 – 0.78). This indicates that the benefits are perceived more strongly than barriers in our sample.

3.5.4. Discussion

With the findings from both the qualitative and quantitative study we can argue that a major effort needed in our research cluster is the facilitation of the communicative capabilities within the cluster. This should address improving the capabilities in regard to overcoming the barriers of interdisciplinary *language* differences. Furthermore, fostering an exchange regarding disciplinary methods, approaches and research questions is needed. Using strategic knowledge management to convey knowledge about disciplinary differences and to establish a common language is recommended. In the following section, we show how the scientific cooperation portal addresses these benefits and barriers in each of its features.

3.5.5. Mapping to the Scientific Cooperation Portal

The Scientific Cooperation Portal (see Sect. 3.7) provides various features that help overcome barriers of interdisciplinary work and leverage perceived benefits. The cluster terminologies app for example addresses both the strongest barrier (i.e., *language*) and the strongest benefit (i.e., *widening of own horizon*). By visualizing the usage of terminologies in different disciplines, researchers are able to glimpse into different terminologies while at the same time overcoming the interdisciplinary language barrier. For all barriers and benefits we found functions in the scientific cooperation portal (see Figure 9).

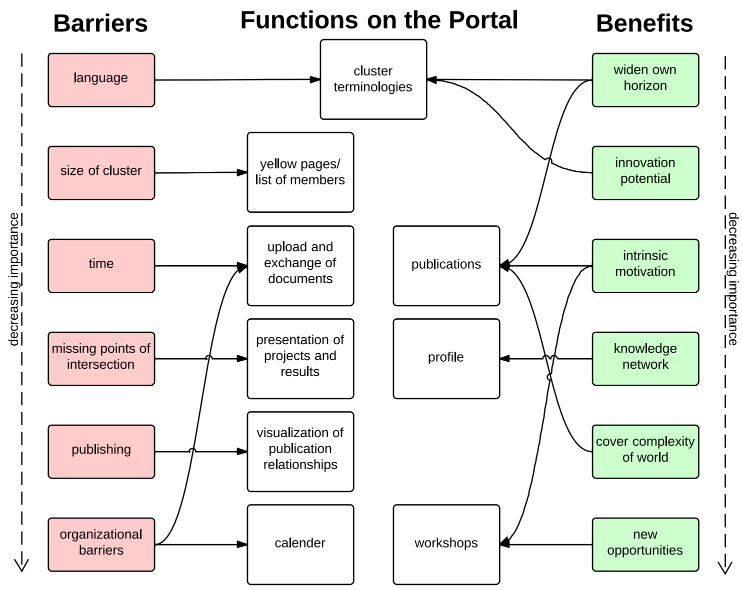

Figure 9: Mapping of benefits and barriers to the functions on the Scientific Cooperation Portal

3.6. Perception of Scientific Success from Different Disciplinary Perspectives

André Calero Valdez, Anne Kathrin Schaar, Martina Ziefle

As seen in the previous section, benefits and barriers play a key role in fostering interdisciplinary collaboration and performance. Still, the meaning of what performance in an interdisciplinary setting constitutes is objectionable. Finding a shared vision of scientific success in an interdisciplinary setting is crucial to steering the endeavor.

The CoE follows a cybernetic management approach. This means that key performance indicators are measured and evaluated to derive actions to steer the CoE to success. One measure that is particularly hard to define is success in science. This is due to differences between disciplines in culture, method, and publishing behavior that reflect on typical scientific indicators. Possible indicators are related to publications, acquired third party funding, prizes, established collaborations and many more. All of them are dependent on factors that are defined by the individual disciplines.

3.6.1. State-of-the-Art

Good examples of the multitude of possible indicators are bibliometric indicators (Persson et al. 2004). Counting the number of publications is a measure of scientific productivity – the more you write, the more productive you are. However, comparing publication output between researchers is not this simple. Senior researchers often supervise younger researchers and become co-authors of their articles as well. Larger hierarchies thus lead to longer co-author lists. Fractional counting alleviates this partially, as an individual publication count must be shared between its authors. But math alone is not the problem here: Differences between disciplinary cultures in how many co-authors are acceptable for a publication are only the tip of the iceberg of the differences between disciplinary publishing cultures. The extremes of particle physics with articles that have over thousands of authors and sociology with mostly monographies demonstrate the breath of disciplinary differences.

Trying to measure scientific impact (often done by citation-based metrics) makes this problem even worse (Bornmann et al. 2008). Not only do disciplinary citation cultures come into play (e.g., how many references per article?), but also the sheer size of the community determines the possible citation limits. For this reason researchers from medicine often get the highest citation impact in comparison to other disciplines. Many other factors influence citation impact (e.g., citation half-life, citation lag), which also depend on disciplinary culture. But even within relatively similar subjects (e.g., particle physics and condensed matter physics) methods and publication behavior differ (Alexander von Humboldt-Stiftung 2009).

In order to understand how the disciplinary differences play out in the CoE, we conducted a survey on the perception of scientific success factors with the members of the cluster. The purpose of this study was to assess the influence of scientific success factors and how they are influenced by the disciplines present in the cluster. In the end, the results may be used to measure scientific success appropriately within the CoE – and fairly for all disciplines.

3.6.2. Method

The study was conducted using an online questionnaire survey. As independent variables demographic factors and disciplinary background of the participants were assessed. Then, as dependent variables, the perceived importance of six criteria were evaluated from five perspectives. The criteria were *industrial funding, third-party funding, publications, student supervision, teaching,* and *patents*. The perspectives were: *own point of view, project, department, university,* and *community*. Each combination was phrased and agreement with the phrase was rated on a six-point Likert scale (e.g., “From my point of view publications are important when evaluating scientific success.”). Participants were allowed to give comments on the survey.

Of the 180 researchers addressed in the study, 66 started the online questionnaire and 52 completed the survey. Out of the sample 79 % were male, and most participants had obtained a master degree or similar. Only ten participants already held a PhD. Most participants came from the field of mechanical engineering (73 %), followed by material science (16 %). Only four participants came from the field of mathematics, physics or computer science; and just two from psychology and sociology.

3.6.3. Results

In general, a strong agreement between the perspectives for all scientific success criteria was found. Strong differences were identified in particular for *industrial funding* and *teaching*. The importance of industrial funding was seen as lower from the researchers' perspective than from the university's perspective (see Figure 10). Another contrast could be seen for *teaching*. Researchers perceived teaching to be highly important as a means of measuring scientific success, but felt that neither the project nor the community valued it as much. Overall *publications* were perceived most unanimously for all perspectives as the most important criterion for scientific success while *teaching* was perceived as the least important.

3.6.4. Discussion

In order to understand the influence of the discipline on scientific success criteria – or at least the perception of it – a survey in the CoE was conducted. Differences in perspectives for some of the criteria that were measured were found. Sadly, only find weak differences could be pinpointed between the disciplines in the cluster in question. This could be due to sample limitations in the study. Most of the researchers in the sample came from the field of mechanical engineering. The other researchers clustered only in little numbers in few different fields. No statistically relevant information could be extracted from comparison of means in this case. For this purpose, the study will be extended to another research cluster and a 'Sonderforschungsbereich' (SFB) in order to boost the sample size of the other fields.

Nevertheless, it can be argued that publications are indeed seen as important criterion when measuring scientific success. Other factors are seen as important as well, and a metric measuring scientific success from these key performance indicators not only should include publication data, but also acquired funding, patents, and teaching activities.

Participants used the chance to give comments in the questionnaire extensively. A comment that recurred often was that not only the quantity of publications should be considered, but also the quality of the publications. This also reflects upon other difficulties that may arise from interdisciplinary collaboration. Differences in publishing culture arise from differences in values and goals that must be unified to achieve interdisciplinary success (Blackwell et al. 2009). This challenge is addressed in Sect. 3.9.

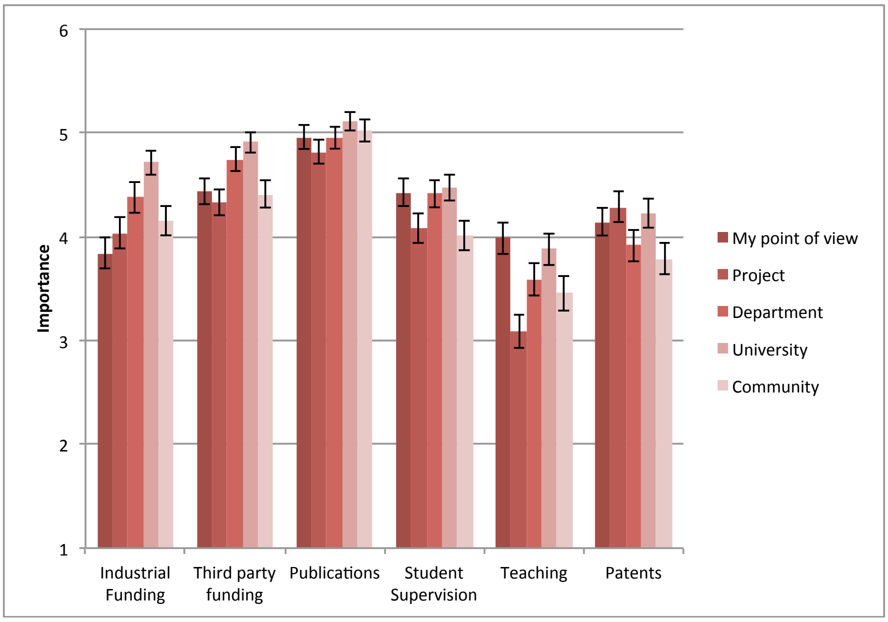

Figure 10: Perceived importance of criteria of scientific success from different perspectives. A higher bar means that the importance of the criterion is perceived higher. Error bars denote standard errors.

3.7. Scientific Cooperation Portal

Günther Schuh, André Bräkling

Beyond physical networking and training approaches, a permanent virtual platform called Scientific Cooperation Portal (SCP) is also provided to support the interdisciplinary location and time-independent collaboration within the CoE (see Figure 11). Based on the open source community portal Liferay[2], the SCP offers a broad set of information and collaboration features like CoE news, cluster information, an event calendar, seminar registration, member profiles, a filespace including version control and seminar registration (Vaegs et al. 2014). The cluster information contains basic information, like an introduction text and descriptions of the several sub-projects, but also technology datasheets that show the competences of

[2] https://www.liferay.com/

the CoE's actors. Furthermore, each sub-project is able to run its own sub-community with additional components like a discussion board, a wiki, and a task management tool.

