Strategic Knowledge Management for Interdisciplinary Teams. Overcoming Barriers of Interdisciplinary Work via an Online Portal Approach.

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Abstract. Although widely applied, interdisciplinary collaboration and its success is still not fully understood. In this paper we investigate the benefits and barriers of interdisciplinary work in a research cluster and the option to support interdisciplinary work via an online portal approach. In two explorative studies we examined both the existence of benefits and barriers of interdisciplinary collaboration as well as the leverage of a social portal to support benefits and lower the barriers of such cooperations. Results identified problems of language and missing depth of research as the strongest barriers in a triangulation of qualitative (N=6) and quantitative results (N=45). In contrast we found intrinsic motivation and widening of one's own horizon as well as the combination of knowledge as key benefits of interdisciplinary collaboration. In the second interview study (N=5) we found that our social platform approach could address the barriers and leverage the benefits from the first study.

Keywords: Interdisciplinarity, Knowledge management, Collaboration support, Online portal, Web 2.0 technologies

1 Introduction

Since the 1980s interdisciplinary research is considered as a "mantra for change" [1]. Especially when research focuses on global challenges interdisciplinary cooperation is perceived to be an appropriate measure. At the flip-side of this approach still several challenges exist and the benefits are critically discussed. One central question in this context is how to support scientific cooperations successfully. Therefore the presented paper focuses on research regarding benefits and barriers of interdisciplinary work and the evaluation of a knowledge management tool "Scientific Cooperation Portal" (SCP) that was designed as a tailored measure to support interdisciplinary cooperation in large interdisciplinary research project in Germany[1].

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Due to the fact that successful interdisciplinary work is in most cases still a black box, the presented paper focuses on an empirical evaluation of benefits and barriers of interdisciplinary work and the derivation and evaluation of adequate measures to establish a target support for interdisciplinary innovation management.

In order to work out the character of interdisciplinary work section 1.1 presents a review of known benefits and barriers. Afterwards section 2 presents general information about the research cluster "Integrative Production Technology for High-Wage Countries" (IPTHWC) and its specific interdisciplinary situation as the field of application of the presented research (see section 2.1). In that section we also present the first part of empirical results in form of a qualitative and a quantitative evaluation of benefits and barriers of interdisciplinary work. Afterwards the concept of the SCP is portrayed (see section 3) as our measure for strategic knowledge management in interdisciplinary teams. In section 3.1 a second quantitative study in the context of knowledge management for interdisciplinary teams is presented. The presented study is focused on the impact of the online portal on perceived benefits and barriers of interdisciplinary work. Concluding this paper in section 4, the results of both studies are discussed and triangulated, while taking into account the lessons learned in the context of social media based knowledge management in interdisciplinary teams. Section 5 finally addresses limitations and gives an outlook on future research activities.

1.1 Benefits and Barriers of Interdisciplinary Cooperation

There is no widely accepted definition of interdisciplinarity, although the importance of a common definition should be taken seriously [2]. Different researchers focus different aspects of this phenomenon. Key definitional components in literature are the qualitatively different modes of interdisciplinary research and different forms of collaboration. Other definitions rather focus on the outcome of the collaboration or outline the existence of a continuum of collaboration [3].

In this paper we understand interdisciplinarity as a coordinated collaboration between researchers from at least two different disciplines, which can manifest itself in a simple exchange of ideas to the point of integration of methods, concepts and theories. The goal is primarily to solve problems and optimize research on certain topics by continuously conducting exchange [4]Since knowledge about interdisciplinary success criteria or working guidelines are as fuzzy as the definition itself, we first shortly present the status quo of known and named benefits and barriers in the context of interdisciplinary work from literature.

Benefits. Since the 1980s various (research) projects and cooperations were initiated under the label "interdisciplinary", based on the promise of being preferable. But which benefits of interdisciplinarity really exist or are aspired? Moti Nissani [5] stresses the *creative breakthroughs* of interdisciplinary work [6, 7]. Hübenthal [8] calls it *fertilization* when researchers break out of standardized questions and approaches and look beyond the borders of their discipline. They

widen their own horizon by getting insights into foreign disciplines and develop ideas they probably would have never had by staying in their field. Repko [6] criticizes that disciplinarity promotes a tunnel vision and blinds researchers from seeing the bigger context. Especially in times of *dead ends* a foreign discipline can help to expose mistakes or to balance weaknesses and borders of a single discipline [4]. Moreover, *interesting, exciting, and satisfying work* [7] can be a *personal benefit* and cause intrinsic motivation for the scientist.

Experts have come to the agreement that global challenges, e.g. climate change, demographic changes, etc., are far too complex to be studied by only one discipline. Although it seems that in literature the sole reliance on disciplinarity and profound technical knowledge are criticized, yet they are nevertheless considered the most important factors for successful interdisciplinary collaboration.

Summarizing we can say that it is especially the perceived innovation potential to overcome dead ends in science, which makes interdisciplinary cooperation so attractive. But besides this goal oriented view on benefits, there is another component of interdisciplinary work that is highly correlated to the success of such cooperation – the personal motivation of people involved in such cooperation. It is not until the intrinsic motivation and persuasion of involved researchers are known that such cooperation can be beneficial.

Barriers. Beside the aforementioned positive attributes of interdisciplinary work, there are obviously just as much critics as proponents. Negative associations of interdisciplinary cooperation are addressing different facets of the interdisciplinary working process, which are often a result of disciplinary differences. Differences become relevant in the way methods are used and also organizational barriers within universities or other institutions can interfere with the collaboration. Jacobs and Frickel [9] appoint the *missing reputation and acknowledgements* for researchers that work interdisciplinary as a meaningful factor. But almost the hardest part of interdisciplinary cooperation is in most cases *communication*Even if researchers try to agree on one definition or expression the disciplinary assumptions and epistemology standing behind the terms cannot be "carried over" easily along the definition [10]. To simplify communication and avoid misunderstandings researchers use simplifications, which can lead to *falsifications* [11]. Moreover there is the risk of staying on a *superficial* level during interdisciplinary work [4]. Another factor that is important in interdisciplinary cooperations is *time*. Interdisciplinary work is described as immensely time-consuming [12].Additionally several studies on interdisciplinary work have shown that *spatial distance* is a central aspect of successful cooperation, which contributes to the generation of knowledge. In this context Toker and Gray revealed that the innovation potential in research is often negatively influenced by the distance between involved researchers [13]. More barriers that can have a negative impact on interdisciplinary work are *coordination costs* and *effort* of the single researcher [14].

In the following section, we present an evaluation of benefits and barriers of interdisciplinary work within an exemplary research cluster. Derived from

identified benefits and barriers the need for a strategic knowledge management within interdisciplinary teams is depicted.

2 Benefits and Barriers of Interdisciplinary Work in a Research Cluster

Within the cluster IPTHWC we investigated benefits and barriers in two studies to define a starting point for target measures that should support the cluster members and serve as a baseline for the investigation of effectiveness of conceptualized measures. To ensure a deep insight into these aspects, both quantitative and qualitative methods were applied. At first qualitative semi-structured interviews were conducted with a total of $N = 6$ participants. All participants are currently working or have been working in the Cluster of Excellence IPTHWC at RWTH Aachen University. In a second step the results of the interviews were used to create a questionnaire to verify the findings quantitatively. $N = 45$ participants completed the questionnaire. In the following sections we first present the context, then the design and results of the qualitative study. Afterwards the design and results of the questionnaire study are presented.

2.1 The Interdisciplinary Research Cluster "Integrative Production Technology for High-Wage Countries"

The research cluster consists of more than 25 institutes of material and production technology at RWTH Aachen University in Germany. Since 2006 this project is funded by the Excellence Initiative of the German federal and state governments, integrated into the RWTH Aachen's concept of an integrated interdisciplinary university of technology. The main focus of the cluster is to assure the production in high-wage countries considering principles of sustainable production strategies and theories, as well as approaches for technologies that are needed to realize them. This challenge is worked on in four cluster domains that address different emphases (individualized production, virtual production systems, integrated technologies, self-optimizing production systems). The cluster domains are flanked by so-called "Cross Sectional Processes" (CSP), which were implemented to support the (interdisciplinary) work within the cluster. The topics *scientific cooperation engineering*, *production theory*, and *technology platforms* were conceptualized "cross-sectionally" and are supporting but also investigating the three aspects people, theory, and technology transfer. This paper is a product of the field of *scientific cooperation engineering* with a special focus on *interdisciplinary innovation management*, which aims to investigate and conceptualize measures that support the interdisciplinary cooperation.