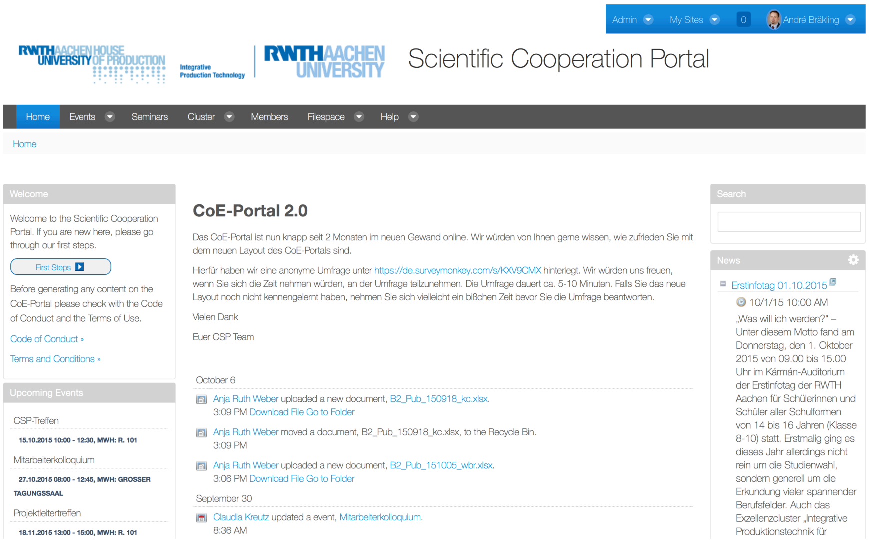

Figure 11: Screenshot of the Scientific Cooperation Portal

In the next section, an overview on related research is given. During the operation of the SCP, quantitative analyses and qualitative user studies were performed, which results are described in Sect. 3.7.3 and 3.7.4.

Besides, the SCP is a technical frame for additional applications, in detail: the Cluster Terminologies (see Sect. 3.8), the Collaboration Graphs (see Sect. 3.9), the FlowChart (see Sect. 3.10), and inquiry and information linking tools (see Sect. 3.7.6).

3.7.1. State-of-the-Art

As already mentioned before, interdisciplinary research and scientific cooperation are important drivers for innovative knowledge production (see Sect. 2). This interdisciplinary nature requires collaboration and technology transfer between several scientific areas and research fields, between academic research and potential industrial partners, but also between academia and the public in case of publicly-funded projects (Schuh et al. 2014; Schuh and Aghassi 2013).

This results in a common usage of documents, which becomes cumbersome because different systems are used and necessary data is distributed over several, non-integrated systems (Jeners 2015). To close this gap, the CoE set up the SCP as a central collaboration platform and decided to use modern web technologies and social media approaches that support knowledge and technology transfers (Leonardi 2014; Leupold 2010).

3.7.2. Method

To rate the established platform's success and the community's health, several metrics are known like active users, page views or actions (like uploading or downloading a document). Matthews et al. (2013), however, showed that member views were "by far the most-used health indicator".

On account of this, we observed the quantitative usage, before we validated and extended the findings by user questionnaires.

To get quantitative data about the SCP usage, the open source analytics tool Piwik[3] was used between October 2013 and April 2015. By adding a few lines of code to each single page, the tool is able to measure page views, the time spent on each page, the movement path, user configuration details and much more. The results are discussed in Sect. 3.7.3.

Towards the end of the quantitatively observed period, two user questionnaires were conducted to gain a more detailed insight into the users' expectations and perceptions. The detailed proceeding and results of both questionnaires are shown in Sect. 3.7.4.

3.7.3. Quantitative Usage Analysis

The data of 925 unique sessions[4], which were measured by Piwik, showed that an average user visited about 10 pages per sessions. These sessions took 10 minutes and 45 seconds on average.

The different pages of the SCP were clustered into 7 superior sections:

- **Cluster-Information:** Pages giving a description of the CoE itself and demonstration sites of upcoming portal features.
- **News:** Pages showing current news and giving an overview of the activities inside the portal, including the homepage.
- **Events:** The calendar page and all pages containing information about upcoming events.
- **Members:** The member overview page and the specific member profiles.
- **Filespace:** The portal's filespace section containing all CoE documents, templates and publications.

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[3] http://piwik.org

[4] Due to several user configurations, not all sessions were measured – e.g., if JavaScript was blocked. Also mobile sessions were not included.

- **Seminars:** Pages offering information about seminars and pages to register for a seminar.
- **Help:** Pages containing portal related help.

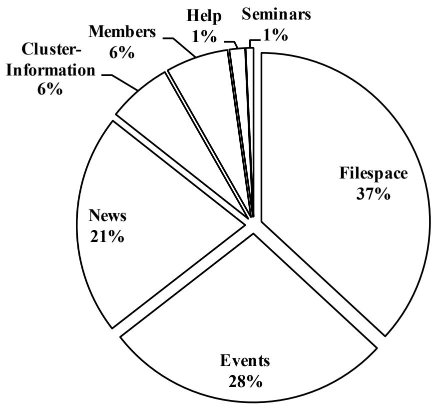

Figure 12: Distribution of portal section views between October 2013 and April 2015

The most used portal sections were Filespace and Events, as shown in Figure 12. Even the News section, which contains the homepage shown to every user after login, was viewed less. The general Cluster Information and the Members section were infrequently used, while the Seminars and the Help section were hardly ever accessed.

3.7.4.Qualitative User Questionnaire

A group of users (Group 1) had to fulfill concrete tasks using the SCP and to answer a questionnaire. Based on these results, a second user group (Group 2) was asked to do the same with a revised SCP. Major changes were an update to the latest software version Liferay 6.2 and a simpler user interface.

Table 2: For which purpose are you using the SCP? (1 = strongly disagree, 6 = strongly agree)

	Group 1		Group 2	
Item	**n**	**Mean (SD)**	**n**	**Mean (SD)**
Knowledge Management	4	3.50 (1.00)	6	2.67 (1.51)
Communication	4	1.50 (0.58)	6	2.33 (1.75)
Information Search	4	3.75 (1.89)	6	4.83 (0.75)

As shown in Table 2, users of both groups prefer to use the portal as a knowledge management platform. This fits the findings of the quantitative study, which showed that most users focus on Filespace.

Table 3: How strongly do you agree with each of the several statements? (1 = strongly disagree, 6 = strongly agree)

	Group 1		Group 2	
Item	**n**	**Mean (SD)**	**n**	**Mean (SD)**
I would find the SCP useful in my job.	5	4.80 (0.84)	5	4.40 (0.55)
My superiors were helpful in using the SCP.	4	2.00 (0.82)	5	1.60 (0.55)
The SCP is compatible with other systems I use.	5	2.00 (1.73)	5	2.80 (2.05)
The SCP allows me to complete my tasks more quickly.	5	4.20 (1.30)	5	3.20 (0.84)
The SCP will improve my productivity.	4	2.75 (1.50)	5	3.00 (1.00)
I find the SCP easy to use.	5	2.80 (1.64)	5	3.80 (0.45)
I think that I would like to use the SCP frequently.	5	3.80 (1.92)	5	4.60 (0.55)
I thought there was too much inconsistency in the SCP.	5	5.00 (1.22)	5	3.20 (1.30)

Overall, most attendees can imagine using the portal regularly (see
As shown in Table 2, users of both groups prefer to use the portal as a knowledge management platform. This fits the findings of the quantitative study, which showed that most users focus on Filespace.
Table 3). The new version of the SCP improved several usability ratings, but also got a worse rating in task processing time. Presumably, this is caused by a missing period of getting accustomed to the new version. The entire results are shown and discussed by Schuh et al. (2016).

3.7.5. Usage Barriers and Usability Findings

Following the previous results, most users prefer to share files and get information using the portal. It is not used for communication and rarely for knowledge management tasks. Accordingly, the portal is not used constantly, but in case that documents are required or the submission of documents or results is required.

Analyzing the results of the qualitative questionnaire, the users see the benefit of the provided portal, but are dissatisfied with the usability, and criticized inconsistencies within the old version. Based on the new version (see Figure 11) these issues are partly resolved. The impact on user behavior has to be observed in the future.

Noticeable is the rating on support given by superiors. The attendees disagree on the statement “superiors were helpful in using the SCP”. Several discussions showed that, in most cases, only project leaders manage the file exchange within the portal.

Therefore, in addition to overworking the software’s usability, feature offerings for project members should be improved so that not only project leaders see a need to use the portal. Superiors should also encourage project members to use the portal and offer support if necessary.

Furthermore, support questions showed incomprehension related to the portals structure and permissions inside the system. User roles and user permissions should be clarified and visible in the future.

Finally, the results also show a relation between content and usage. All sections that produce new content regularly – the Filespace, News, and Events – were also visited regularly. In contrast, the Seminars section has not been updated since early 2014, which fits with the users’ disinterest shown in the statistics.

In summary, we can mention these findings:

- The portal structure and the user’s permissions have to be clear and consistent.
- The features should address all existing user groups, and the usage should be motivated and supported by superiors.
- The content should be relevant and always up to date.

3.7.6. Outlook: Intelligent Inquiry Tools and Information Linking

To support the internal organization and management of the CoE, the database of the RWTH Aachen University Library was linked to the SCP. This allows listing all cluster-related publications, and is used to create the collaboration graph (see Sect. 3.9).

Furthermore, the portal allows uploading technology datasheets and to link these to users or their facilities that offer related technology knowledge.

Additionally, a focused crawler is under development. In contrast to a typical web crawler, a focused crawler is trained to collect data related to a defined context (Chakrabarti et al. 1999). In conjunction with the CoE, the crawler is intended to take each sub-project's material as training data to monitor selected research databases for new publications fitting the sub-project's interests. First thoughts on a configuration model to prepare such crawlers are presented in Schuh et al. (2015).

3.8. Cluster Terminologies: Data Science in Cooperation Engineering

Thomas Thiele, Claudia Jooß, Anja Richert, Sabina Jeschke

As mentioned in Chap. 3.7, *Scientific Cooperation Engineering* contains virtual approaches to support the communication and networking among the actors. The Cluster Terminologies extend this aim towards the utilization of data science as a mean of knowledge and cooperation engineering. Therefore, cooperation engineering is interpreted as the establishment of topic-based links between entities (e.g. projects). The Cluster Terminologies represent one possibility to address this linkage by the use of Text Mining and Visual Analytics.

3.8.1. State-of-the-Art

In the context of this chapter, the term *Cluster Terminologies* can be defined in two ways. First, it represents one possibility to address an empirically proven demand of the actors in the CoE. Jooß pointed out that a visualization of interfaces as well as the exchange on terminologies are important aspects when focusing on the actors' perspective. These features can be seen as requirements in the development for the *Cluster Terminologies*:

- "Exchange and terminology: A constant communicative exchange is important in the context of interdisciplinary collaboration. This exchange is based on acquiring a common understanding of terms." (Jooß 2014)
- "Visualization of the vision: In the context of interdisciplinary collaboration, it is important to raise awareness for the (interdisciplinary) vision. It is based on the visualization and localization of the individual projects and involved researchers." (Jooß 2014)
- "Identification and visualization of interfaces: A localization of individual researchers involved, projects and contents into the overall context is important as far as interdisciplinary collaboration is concerned. Interfaces can be identified and further processed by means of visualization." (Jooß 2014)

Second, the *Cluster Terminologies* are implemented as a virtual mean and can be defined as a tool that is used for cooperation support. Hence, the primary methodology is based on a technical framework. This framework is able to provide definitions of terminologies which enable scientists to recognize further research activities in the CoE and to depict interfaces between them (Thiele et al. 2015). This so-called *Terminology Framework* is then used in form of an application, the *Terminology App* on the Scientific Cooperation Portal (see chapter 3.7). This tool aims at the support of the development of and the semantic negotiation towards a common understanding of terminologies. The topology of the dependencies between the publication database, the framework, and the app is displayed in Figure 13.

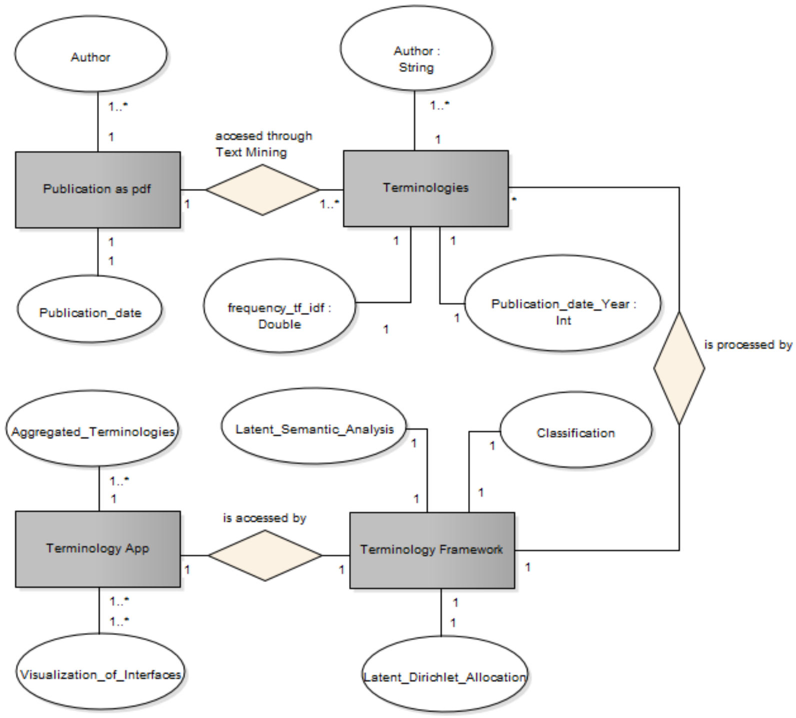

Figure 13: Entity Relationship Diagram of the Cluster Terminologies

Currently, this development is fostered by physical networking events (see Sect. 3.4). Although these means have proven as a vital concept of the networking strategy of the CoE, they can be supported with a terminology framework. The benefits are displayed via faster information processing as well as a place and time-independent availability of information (Eppler 2007).

3.8.2.Method: Terminology Framework

The main aim of the *Terminology Framew*ork is characterized by the processing of scientific publications in order to derive the research terminologies of the CoE. To enable this processing the *Terminology Framework* is based on Text Mining that is used to transform the publications into a vector space model. This transformation allows the statistical examination of the publications as they “are represented in high-dimensional space, in which each dimension of the space corresponds to a word in the document collection” (Manning and Schütze 2003).

At first, the extraction of terminologies from CoE publications is outlined. The extraction process consists of several pre-processing steps aiming at a vectorial representation of those publications. This so-called feature vector represents a statistic form of the publications that is accessible via Text Mining Algorithms and contains term-dependent frequency measures as well as metadata. In order to allow faster access, the features are transferred to an underlying NoSQL database. It results in a flexible alignment of features, as the collections of terms and their frequencies can be retrieved depending on the use case and the aim of the database query. The extracted terms can be automatically enriched with metadata like publication date, project affiliation or names of authors. This metadata can then be used to supplement user-specific visualizations in the *Terminology App*.

After extraction, the next step contains a mapping to derive connections between entities in the CoE based on the underlying statistics. As there are twelve projects, they serve as the thematic layer that provides a common ground for exploring connections by means of their research topics and related terminologies. Therefore, two tasks arise: The first task entails modeling the topics of projects from the extracted terminologies. Within this context, algorithms like Latent Semantic Analysis (LSA) and Latent Dirichlet Allocation (LDA) are applicable. The *LSA* covers the aspect of similarity between different terminologies: By means of comparing different similarity matrixes between terminologies, features are computed aiming at a statistical description of different meanings based on their context (Wiemer-Hastings et al. 2004; Landauer 2014). Furthermore, the *LSA* creates a semantic reduction by the application of a Single Value Decomposition to the terminologies. As a result, only the most important terminologies of the current discourse emerge (Thiele et al. 2015).

On that basis, *LDA* provides topic mapping at a project level. Following the idea that documents can be interpreted as random mixtures over topics, each topic can be characterized by a word distribution (Blei et al. 2003). Each distribution is defined by a multinomial spreading over the terminologies (Hoffman et al. 2010). The combination of LSA and LDA results in the definition of statistical project topics, in which meaning similarities between the topics are evaluated.

The results are further evaluated in a classification process. By the use of classification algorithms “the task is to classify a given data instance into a pre-specified set of categories” (Feldman and Sanger 2007). Applied to the project topics, interfaces between the projects are derived: The topics of one project are classified to the topics of all other projects in the CoE.

As a primary outcome, the classification process creates a prediction that determines how semantically close the classified topics and – as a consequence – the projects are. The metrics of the visualization are derived from this classification process aiming at a data-driven visualization. This visualization is accessible and, thus, usable by the actors of the CoE to initialize and support the communication and networking activities. The main benefit of this process lies in the statistical determination of interfaces that also includes a probability as a statistical measure of “quality” for the depicted interfaces. Hence, not only a simple prediction is provided, but also a statement on how the topic overlaps the mapped projects and terms.

3.8.3. Terminology App Functionalities

On the one hand, the Terminologies Framework allows the gathering of term spaces individual to the project, and a state-of-the-art overview of project topics and thematic interfaces based on the CoE’s publication database is created on the other. In order to create further use of these results, a user interface for the actors in the CoE is currently under development: the *Terminology App*.

Using the technical framework of the Scientific Cooperation Portal (see Sect. 3.7) the *Terminology App* is part of the virtual method suit for the CoE (Vaegs et al. 2014). As depicted in Chap. 3.8.2, the underlying *Terminology Framework* serves as the engine to enable various knowledge management functionalities. First, all Cluster Terminologies can be enhanced with additional information by its users. This includes short and long definitions of terminologies, an assignment of each terminology to a scientific discipline, and further references (Vaegs et al. 2013a). Furthermore, functions are implemented that facilitate an easy-to-use information retrieval. A search function for Terminologies as well as an alphabetical glossary (Yao et al. 2007) are also included.

The main core of the *Terminologies App* is characterized by the implementation of various data-driven visualizations of the dataset. The visualization is computed with the underlying *Terminology Framework*. A tree graph that depicts the interfaces and the predictions of projects as well as the similarity between terminologies of visualizations is currently under development. This visualization depends on the user’s own project affiliation and is centered on the terminologies of this project.

The tree graph connects the different projects and terms, if a similarity has been detected. By means of this type of graph as well as the coloring, different meanings are presented in one visualization (see Figure 14). The blue lines depict interfaces between projects, for instance, between P1, P2 and P4. As there is no blue line between P3 and the other projects, no computed statistical interface between this project and the others exists.

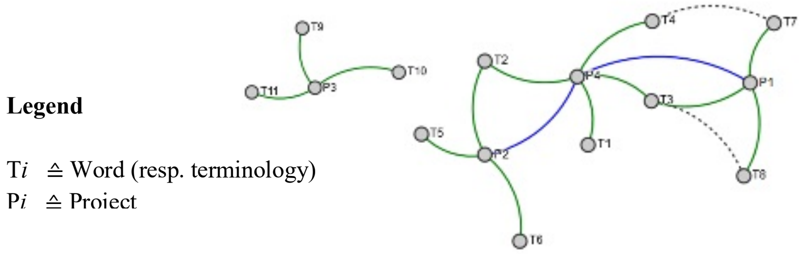

Figure 14: Exemplary visualization of a Terminologies Tree Graph (Thiele et al. 2015)

The green lines connect terminologies that are semantically related. There are several possible explanations for this relationship. The simplest reason is that the terminology belongs to the project itself. If a terminology (e.g., T2) is part of the terminology corpus of two projects (e.g., P2 and P4) and the *LSA* has proven that there is a semantic relation between the terminologies, it is connected to both projects. A third case occurs if two terminologies are different with respect to its spelling while similar regarding its meaning. In this case, it is likely that the *LSA* detects a semantic similarity, which then results in a dashed line in the visualization (e.g., T4 and T7).