2.2 A Qualitative View on Benefits and Barriers of Interdisciplinary Work

The semi-structured interviews (N=6) were conducted face-to-face. All participants were visited at their current workplace. We started with general warm-up

questions, e.g. what the interviewees have studied or how long they have been working in interdisciplinary projects. The following questions focused the experiences and general impressions of the participants concerning barriers and benefits of interdisciplinary work within their research project. The interviews took between 16 and 43 minutes. The interviews were analyzed in order to identify potential benefits and barriers of interdisciplinary work, using the qualitative content analysis method according to Mayring [15]

Results. In the following subsections the results for revealed benefits and barriers are presented.

Barriers. As Figure 1 shows, *language* and *missing depth* were identified as the central barriers of interdisciplinary work. The participants named problems and misunderstandings due to the use of different definitions or the use of different words (i.e. synonyms) to describe the same thing. Another aspect, mentioned in this context, was the experience that *discussions about the research object stay on the surface* due to the fact that no one can learn a completely foreign and remote discipline in a short time and communication is simplified.

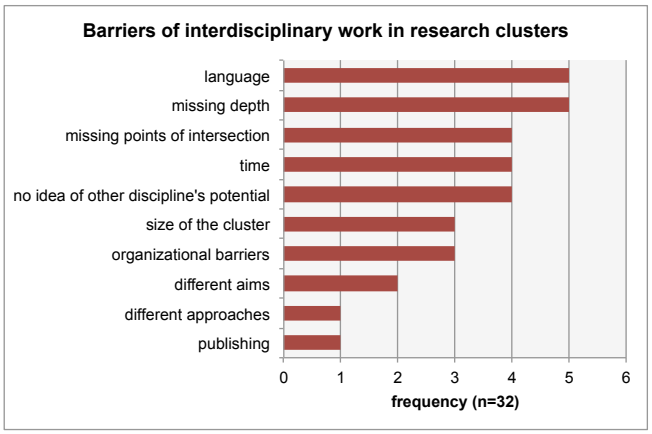

Fig. 1. Barriers of interdisciplinary work within the cluster integrative production technologies according to their number of mentions

Three aspects that were mentioned by four participants were *missing points of intersection*, *no idea of other discipline's potential* and *time*. The first two aspects are addressing challenges that arise directly from the character of interdisciplinary cooperation. *Time* as another factor can have different influences on interdisciplinarity: on one hand it can be an organizational aspect and on the other it can stand for the workload that arises with the time that is needed to get to know and understand other disciplines. On the third rank there were

mentioned further two barriers: *size of the project* and *organizational barriers*. Both complicate the collaboration between researchers of different disciplines. Organizational barriers can be e.g. a missing structure or even a oversized administrative organization. The size of the team can also have a negative influence on collaboration. As less important barriers *different aims in the research process*, *different approaches* and *publishing* in interdisciplinary teams were mentioned. These aspects are related the aforementioned barriers that addressed the different workflow and rules of disciplines, which can hinder a smooth cooperation.

Benefits. In contrast to the presented barriers this study also revealed benefits that come up in the context of interdisciplinary teams. The most important benefit in the context of interdisciplinary work in this study was *intrinsic motivation*. All participants reported that the spiking of their own interest in the interdisciplinary scope of the project is the most important benefit for them. In line with intrinsic motivation the benefit *widening of the own horizon* ranks No. 2 of the mentioned benefits. The three benefits that follow on rank 3 are: *combination of knowledge*, *innovation potential*, and the potential of *covering complexity of global challenges* (four mentions each). The benefits to work in a *knowledge network* and *new opportunities* that arise from interdisciplinary work were each named by three participants. The network of scientists from various disciplines allows the single researcher to find an expert for a specific task whom he can ask for help. The last benefit that could be identified was *getting to know better one's own discipline*. Through interdisciplinary work and the comparison with other disciplines researchers got an impression of advantages and disadvantages of their own disciplines.