The *Terminologies App* comprises of various tools that visualize thematic interfaces and topics – but it is only a first step towards initiating further cooperation in the CoE. This first step primarily includes the creation of awareness: Only if a scientist knows about the topics in the CoE and the persons related to them, she or he is able to interact with them. The development of a common understanding overresearch topics is also tackled, as an advanced understanding of different terminologies is emphasized (Vaegs et al. 2013a).

The *Terminology App* represents a virtual mean of cooperation support that tries to enhance physical networking processes by the creation of transparency regarding the topics in the CoE. In addition, the user is able to access these pieces of information without his or her personal effort. Although the computed interfaces serve as a first enabler of cooperation, the next step has to be a semantic negotiation on a personal level (Thiele et al. 2015). Therefore, the *Terminology App* serves as a first-step information system supporting a more purposeful approach in networking for cooperation support.

3.9. Visualization of Collaboration as a Means to Support Interdisciplinary Cooperation and Integration

André Calero Valdez, Martina Ziefle

Tackling the challenges of a cluster that is both large and has to deal with fast staff turnover must include strategic knowledge management. The hard question is where to integrate the knowledge management processes. One of the main results from our study of interdisciplinary success factors was that publications are unanimously seen as an indicator of scientific success in the CoE. This led us to the conclusion that publications could be used not as a key performance indicator but also as a means for knowledge management. The idea is to visualize publication efforts from the cluster in a way that it fosters both knowledge integration and collaboration.

3.9.1. State-of-the-Art

Publication-based indicators have been proposed as means to steer scientific endeavors in various places. Jaeger (2008) argued for the use of indicators such as publishing output and citation impact as a means of motivation in university settings, with the additional finding that they are caused by more transparency and not financial incentives. Most criticism is caused by the design of individual indicators and their imperfections in comparing different disciplines.

In a cybernetic approach indicators are not only used as a means of steering the cluster but also as a means to communicate the status quo to the members in the cluster. Therefore, an approach should be used that integrates visualizing publishing indicators not just to measure success but also to improve knowledge management. This should improve the motivation of researchers to improve their publication output as well as take part in interdisciplinary exchange. No financial incentive is used.

Visualizations of publications have been used in various contexts. Often visualizations are used to show how researchers, institution (Perianes-Rodr\'\iguez et al. 2010) or nations have collaborated in science in so-called co-authorship graphs (Kumar 2015). Beyond showing who has collaborated with whom, visualizations have been used to show how topics have evolved in keyword based graphs (Bruns et al. 2015; Calero Valdez et al. 2015). These graphs visualize how authors have used certain keywords over time and how their use has changed. By visualizing co-citation in graphs, one can see how a certain publication is being used in different settings (White and Mccain 1998).

Beyond visualization efforts, social network approaches have been implemented to foster knowledge exchange and collaboration. Academic social networks such as academia.edu, Mendeley, and Researchgate collect author information and present those in author profiles. Here, researchers can connect with their peers in their community and find relevant publications. Microsoft Academic Search and Arnetminer offer visualizations that show how researchers are connected in their co-authorship network.

In our approach we try to combine the results from academic social networks and graph-based visualizations with recommender systems to provide tailored support to the CoE (Vaegs et al. 2014) and to understand the influence of interdisciplinarity on publishing (Holzinger et al. 2013; Calero Valdez et al. 2014).

3.9.2. Publication Visualization on the Scientific Cooperation Portal

The SCP offers social media capability by providing each researcher with a profile. By connecting the SCP with the library database of the university, we obtain full information on the publications of each individual researcher without the hassle of using external databases. This helps overcoming problems such as meta-data extraction or identifying individual researchers from last names.

The main idea of our publication visualization is to view the publications from the CoE and their keywords. The profiles of the users contain research interests (also generated from publication data), which can be used to pre-filter data to improve the visualization scope.

Our visualization starts by showing all publications and their related topics (see Figure 15). Then, the user may filter the graph by entering keywords, titles, authors or outlets. Each keyword is measured against a relevance threshold. This allows determining the main content of the publication in relation to all listed keywords. With this information we can show a profile-based visualization that only shows publications that are relevant to the user.

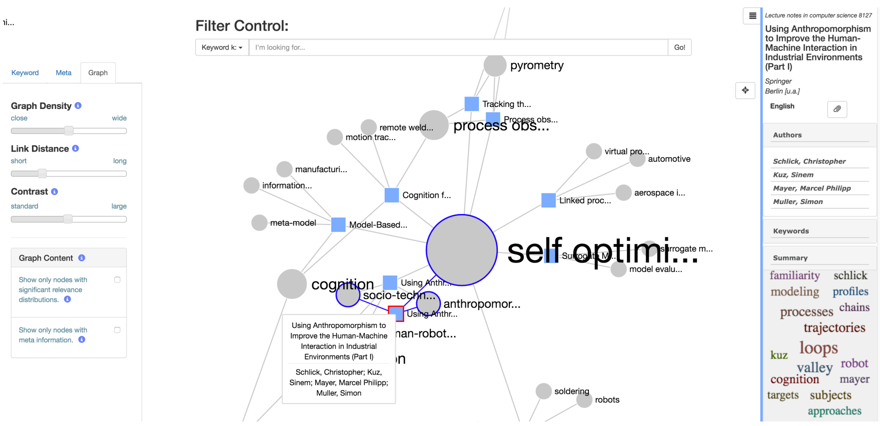

Figure 15: Publication visualization used to show how publications are related to different keywords

The aforementioned threshold can then be adjusted using a slider by the user to also view publications that are related to his keywords but not in the center of his focus (see Figure 15). A user that is looking for *self-optimization* could then also find articles that deal with *cognition* or different related keywords.

Our second visualization shows the organizational structure of the cluster and can be used to interactively explore keyword relationships between authors.

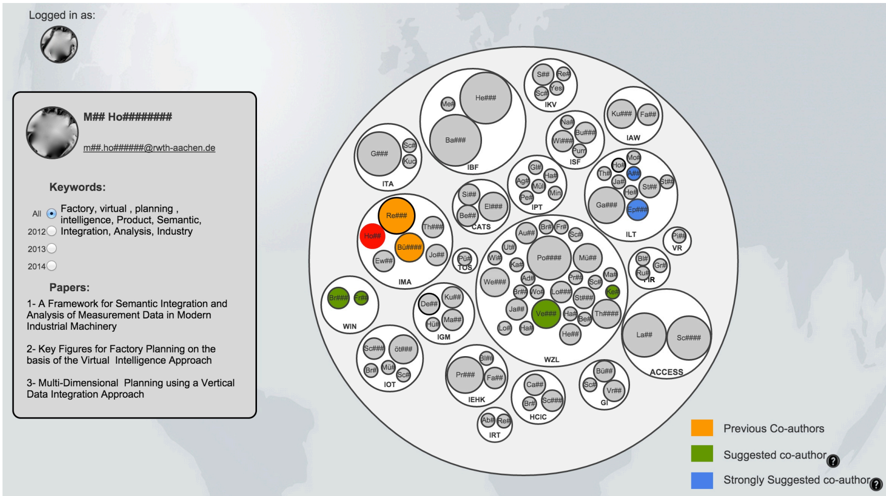

Figure 16: Collaboration visualization using bubble-bag visualization. Suggested collaborators are highlighted in different colors

By hovering over an author node, all other authors that published to similar keywords light up indicating possible collaborators. When clicking on a node, a full list of the author's publications is shown, which is also filterable (see Figure 16). The profile of the user also shows immediate contact information, so that a user may immediately contact the possible collaborator.

3.9.3. Evaluation of the Visualizations

In order to ensure that our visualizations are seen as helpful by the researchers, the software was evaluated with members of the CoE. For this purpose, two user studies were conducted – one for each visualization.

Both user studies were conducted using a task-based analysis. Users had to perform tasks in a prototype with little instruction and were afterwards asked to fill out a questionnaire to report their impression of the prototype. Questions were asked for the System Usability Scale (SUS) (Brooke 1996) the Net Promoter Score (NPS) (Reichheld 2003) and used some of the items on the ResQue Recommender Systems Evaluation scale (Pu et al. 2011). All user interaction was video recorded and transcribed for later analysis.

In the user study evaluating the collaboration suggestion visualization (Study 1, see Figure 16) 16 researchers participated; while in the other 20 researchers took part. The average age was around 33 years in both samples. About half of the participants in both studies were female.

Overall, both visualizations received positive usability evaluations ($SUS_1 = 81.5$, $SD = 2.17$, $SUS_2 = 82.5$, $SD = 24.4$). The NPS was low for the first study ($NPS = -7$) and high for the second prototype ($NPS = 40$). This result led to the decision to further examine the second prototype (keyword-publication-graph, see Figure 16).

For the second prototype some interesting qualitative findings were found. Users were applying different search strategies depending on their degree of experience. More experienced researchers were using the filtering system in a *drill-down* fashion. They first picked a keyword suitable for their search and then filtered the results set further to find a specific publication. The less experienced researchers implemented an *incremental bag* strategy. They searched for relatively specific terms and incremented the result by adding further keywords to their search.

When asking them how well they liked the visualization for different tasks in comparison to search engine results presentations (i.e. lists), all researchers preferred the visualization rather than typical list-based presentations. The only exception to this rule was in cases where a researcher was looking for a specific publication and when they knew the full title of the publication. This finding was expected, as the visualization changes in every search and no spatial information can be used to re-find results from older searches.

The positive evaluation of the second prototype must be seen in the context of the experiment. Researchers were asked to test an interactive visualization in a time-constrained setting with no time pressure as in real life. Whether these findings hold in an everyday setting, must still be seen. Still, one user reported having used the visualization to look for an article when writing a publication. At the time of writing, the database “connection” with the library database was a one-time synchronization. When the system automatically updates to the current status, more use-based evaluations in everyday work can be derived.

3.9.4. Interdisciplinary Publication Workshops

As an additional measure to foster collaboration between different disciplines, publication workshops are conducted twice a year. These workshops are conducted with about eight researchers as full-day seminars. In these seminars researchers are asked to share their experiences with publishing in a protected environment. The workshops are designed to share hands-on experience on writing publications in interdisciplinary settings as well as giving tutorials on how to use publications tools (e.g., databases, reference management).

Most of the time researchers are unaware of the disciplinary differences in publishing outlets (e.g., computer scientists mostly publishing at conferences). But also organizational differences that may be unknown to other researchers have implications for practical purposes. Understanding how publishing works at other departments helps researchers understand how to improve their writing process to overcome typical organizational barriers when deadlines near. The workshops were also evaluated positively. All participants reported to have gained practical knowledge that was helpful to their everyday work.