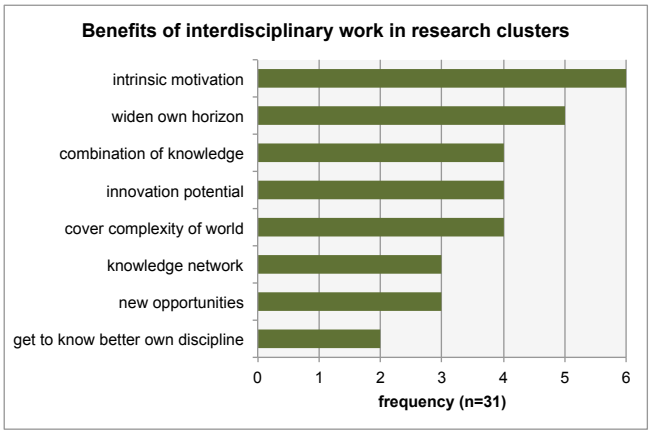

Fig. 2. Benefits of interdisciplinary work within the cluster integrative production technologies according to their number of mentions

To sum up this section we can state that interdisciplinary work within the research cluster reveals both benefits and barriers. The good news so far is that the personal motivation to work interdisciplinary is given and attractive for the involved persons. For the identified barriers we can say that main barriers all deal with challenges that address the organization and collaboration in the workflow. Due to the fact that we only interviewed a small number of representatives we additionally conducted a second study. A follow up study in a different context has been also performed and published [16]. Based on the first explorative findings a questionnaire was designed and distributed among the members of the cluster. Results are presented in the next section.

2.3 A Quantitative View on Benefits and Barriers of Interdisciplinary Work

Based on the results of the qualitative study we designed a questionnaire study. The questionnaire was paper-based and conducted during a meeting of the members of the research cluster. It was divided into three parts. Part one asked for personal data, part two asked for a evaluation of the identified benefits and barriers on a 4-point scale ("correct" to "incorrect"), and part three focused on the emergence of new barriers by introducing the portal. A total of 45 participants answered the questionnaire.

Results. In the following subsection the results for benefits and barriers are presented separately. Results were conducted using descriptive mean analysis.

Barriers. In the context of evaluated barriers, we found that the biggest barrier is the presence of *different approaches* ($M = 2.77$, $SD = 0.71$), based on different disciplinary cultures and backgrounds. The *lack of a unified language and terminology* ($M = 2.65$, $SD = 0.83$) was followed by the *size of the cluster* ($M = 2.65$, $SD = 0.91$). According to the participants, research group size can be a barrier for interdisciplinary work (in what aspect is not further investigated). *Time* resources that have to be applied for this kind of cooperation were also evaluated as an existing barrier ($M = 2.64$, $SD = 0.95$). *Organizational barriers* ($M = 2.11$, $SD = 0.85$) as well as problems in the *publishing* process in interdisciplinary teams ($M = 2.42$, $SD = 0.80$) are less strongly experienced as barriers.

Benefits. For the evaluated benefits we could reveal that *widening of the own horizon* ($M = 3.23$, $SD = 0.64$), *innovation potential* of interdisciplinary teams ($M = 3.11$, $SD = 0.69$) and the *combination of knowledge* ($M = 3.06$, $SD = 0.72$) were considered as the main benefits of interdisciplinary collaboration among the members of the excellence cluster. The other benefits were all confirmed with means ranging from $M = 2.81$ for *intrinsic motivation* to $M = 2.38$ for *new opportunities*.