3.10. Research Planning Using the *FlowChart* Tool

Ulrich Jansen, Wolfgang Schulz

Clear communication and a common understanding about the research process are crucial elements in research collaborations with multiple partners involved. To support the knowledge and cooperation engineering field of action inside Cross Sectional Processes 1, a web-based research planning tool is developed and tested inside the CoE.

Project planning and managing tools of different complexity exists – but these tools suffer from poor usage in research projects. Literature review on so-called Project Management Information Systems lead to key features for project planning systems. Additional requirements analysis leads to a lightweight and easy-to-use standardized project planning form that is implemented as a centralized web-based tool. A small usage study of the tool is carried out in the developing department and enhancements of the concepts are derived from interviews. In 2016 the tool will be rolled out on the Scientific Cooperation Portal, and a study about usage and effects on project performance will be accomplished.

3.10.1. State-of-the-Art

Project planning and scheduling tools exist and – if these tools have extendable items that can handle additional information – these tools are called Project Management Information Systems (PMIS). To indicate that PMIS need to be flexible enough to cope with changing demands during the project lifetime (Jaafari and Manivong 1998) extends this term to Smart PMIS. Jaafari defines five main capability items for a Smart PMIS:

1. Management and real-time control of information relevant for a project
2. Integration of information across the entire lifetime of a project, including initial feasibility analysis and final post-project phase
3. Processing and reporting capabilities like alerts and decision impact measurements

4. Real-time management support by objective functions like cost/worth ratio (Jaafari calls this proactivity facilitation)
5. Integration into existing systems to provide all relevant information to all members of a project team

Using these capabilities, 25 functions of an idealized PMIS are posed.

An empirical study on impact of PMIS on project success is performed by (Raymond and Bergeron 2008b) using questionnaires. A five-component success model is specified which is connected by hypotheses that have been tested by a questionnaire with 39 valid returns from project managers. A significant impact on project success by use of PMIS is concluded.

The importance of good quality information of PMIS was analyzed by (Caniëls and Bakens 2012). A spillover effect was found in multi-project environments – so if the PMIS offers poor quality information for one project, project managers assume poor information quality for other projects too. Thus, PMIS should provide good quality information for all projects in a multi-project setup to furnish satisfying results for decisions made by PMIS information. The importance of good quality information for success and acceptance of PMIS was also found by (Tromp and Homan 2015).

3.10.2. Method

To support the CoE in a goal-driven proactive praxis in project and research management, a reduced PMIS is developed inside *Scientific Cooperation Engineering* as a web-based application. This application is called *FlowChart* and it provides a graphical representation of the project's initial situation, the project objectives and the project tasks or work packages. To develop this tool, an expert interview based requirements analysis is carried out in the developing department. The derived requirements are grouped to functional and non-functional ones. Important non-functional requirements include extensibility and flexibility, integration into existing systems and licensing costs. Especially because of these non-functional requirements the decision was made to develop an in-house solution for the *FlowChart* tool. The developed *FlowChart* Tool is beta-tested inside the developing department and prepared for the SCP release in 2016.

3.10.3. Requirement Analysis

Existing project planning tools suffer from poor usage in research projects. A precise requirements analysis is demanded to ensure that the *FlowChart* tool will generate a real benefit inside the CoE. The requirements analysis is carried out inside the developing departments modeling and simulation at Fraunhofer ILT and at the NLD chair of RWTH Aachen University. The typical structure of research projects is analyzed and a common pattern is found. Typical running times of projects range from a few months up to one year. Publicly-founded projects with larger running times usually can be split into single phases and handled as consecutive projects. Each project has an initial situation that represents the state of current research, available methods, and tools and the capabilities of all project partners. Typical project objectives aim at optimization of production processes, enhancement or redevelopment of tools or the increase of process understanding.

By analyzing requests for research projects and feedback of partners on project results, three main problems were identified that may lead to unsuccessful projects or dissatisfying results:

1. Model assumptions are not fully understood by the client or partner. This refers to the applicability of a specific tool or method for a certain research question. Most likely the selected tool or method is not suitable for the analyzed use case.
2. Incorrect application of existing tools and solutions. The tool or method is suitable, but not used correctly.
3. Client side application of results is inoperative or dissatisfying. Important assumptions and parameters do not apply for the machine or specific use case of the customer.

To ensure satisfying project results, three crucial elements for successful research cooperation are identified:

1. Clear communication with each research partner.
2. Limitations for derived measures have to be recorded and communicated.
3. A flexible research plan as a classical straight forward project schedule is not well applicable as it does not reflect the real systematic trial-and-error approach in research projects.

The *FlowChart* tool is developed as a standardized web-tool to offer an easily understandable and easily applicable form for the common research plan. The tool provides a basis for communication between project partners and has to fulfill the following requirements:

1. Start-up schedule: Represent the initial project schedule including resources plan, role allocations and responsibilities definitions.
2. Initial situation: Show the state of current research and define the preconditions for the project. Sum up conclusions from possibly preceding projects.
3. Feasibility: Connect initial situation and project objectives by project tasks that can be realized in the given time frame and given resources. If tasks that can possibly threaten the project are identifiable in this stage, these should be clearly highlighted. Alternative paths should be drawn and marked by conditional elements.
4. Work allocation: Allocate workers for all defined tasks.

5. Resource allocation: Assign tasks to individual resources. By overlaying all projects that allocate a specific resource, resource bottlenecks can be identified early and the project manager can be warned.
6. Project control: Enable the project leader or stakeholder to check the fulfillment level of each project task.
7. Post completion review: Representation of successes and failures and lessons learned by this project. Point out open questions of this project.
8. Risk management: Identification of critical tasks/threats to project objectives.
9. Time management: Overview of milestones, points-of-decision and time frames of all work packages.
10. Stakeholders' management: Control sheet for those with a direct stake in the project.

3.10.4. The *FlowChart* Tool

To meet the requirements gathered from the requirements analysis, a pictorial representation of the research plan has been derived in a flowchart-like approach. The *FlowChart* tool displays a single screen view of initial situation, research plan and project objectives as an interactive web application. The flowchart view of the tool shows three columns placed on an arbitrary number of project category bars as Figure 17 shows.

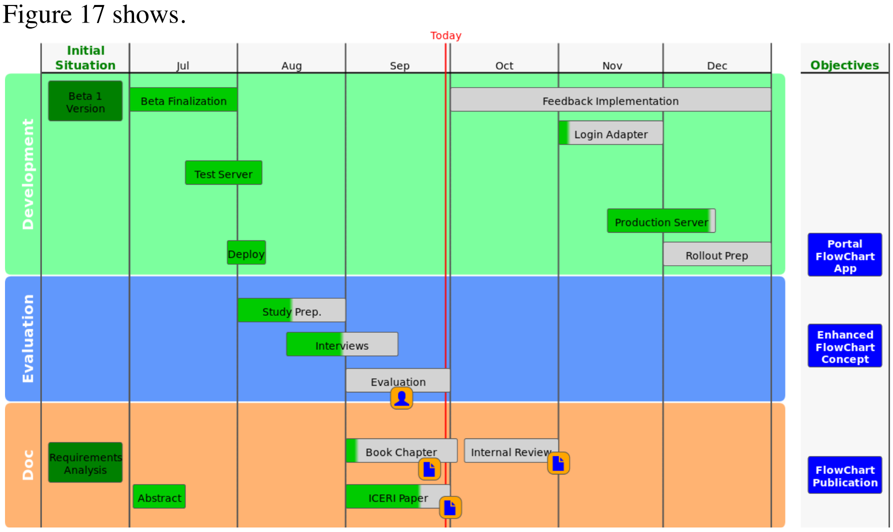

Figure 17: Flowchart view of the *FlowChart* application

The main elements of the flowchart view are categories, initial situation, tasks and objectives. A detailed description of the FlowChart's elements is given (Jansen and Schulz 2015).

3.10.5. Implementation

The *FlowChart* tool is implemented as Web 2.0 application incorporating modern web techniques from the HTML 5.0 specifications like Server Sent Events (SSE), Asynchronous JavaScript and XML (AJAX) and Scalable Vector Graphics (SVG). The underlying application framework is Ruby on Rails 4.0 (Ruby et al. 2013). As database application PostgreSQL is used because of its built-in listen/notify channel mechanism. This mechanism is used to directly notify all connected clients, showing a view of a specific flowchart. To send messages from the server to the client without the use of a polling mechanism, SSE are used. This approach enables a concurrent view of every flowchart as all changes are stored directly to the server and transmitted to all clients. The tracking of all changes by date and user provides a change history of all items.

3.10.6. Results

The *FlowChart* application is developed inside the *Scientific Cooperation Engineering* team and beta tested by the department modeling and simulation at ILT and the NLD department of the RWTH Aachen University. The beta tests will be extended to the *Cross Sectional Processes* team and the beta phase will be closed in 2016. The rollout of the tool on the SCP will be carried in 2016 and further tests and extensions of the tool are planned until the end of the funding period of the CoE. A first two-part usage study with four members of the two institutions mentioned above has been performed. The first stage is a usage test with four tasks: (1) generate a new project, (2) generate a new flow chart including categories, (3) create a project plan, and (4) explain the project plan. The second stage of the usage study is an interview about the flowchart concept itself and on how to extend the concept and the *FlowChart* tool. The usage and interview study of the beta version of the *FlowChart* tool pointed out the following enhancements and extensions of the current version of the tool:

- Relation management: the not-yet implemented relations between work packages (dependencies, conditionals etc.) should have a smart component that detects dependency conflicts between packages like circular dependencies and warns the project members if strong project threatening dependencies that have not been met on a specific date were found.
- Resource management: the not-yet implemented assignment of resources (researchers, machines, materials) to project tasks should be invertible so that a resource to project relation is shown and possible resource conflicts

might be detected early. Also, the system should warn automatically if a possible resource conflict might occur during project planning and/or a resource is allocated multiply at the same time.

- Summary and detailed view: for larger projects and/or long-lasting projects, several levels of detail should be possible. For example, in a five-year project an overall time schedule should be shown that might be zoomed to specific half-year views of the project that include the detailed project plan for this phase of the project.
- Notification of changes: If project tasks are postponed or canceled, the effect on dependent tasks and objectives should be highlighted. Automatic notifications for project partners or a review system for project changes are that correspond to a dynamic relation management system are desirable.

The *FlowChart* tool will be enhanced by these features in 2016.

3.10.7. Future Research and Development

The positive effect of PMIS on project success has been analyzed by Raymond and Bergeron (2008a). A transfer of these results into a scientific research cooperation and the extensive testing of a lightweight and easy-to-use PMIS for research projects is performed inside *Scientific Cooperation Engineering*. The developed *FlowChart* tool will be used for close industry/university collaborations by the developing institute and knowledge about managing research projects will be led back into enhancements of the *FlowChart* tool itself. Additionally, the *FlowChart* tool will be rolled out in the SCP, and in 2016 the tool will be enhanced by the items found in the first usage study. By making the tool available on the SCP, it will be accessible for around 200 researchers within the CoE. A questionnaire and expert interviews with members from different institutions will be carried out in 2016. To analyze the effect of this research planning tool on project performance, repetitive interviews with individual users will be performed in 2016 and 2017.

4. Industrial Relevance

Cooperation gains in importance, especially in scientific research. Regarding the industrial applicability, the CoE tries to extend this cooperation towards the integration of industrial partners, – for instance, by means of the integrating stakeholders in the Industrial Advisory Board. This specific integration serves the purpose of providing strategic consulting and giving feedback on research results. The measures of *Scientific Cooperation Engineering*, however, focus on the operative level. The integration of interdisciplinary researchers is addressed in their daily working environment by supplemental measures that aim at enhancing networking processes.

These measures include the support of communication, cooperation and collaboration in the scientific working environment of the CoE. Kaufmann and Tödtling (2001) stated that "communication and collaboration between actors embedded in different systemic contexts is costly". Nevertheless, fostering the cooperation of science and industry can result in an increased innovativeness for business partners and in more stimulated research on the side of the scientists (Kaufmann and Tödtling 2001). Although this statement refers to research cooperation between science and industry, the collaboration in the CoE shows many similarities. There are actors in the CoE, for instance, who have a background in science as well as have gained industrial experience (Vossen 2012; Welter 2013). Furthermore, the aims of the CoE are related to applicable results, like production technology demonstrators. The measures of *Scientific Cooperation Engineering* share this applicability. All of those, thus, have been developed based on a scientific methodology, but are actively implemented and used in the CoE.

Therefore, the portability of most of the measures fostering cooperation towards an industrial application is likely to be high. The employee survey of the CoE, which is based on a Balanced Scorecard approach (see Sect. 3.1), can be adapted, for instance, in order to support further surveys in an industrial R&D context. This circumstance mainly includes the measurement of the employee's perception of a financial, output and customer, cooperation and learning perspective. As a follow-up, organizational design processes are supported with *Scientific Cooperation Engineering*. The design and implementation of workshops aim at a reflection of the surveyed topics on various hierarchical levels. In the context of the demographic change, an implementation of these processes has already been initialized in the automotive sector.

Another field of attention is the one on organizational learning processes. *Scientific Cooperation Engineering* – in close connection with the cluster management – is responsible for the development and implementation of so-called *microtrainings*. These trainings are learning units of short duration that support on-the-job learning processes in particular (Welter et al. 2010). In the context of the CoE, a didactical concept of the *microtrainings* has been adapted to fulfill the requirements of cluster employees and serve as a mean to initiate organizational learning processes. The concept of *microtrainings* could be transferred to an industrial use case, focusing on on-the-job learning processes.

Furthermore, the virtual measures of *Scientific Cooperation Engineering* can also be transferred to an industrial context. Considering a holistic approach on virtual communication and exchange, a cooperation portal has been established in the CoE especially supporting knowledge dissemination that is independent from time and space. This portal also includes basic functions like cluster news bulletins or calendar functionalities. In addition, cluster-wide and project-specific collaboration spaces have been established in order to create customer-dependent collaboration suits. Furthermore, cloud functionalities are available if needed. This portal can also be adapted by focusing especially on easy-to-use collaboration suits for small and medium-size enterprises, as there are little investment costs in terms of server architecture or development.

Within the virtual collaboration platform, a range of applications that try to enhance the depicted knowledge dissemination in various ways are currently under development. The Terminology App tries to find hidden synergies between the projects in order to enable further cooperation and communicative exchange. This exploration aims at establishing topic-based links between entities (e.g., projects) in the CoE. Based on publications, topical links are revealed by means of a Data Analytical approach. The database is then visualized in a data-driven user front-end. In an industrial context, the application could be used to detect synergies between different departments, which are possibly unknown yet.

From a management perspective *Scientific Cooperation Engineering* serves as an evaluation and steering element of the CoE. The feedback gained through evaluation is used to support decision-making by a tracing back the impact of implemented measures. This leads to an enhanced steering of the CoE as measures can be developed based on the direct and indirect feedback of the actors. On a cybernetic level the CoE management is based on iterations in decision-making, in which the actors' feedback is used as a start for a new iteration for a redesign of measure, for example. This circle is depicted in Figure 18.

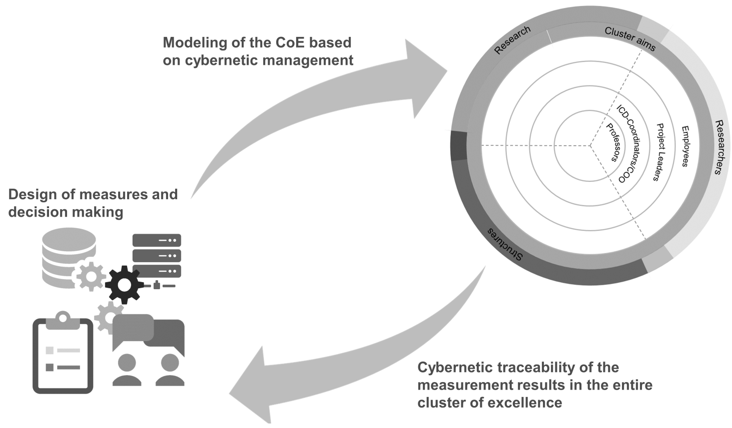

Figure 18: Cybernetic Management of *Scientific Cooperation Engineering*

In conclusion, *Scientific Cooperation Engineering* contains a large variety of measures that fulfill individual requirements. Within this chapter, the topics of knowledge management, leveraging synergies and learning were addressed in particular. Within this context, various cooperative situations are covered. Although the CoE consists only of science-to-science cooperation, this relation can be extended towards science-to-industry as well as industry-to-industry cooperation – for instance, in large R&D locations.

5. Future Research Topics

The wide range of methods and topics of *Scientific Cooperation Engineering* has already been outlined in Chap. 3. There are four fields of action: *Knowledge & Cooperation Engineering, Interdisciplinary Innovation Management, Performance Measurement and Diversity Management*. The development of the depicted measures will continue in the next years. Within these fields of action, four trends arise in the scope of the project:

- Measurement and evaluation of impact,
- learning and advanced trainings,
- data science as a tool for cooperating engineering,
- visualization and usability.

In the following, the topics of these trends will be discussed.

On the one hand *measurement and evaluation of impact* refers to the field of *Performance Measurement*. The next steps will include the design and concepts of benchmarking using the data conducted from earlier surveys in the CoE. Factors will be derived that allow a relation to comparable clusters and research networks. The Balanced Scorecard and the formative evaluation (see Sect. 3.1) will maintain a vital element of employee surveying and will be further developed and adapted, if necessary. On the other hand, the Critical Incidents of interdisciplinary research (see Sect. 3.2) have proven as desirable directions regarding the actors' perspective in the CoE.

Two further topics are currently under development regarding the Critical Incidents' measurement of impact. First, the Critical Incidents in their current stage are qualitative indicators for the actors' perspective. They will be extended towards a quantification regarding their individual characteristics in the CoE. Based on a coherence analysis of Critical Incidents, this extension will lead to a measurement of perceived quality of interdisciplinary cooperation in general. Second, the Critical Incidents are derived on a data basis of surveys and interviews in the CoE. Further research aims at the measurement and evaluation of impact in comparable research clusters and structures in order to extend the validity of the Critical Incidents.

The Critical Incidents also include a strong connection towards the second trend, *learning and advanced trainings*. Considering the derived Critical Incidents from a management perspective, they allow deeper insights into the needs of the actors and their requirements on further developments in the CoE. These needs will be addressed by the development and support of further learning formats, such as *micro-trainings*. Contributing to further learning means, first concepts for a CoE Massive Open Online Course (MOOC) have been made and will be further examined. The most decisive point can be seen in the fact that a research project, the CoE, conducts a MOOC about topics that are currently developed in the CoE and, thus, extremely up to date for students Hence, the MOOC will allow a strong connection of research in the CoE and higher education that will possibly lead to a stronger exchange with undergraduate and PhD students. As a future research topic, this trend will be monitored with *Scientific Cooperation Engineering*.

The ongoing trend on *data science as a tool for cooperation engineering* has already been included in the research of *Scientific Cooperation Engineering*. The *Cluster Terminologies* (see Sect. 3.8), for instance, are a typical feature in order to derive answers for the question whether there are hidden synergies in the CoE that can be detected on the basis of publication data. The development of the *Cluster Terminologies* will include the further implementation of algorithms in order to improve predictions for project-to-project relationships as well as topic mapping. As it is the user front-end of the *Cluster Terminologies,* the Terminology App is also strongly connected to the visualization of data. Hence, future research will aim at improving the visualization functionalities towards the requirements of the CoE.

As structures of research networks intend to grow in size, complexity and heterogeneity, the requirements to projects enabling cooperation raise together with these three dimensions. For instance, from a European perspective the Knowledge and Innovation Communities form one of the biggest steps of self-organized research networks. Within the triangle of higher education, research and business, this type of networks demands a high degree of integration focusing on a combined research effort of education and entrepreneurship with research and innovation (European Institute of Innovation and Technology). As the size of these research networks grows, measures supporting cooperation become necessary that meet these challenges. Within this context, *Scientific Cooperation Engineering* represents a proven concept to derive requirements from these challenges and create tailor-made solutions for a cooperative environment.