Barriers	M	SD
different approaches	2.77	0.71
language	2.65	0.83
size of cluster	2.65	0.91
time	2.64	0.95
missing points of intersection	2.55	0.82
missing depth	2.54	0.63
no idea of other discipline's potential	2.54	0.76
different aims	2.47	0.86
publishing	2.42	0.80
organizational barriers	2.11	0.85

Table 1. Evaluation of barriers on a four-point Likert scale (1=incorrect to 4=correct).

2.4 Triangulation of Qualitative and Quantitative Findings and Derivations for Strategic Knowledge Management

Triangulating both studies a trend is visible: *Organizational barriers*, *different aims*, and *publishing* are of minor importance in the analyzed research cluster. Additionally we can say that the barriers are almost in line in both studies: *language* was rated as the biggest barrier in the qualitative study, while it is the second important barrier quantitative study. *Time* and the *missing points of intersection* are on the middle ranks in both studies. Striking is the barrier of *different approaches in the research process*, which is highly rated in the quantitative study ($M = 2.77$, $SD = 0.71$) but very low in the qualitative. Only one participant experienced it during interdisciplinary work. Concerning benefits there is clear agreement: the first four benefits are ranked similarly in both studies: *widening of the own horizon*,*innovation potential*, *combination of knowledge*, and *intrinsic motivation*. In the qualitative interviews intrinsic motivation was mentioned by all interviewees. It is not certain that especially in this case the interview situation has had some influence on the participants' statement.The *new possibilities* arising from interdisciplinary work and *getting to know better the own discipline* are the last two benefits in both cases.

Based on the findings of the presented study we can say that, for the case of research cluster IPTHWC, there are special needs and difficulties that should be supported by strategic (knowledge) management. Central aspects in this context are measures that address a better understanding of the involved disciplines. These address on one hand the need for enhancing the communication of disciplinary skills (methods, approaches etc.) and on the other one steered definition and discussion of/about central terminologies. Our findings support prior studies on interdisciplinary work within his research project [17]which also underline the necessity to manage interdisciplinary cooperation strategically. In the next section the SCP is portrayed, which is the product of a cooperation of the CSP within this cluster.

Benefits	M	SD
widen own horizon	3.23	0.64
innovation potential	3.11	0.69
combination of knowledge	3.06	0.72
intrinsic motivation	2.81	0.65
knowledge network	2.77	0.74
cover complexity of global challenges	2.74	0.75
get to know better own discipline	2.74	0.72
new opportunities	2.38	0.78

Table 2. Evaluation of benefits on a four-point Likert scale (1=incorrect to 4=correct).

3 Strategic Knowledge Management for Interdisciplinary Teams - The Scientific Cooperation Portal (SCP)

As presented in the section above, interdisciplinary cooperation reveals a need for measures that address strategic exchange of knowledge and knowledge management across disciplinary borders. In order to cope with the demands of integrating knowledge in interdisciplinary teams a social portal approach (SCP [16]) was designed, which should address different requirements i.e. knowledge management, communication, and target support for interdisciplinary topics (e.g. terminologies, publications, project and project management). The underlying software architecture is a social networking site with added collaboration tools specifically suited for interdisciplinary scientific research. The functionalities reach from employee profiles with specific competences to a virtual meeting-point, which allows scheduling of appointments, exchange of documents and storage of results. In addition to these basic functions target solutions are provided to support the interdisciplinary collaboration [18]. These are a project management tool, a tool for cluster specific terminologies [17], a technology-platform [19], and a publication visualization tool [20, 21, 16], which should foster the understanding of interconnectedness based on publication data.

3.1 Evaluation of the Scientific Cooperation Portal (SCP)

In order to find out whether the implementation of a online portal leads to a perceived improvement of interdisciplinary cooperation we initiated a first study with focus on the scientists opinion about the technical solution.

Methodology. The aim of this study was to evaluate the SCP with regard to the identified barriers and benefits. For this purpose we conducted an exploratory interview study with five members of the cluster of excellence. During the interviews they were shown the results of the results of the quantitative evaluation of benefits and barriers (see Table 1 and 2) and logged in into the SCP.