6. References

Aboelela SW, Larson E, Bakken S, Carrasquillo O, Formicola A, Glied SA, Haas J, Gebbie KM (2007) Defining Interdisciplinary Research: Conclusions from a Critical Review of the Literature. Health Serv Res 42(1p1):329–346. doi: 10.1111/j.1475-6773.2006.00621.x

Alexander von Humboldt-Stiftung (2009) Publikationsverhalten in unterschiedlichen wissenschaftlichen Disziplinen. Beiträge zur Beurteilung von Forschungsleistungen 2

Aram JD (2004) Concepts of interdisciplinarity: Configurations of knowledge and action. Human Relations 57(4):379–412

Baer M, Niessen A, Ruenzi S (2007) The Impact of Work Group Diversity on Performance: Large Sample Evidence from the Mutual Fund Industry

Bantel K, Jackson S (1989) Top management and innovations in banking: Does the composition of the team make a difference? Strategic Management Journal 10:107–124

Bassett-Jones N (2005) The Paradox of Diversity Management, Creativity and Innovation. CREATIVITY AND INNOVATION MANAGEMENT 14(2):169–175

Bergmann M, Schramm E (eds) (2008) Transdisziplinäre Forschung: Integrative Forschungsprozesse verstehen und bewerten. Campus Verlag, Frankfurt, New York

Berry LL (ed) (1983) Emerging perspectives on services marketing. Proceedings series / American Marketing Association, Chicago Ill.

Blackwell AF, Wilson L, Street A, Boulton C, Knell J (2009) Radical innovation: crossing knowledge boundaries with interdisciplinary teams. University of Cambridge/NESTA Report. Cambridge, UK: University of Cambridge Computer Laboratory.

Blei DM, Ng AY, Jordan MI (2003) Latent Dirichlet Allocation. J. Mach. Learn. Res. 3:993–1022

Bornmann L, Mutz R, Neuhaus C, Daniel H-D (2008) Citation counts for research evaluation: standards of good practice for analyzing bibliometric data and presenting and interpreting results. Ethics in Science and Environmental Politics 8(1):93–102

Brooke J (1996) SUS-A quick and dirty usability scale. Usability evaluation in industry 189(194):4–7

Bruns S, Calero Valdez A, Greven C, Ziefle M, Schroeder U (2015) What should i read next? a personalized visual publication recommender system. In: Human Interface and the Management of Information. Information and Knowledge in Context. Springer, pp 89–100

Bullinger H-J, Bauer W, Kern P (2009) Innovationen der Arbeit: Zukunft für Menschen durch nachhaltige Arbeitskonzepte. In: Spath D (ed) Arbeits- und Dienstleistungsforschung als Innovationstreiber: [Bilanzen, Herausforderungen, Zukünfte ; Fachtagung, 22. Mai 2009]. Fraunhofer-Verl., Stuttgart, pp 4–14

Bundesministerium für Wirtschaft und Technologie (ed) (2008) Kompetenznetze initiieren und weiterentwickeln – Netzwerke als Instrument der Innovationsförderung, des Wirtschaftswachstums und Standortmarketings, 2nd edn., Berlin

Calero Valdez A, Bruns S, Greven C, Schroeder U, Ziefle M (2015) What Do My Colleagues Know? Dealing with Cognitive Complexity in Organizations Through Visualizations. In: Learning and Collaboration Technologies. Springer, pp 449–459

Calero Valdez A, Schaar AK, Ziefle M, Holzinger A, Jeschke S, Brecher C (2014) Using mixed node publication network graphs for analyzing success in interdisciplinary teams. In: Automation, Communication and Cybernetics in Science and Engineering 2013/2014. Springer, pp 737–749

Caniëls M, Bakens R (2012) The effects of Project Information Systems in decision making in a multi project environment. International Journal of Project Management(30):162–175

Caye JM, Teichmann C, Strack R, Haen P, Bird S, Frick G (2011) Hard-Wiring Diversity into Your Business

Chakrabarti S, van den Berg M, Dom B (1999) Focused crawling: a new approach to topic-specific Web resource discovery. Computer Networks 31:1623–1640

Cluster of Excellence (2012) Integrative Production Technology for High-Wage Countries: Renewal Proposal for a Cluster of Excellence – Excellence Initiative by the German Federal and State Governments to Promote Science and Research at German Universities, Unpublished

Cox TH (1993) Cultural Diversity in Organizations: Theory, Research and Practice, San Francisco

Defila R, DiGiulio A (1998) Interdisziplinarität und Disziplinarität. In: Olbertz J-H (ed) Zwischen den Fächern - über den Dingen?: Universalisierung versus Spezialisierung akademischer Bildung. Leske + Budrich, Opladen, pp 111–137

Deinhammer R, Universität Salzburg Poverty Research Group, others (2003) Was heißt interdisziplinäres Arbeiten?: FWF (Austrian Science Fund): Research project Y 164. University of Salzburg/Poverty Research Group

DFG – Deutsche Forschungsgemeinschaft (ed) (2006) 1. Ausschreibung in der Exzellenzinitiative: Auswahl der Antragsteller, Bonn

Eppler MJ (2007) Managing information quality: Increasing the value of information in knowledge-intensive products and processes, 2nd ed. Springer, Berlin, New York

European Institute of Innovation and Technology Innovation Communities. http://eit.europa.eu/activities/innovation-communities. Accessed 9 August 2015

Feldman R, Sanger J (2007) The Text Mining handbook: Advanced Approaches in Analyzing Unstructured Data. Cambridge University Press, Cambridge, New York

Flanagan JC (1954) The critical incident technique. Psychological Bulletin 51(4):327–358. doi: 10.1037/h0061470

Gebert D (2004) Durch Diversity zu mehr Teaminnovativitaet? (in German). Die Betriebswirtschaft 64

Gibbons M (1994) The new production of knowledge: The dynamics of science and research in contemporary societies. SAGE Publications, London, Thousand Oaks, Calif.

Giddens A (1984) The constitution of society: Outline of the theory of structuration. Univ. of California Press, Berkeley, Los Angeles

Gratton L, Erickson TJ (2007) 8 ways to build collaborative teams. Harv Bus Rev 85(11):100

Hoffman L (1959) Homogeneity and member personality and its effect on group problem solving. Journal of Abnormal and Social Psychology 58:27–32

Hoffman M, Bach FR, Blei DM (2010) Online Learning for Latent Dirichlet Allocation. In: Lafferty JD, Williams C, Shawe-Taylor J, Zemel RS, Culotta A (eds) Advances in Neural Information Processing Systems 23. Curran Associates, Inc, pp 856–864

Holzinger A, Ofner B, Stocker C, Calero Valdez A, Schaar AK, Ziefle M, Dehmer M (2013) On graph entropy measures for knowledge discovery from publication network data. In: Availability, reliability, and security in information systems and HCI. Springer, pp 354–362

Horváth P, Seiter M (2009) Performance Measurement. Die Betriebswirtschaft:393–414

Hübenthal U (1991) Interdisziplinäres Denken: Versuch einer Bestandsaufnahme und Systematisierung. Steiner

Jaafari A, Manivong K (1998) Towards a smart project management information system. International Journal of Project Management(16):249–265

Jaeger M (2008) Wie wirksam sind leistungsorientierte Budgetierungsverfahren an deutschen Hochschulen? Zeitschrift für Hochschulentwicklung

Jahn T (2008) Transdisziplinarität in der Forschungspraxis. In: Bergmann M, Schramm E (eds) Transdisziplinäre Forschung: Integrative Forschungsprozesse verstehen und bewerten. Campus Verlag, Frankfurt, New York, pp 21–37

Jahn T, Bergmann M, Keil F (2012) Transdisciplinarity: Between mainstreaming and marginalization. Ecological Economics 79:1–10. doi: 10.1016/j.ecolecon.2012.04.017

Jansen C (2004) Scorecard für die Wissensmanagement-Performance in heterogenen Unternehmensnetzwerken. Techn. Hochsch., Diss.--Aachen, 2004, Als

Ms. gedr. Fortschritt-Berichte VDI Reihe 8, Meß-, Steuerungs- und Regelungstechnik, vol 1024. VDI-Verl., Düsseldorf

Jansen U, Schulz W (2015) An Interactive Approach for Fast and Frugal Decision Making in Innovative Research Cooperation. In: ICERI2015 Proceedings. IATED, pp 7957–7963

Jeners NU (2015) Unterstützung von Wissensarbeit durch Integration heterogener Kooperationswerkzeuge. https://publications.rwth-aachen.de/record/480771/files/480771.pdf. Accessed 13 November 2015

Jooß C (2014) Gestaltung von Kooperationsprozessen interdisziplinärer Forschungsnetzwerke, Zugl.: Aachen, Techn. Hochsch

Jooß C, Welter F, Leisten I, Richert A, Schaar A-K, Calero Valdez A, Nick E-M, Prahl U, Jansen U, Schulz W, Ziefle M, Jeschke S (2012) Scientific Cooperation Engineering in the Cluster of Excellence Integrative Production Technology for High-Wage Countries at RWTH Aachen University. In: Gómez Chova L, López Martínez A, Candel Torres I (eds) ICERI 2012: Conference Proceedings. International Association of Technology, Education and Development (IATED), Madrid, pp 3842–3846

Jungert M, Romfeld E, Sukopp T, Voigt U (2013) Interdisziplinarität: Theorie, Praxis, Probleme

Kaplan RS, Norton DP (1992) The balanced scorecard--measures that drive performance. Harv Bus Rev 70(1):71–79

Katz J, Martin BR (1997) What is research collaboration? Research Policy 26(1):1–18. doi: 10.1016/S0048-7333(96)00917-1

Kaufmann A, Tödtling F (2001) Science–industry interaction in the process of innovation: The importance of boundary-crossing between systems. Research Policy 30(5):791–804. doi: 10.1016/S0048-7333(00)00118-9

Kumar S (2015) Co-authorship networks: a review of the literature. Aslib Journal of Information Management 67(1):55–73

Landauer TK (2014) LSA as a Theory of Meaning. In: Landauer TK, McNamara DS, Dennis S, Kintsch W (eds) Handbook of Latent Semantic Analysis. Psychology Pr, pp 3–34

Lattuca LR (2002) Learning interdisciplinarity: Sociocultural perspectives on academic work. The journal of higher education 73(6):711–739

Leonardi PM (2014) Social Media, Knowledge Sharing, and Innovation: Toward a Theory of Communication Visibility. Information Systems Research 25(4):796–816

Leupold M (2010) Technologietransfer im Web 2.0: Wie das Wissen heute in die Welt kommen kann. Wissenschaftsmanagement 2010(1):20–25

Liebsch B (2011) Phänomen Organisationales Lernen: Kompendium der Theorien individuellen, sozialen und organisationalen Lernens sowie interorganisationalen Lernens in Netzwerken. Univ. , Diplomarbeit--Landau, 1. Aufl. Hampp, München

Lukosch H, Overschie M, Vries P de (2009) Microtraining as an Effective Way towards Sustainability. In: EDULEARN09: International conference on education and new learning technologies, Barcelona (Spain), 6th-8th Juliy, 2009. International Association of Technology, Education and Development (IATED), Valencia, pp 31–38

Lyall C, Bruce A, Tait J, Meagher L (2011) Interdisciplinary research journeys: Practical strategies for capturing creativity. Bloomsbury Publishing

Lyall C, Meagher LR (2012) A Masterclass in interdisciplinarity: Research into practice in training the next generation of interdisciplinary researchers. Futures 44(6):608–617. doi: 10.1016/j.futures.2012.03.011

Manning CD, Schütze H (2003) Foundations of statistical natural language processing. MIT Press, Cambridge, Mass.

Matthews T, Whittaker S, Badenes H, Smith BA, Muller M, Ehrlich K, Zhou MX, Lau T (2013) Community insights: helping community leaders enhance the value of enterprise online communities. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems:513–522

Mayring P (2013) Qualitative Content Analysis: Theoretical Foundation, Basic Procedures and Software Solution, Klagenfurt

Melin G (2000) Pragmatism and self-organization. Research Policy 29(1):31–40. doi: 10.1016/S0048-7333(99)00031-1

Millar MM (2013) Interdisciplinary research and the early career: The effect of interdisciplinary dissertation research on career placement and publication productivity of doctoral graduates in the sciences. Research Policy 42(5):1152–1164. doi: 10.1016/j.respol.2013.02.004

Müller SL, Thiele T, Jooß C, Richert A, Isenhardt I, Jeschke S (2015) Managing Interdisciplinary Research Clusters. In: IEEE International Conference on Industrial Engineering and Engineering Management, pp 606–610

National Academies U.S. (2005) Facilitating interdisciplinary research. National Academies, Washington D.C.

Nickerson J, Sakamoto Y (2010) Crowdsourcing Creativity: Combining Ideas in Networks. In: Workshop on Information in Networks

Nissani M (1997) Ten cheers for interdisciplinarity: The case for interdisciplinary knowledge and research. The social science journal 34(2):201–216

Oskam IF (2009) T-shaped engineers for interdisciplinary innovation: an attractive perspective for young people as well as a must for innovative organisations. In: 37th Annual Conference-Attracting students in Engineering, Rotterdam, The Netherlands, vol 14

Perianes-Rodr\'\iguez A, Olmeda-Gómez C, Moya-Anegón F (2010) Detecting, identifying and visualizing research groups in co-authorship networks. Scientometrics 82(2):307–319

Persson O, Glänzel W, Danell R (2004) Inflationary bibliometric values: The role of scientific collaboration and the need for relative indicators in evaluative studies. Scientometrics 60(3):421–432

Porter AL, Rafols I (2009) Is science becoming more interdisciplinary?: Measuring and mapping six research fields over time. Scientometrics 81(3):719–745. doi: 10.1007/s11192-008-2197-2

Pu P, Chen L, Hu R (2011) A user-centric evaluation framework for recommender systems. In: Proceedings of the fifth ACM conference on Recommender systems, pp 157–164

Raasch C, Lee V, Spaeth S, Herstatt C (2013) The rise and fall of interdisciplinary research: The case of open source innovation. Research Policy 42(5):1138–1151. doi: 10.1016/j.respol.2013.01.010

Raymond L, Bergeron F (2008a) Project management information systems: An emperical study of their impact on project managers and project success. International Journal of Project Management(26):213–220

Raymond L, Bergeron F (2008b) Project management information systems: An emperical study of their impact on project managers and project success. International Journal of Project Management(26):213–220

Redfield R, Linton R, Herskovits MJ (1936) Memorandum for the Study of Acculturation. American Anthropologist 38(1):149–152. doi: 10.1525/aa.1936.38.1.02a00330

Reichheld FF (2003) The one number you need to grow. Harv Bus Rev 81(12):46–55

Repko AF (2008) Interdisciplinary research: Process and theory. Sage

Repko AF, Szostak R, Buchberger MP (2013) Introduction to interdisciplinary studies. SAGE Publications

Ruby S, Thomas D, Hansson DH (2013) Agile Web Development with Rails 4. Pragmatic Bookshelf

Schuh G, Aghassi S (2013) Supporting Technology Transfer with Communities and Social Software Solutions. International Journal of Mechanical, Aerospace, Industrial and Mechatronics Engineering 7(11):1119–1127

Schuh G, Aghassi S, Schneider B, Bartels P (2014) Influencing Factors and Requirements for Designing Customized Technology Transfer Portals. IEEE International Conference on Management of Innovation and Technology (ICMIT):105–110

Schuh G, Bräkling A, Calero Valdez A, Schaar AK, Ziefle M (2016) Using Liferay as an Interdisciplinary Scientific Collaboration Portal A Compara-tive

Usability Study of version 6.1 and 6.2. 18th International Conference on Human-Computer Interaction (in press)
Schuh G, Bräkling A, Drescher T (2015) Configuration Model for Focused Crawlers in Technology Intelligence. Proceedings of 24th International Association for Management of Technology (IAMOT):832–839
Sundstrom E, de Meuse, Kenneth P., Futrell D (1990) Work teams: Applications and effectiveness. American Psychologist 45(2):120–133
Sydow J, Duschek S (2011) Management interorganisationaler Beziehungen: Netzwerke, Cluster, Allianzen. Edition Management. Kohlhammer, Stuttgart
Sydow J, Zeichhardt R (2009) Bedeutung von Netzwerkservices für den Erfolg von Netzwerken. In: Bundesministerium für Wirtschaft und Technologie (ed) Innovative Netzwerkservices: Netzwerk- und Clusterentwicklung durch maßgeschneiderte Dienstleistungen, Berlin, pp 21–29
Thiele T, Jooß C, Richert A, Jeschke S (2015) Terminology Based Visualization of Interfaces in Interdisciplinary Research Networks. In: Lindgaard G, Moore D (eds) The Proceedings of the 19th Triennial Congress of the International Ergonomics Association. Melbourne
Triandis H, Hall E, Ewen R (1965) Member heterogeneity and dyadic creativity. Human Relations 18:33–55
Triandis H, Kurowski L, Gelfand MJ (1994) Workplace Diversity. In: Triandis H, Dunnette, M., Hough, L. (eds) Handbook of industrial and organizational psychology, vol 4. Palo Alto, CA: Consulting Psychologists Press, pp 769–827
Tromp JW, Homan T (2015) How unplanned changes emerge while implementing a Project Management Information System (PMIS) in a complex multi project R&D environment
. Procedia – Social and Behavioral Sciences(194):211–220
Vaegs T, Calero Valdez A, Schaar A-K, Bräkling A, Aghassi S, Jansen U, Thiele T, Welter F, Jooß C, Richert A, Schulz W, Schuh G, Ziefle M, Jeschke S (2014) Enhancing Scientific Cooperation of an Interdisciplinary Cluster of Excellence via a Scientific Cooperation Portal. In: Guralnick D (ed) Proceedings of the Seventh International Conference on E-Learning in the Workplace, New York, NY, USA
Vaegs T, Welter F, Jooß C, Leisten I, Richert A, Jeschke S (2013a) Cluster Terminologies for Promoting Interdisciplinary Scientific Cooperation in Clusters of Excellence. In: Publications: INTED 2013, 7th International Technology, Education and Development Conference : Valencia (Spain), 4th - 6th of March, 2013 / […]. International Association of Technology Education and Development, Valencia, pp 5805–5812
Vaegs T, Zimmer I, Schröder S, Leisten I, Vossen R, Jeschke S (2013b) Fostering Interdisciplinary Integration in Engineering Management. In: Proceedings of

the IEEE International Conference on Industrial Engineering and Engineering Management: IEEM 2013
Vossen R (2012) Ein Verfahren zur Ermittlung und Bewertung des intellektuellen Kapitals von wissenschaftlichen Exzellenzclustern, Zugl.: Aachen, Techn. Hochsch
Welter F (2013) Regelung wissenschaftlicher Exzellenzcluster mittels scorecard-basierter Performancemessung, Zugl.: Aachen, Techn. Hochsch
Welter F, Jooß C, Richert A, Jeschke S, Brecher C (2012) Organisation and Management of Integrative Research. In: Brecher C (ed) Integrative production technology for high-wage countries. Springer, Berlin, pp 64–76
Welter F, Thiele T, Pfeiffer O, Richert A, Jeschke S (2010) Knowledge Management in Vocational Training: A Case Study of the EU Project Reload. International Journal of Advanced Corporate Learning (iJAC) 3(4):45–51
Welter F, Vossen R, Richert A, Isenhardt I (2011) Network Management for Clusters of Excellence - A Balanced-Scorecard Approach as a Performance Measurement Tool. In: Jeschke S, Isenhardt I, Henning K (eds) Automation, Communication and Cybernetics in Science and Engineering 2009/2010. Springer Berlin Heidelberg, Berlin, Heidelberg, pp 195–207
White HD, Mccain KW (1998) Visualizing a discipline: An author co-citation analysis of information science. In: Journal of the American Society for Information Science
Wiemer-Hastings P, Wiemer-Hastings K, Graesser A (2004) Latent semantic analysis. In: Proceedings of the 16th international joint conference on Artificial intelligence, pp 1–14
Wulf WA (2002) The Importance of Diversity in Engineering. In: Diversity in Engineering: Managing the Workforce of the Future. National Academy Press, Washington. D.C., pp 8–16
Yao Y, Zeng Y, Zhong N, Huang X (2007) Knowledge retrieval (kr). In: Web Intelligence, IEEE/WIC/ACM International Conference on, pp 729–735