Afterwards they were asked for every single barrier (derived from the studies presented above) whether they think that the portal could reduce or compensate for the barriers ("yes", "rather yes", "rather no", "no", "not applicable"). Equally they were asked whether the portal could support the benefits and at the same time interdisciplinary collaboration. The last (open) question asked if the participants saw new problems or barriers arise traceable to the use of the portal.

Results. Results of the semi-structured interviews show that especially simple functions of the portal lead to an improvement of interdisciplinary work. Figure 3 illustrates the connection between specified benefits and barriers and the range of services within the SCP. Benefits and barriers are presented according to the level of confirmation from the highest level of confirmation to the lowest (see Table 1 and 2).

Impact of the Scientific Cooperation Portal on Barriers. According to the question whether the functions of the portal could reduce existing *barriers* we revealed that *organizational barriers* and *time* were evaluated as the two factors that benefit most from the SCP. Our participants stated that these barriers are tackled by the functions *upload and exchange of documents* and *calender*. In this context only one participant clearly denied this benefit. This person stated that he already had two calendars and does not need more. According to the exchange of documents (and chat-function) participants think these will save *time* and thus reduce time pressure in interdisciplinary cooperations. For the more specific barriers that arise specifically from the interdisciplinary exchange (*language* and *publishing*) the developed tools *cluster terminologies* and *visualization of publication relations* are evaluated as semi-helpful. The barriers *missing points of intersection* and *size of the cluster* are on the minor important ranks in the context of evaluating the fit and functionality of portal tools for interdisciplinary cooperation. In the interviews *missing points of intersection* were named in the context of function *presentation of projects and results*. *Size of the cluster* was interlinked with the function *yellow page /member list*.

Impact of the Scientific Cooperation Portal on benefits. In regard to the question whether a social portal could enhance benefits of interdisciplinary work we found that this is true for the benefit *knowledge network*. From the point of view of four participants the knowledge network of interdisciplinary cooperations is enhanced by the function *profile*. Additionally the benefits*new opportunities* are supported by the offering of workshops, which are no technical component, but an offer provided via the portal. *Cover complexity of the world* was interlinked with the function *publications*. One participant stated in this context that concerning the *publishing* process different requirements from institutes and universities play a more important role. At most the implemented visualization tool (cf. Schaar et al. [20] and Calero Valdez et al. [21]) can be a help in the publication process as it supports finding neighboring disciplines where e.g. certain methods are

applied and ease citation from neighboring publications. The benefit *intrinsic motivation* was named in the context of two functions of the portal *workshops* and *publications*. On minor important ranks we found *widen own horizon* and *innovation potential* both mentioned in the context of *cluster terminologies*.

Although we found a positive impact of functions of the portal, there are still limitations. At least three of five participants think that the portal cannot help to get an impression of the *other disciplines potential* at all.

New Challenges Emerging from the Scientific Cooperation Portal. At the end of the presented study on the evaluation of the SCP all participants were asked whether they *[...do you] see new problems or barriers emerging with the portal? If so, what kind of barriers?*. Answers were generally linked to the usability of the portal, e.g. the steep learning curve (investment of time to get to know the portal and its functions) and to find the information needed. Alternatively participants were concerned about the general acceptance of the portal. For a successful implementation, adoption and continuous use it is necessary that every member participates and administers precisely. One participant mentioned that the fact that the cluster-management strongly recommends to use the portal makes it unattractive and the use becomes involuntarily. Another participant fears the information overload, he wishes to have the possibility of filtering relevant information, documents or workshops that are only interesting for his sub-project and himself. At the end of this section we can summarize that the portal so far reveals both positive and negative aspects that must be improved and considered in the future to make the approach of a SCP a sustainable benefit for interdisciplinary teams. Open to-do's and future work are presented and discussed in the next sections.

4 Discussion

The presented paper shows that interdisciplinary research cooperations have both benefits and barriers. Main *benefits* were in our case study mostly seen in *personal benefits* (widen own horizon, intrinsic motivation) and *innovation potential* arising from the *combination of knowledge*. In contrast to that *barriers* were predominantly seen in the *differences between the disciplines* (different approaches, language). Additionally *size* and *time* for the interdisciplinary work were evaluated as central barriers. Based on the findings of the study on benefits and barriers we have conducted another study with focus on the impact of the SCP, an online portal approach, designed for an interdisciplinary research cluster in Germany on benefits and barriers of interdisciplinary work. Finding of this study let us say that the concept of a online portal as a measure for strategic knowledge management is on a good way. We could identify a first positive impact on *organizational barriers* and *time*. Additionally the approaches that were especially designed to tackle interdisciplinary communication – and thus support cooperation – the applications *cluster terminologies* and *visualization of publication relationships* were evaluated with a positive connotation.

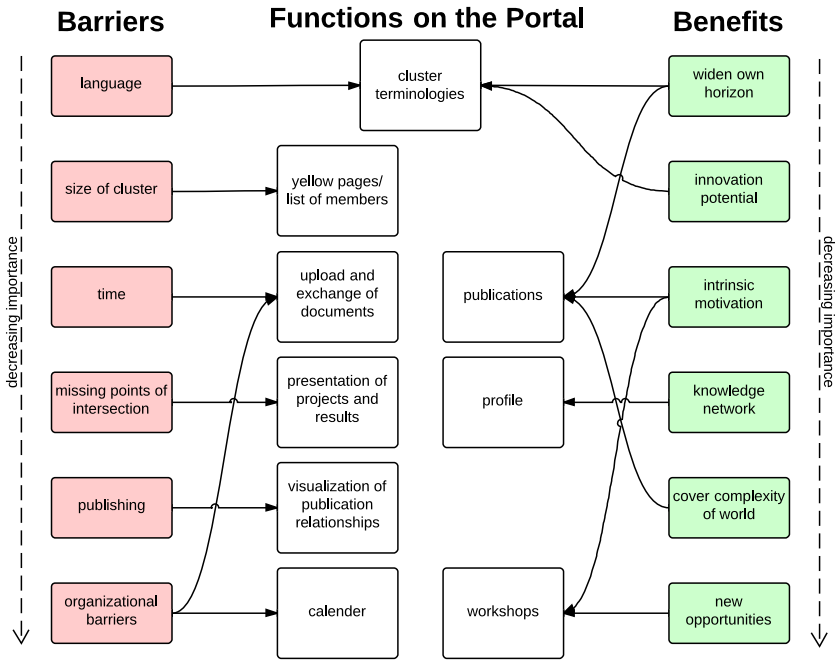

Fig. 3. Connections between possible barriers or benefits and functions of the SCP

But although the tone was positive, there is no doubt that there is still research to do, especially when recognizing that even new barriers arise in the context of a social portal. Open questions and to-do's basically address to big topics: *Usability issues* and *organizational implementation of the portal into the workflow*. It seems that the challenges that emerge through the portal can easily be tackled by technical measures. To face the usability issues it is necessary to evaluate the portal according to established usability testings to optimize the interface corresponding to user needs.

The most complex challenge from our point of view is user acceptance as a multifactorial construct. In this context aspects of motivation [22] and rewarding should be evaluated and considered to find out more about the individual aspects of usage. Only if the personal benefits become tangible it is possible to overcome the fact that the portal is not a "bottom-up" approach, as social media applications often are. It must be considered that the working context comes up with special needs that influence the usage [23] [24] and the personal willingness to disclose information [25].

5 Limitations and Outlook

As limitations of this research we have to name the explorative character. So far we do not have a full-sample or time-series data for the impact of the portal

on strategic knowledge management and on benefits and barriers of interdisciplinary work. Only time can show whether the tool will be a successful, but to support this aim the following steps will be considered in future work. To guarantee maximal acceptance and foster optimal usage conditions further steps should happen iteratively. This allows simultaneous evaluation and optimization. Other mechanisms considered for control of success of the SCP are key performance indicators. Those are: performance of the cluster in form of publications, which are supported by the portal (disciplinary and interdisciplinary), but also user statistics, and qualitative insights in form of perceived level of interdisciplinary integration in meetings. For the realization of this research model a mix of qualitative and quantitative methods (e.g. focus groups, interviews, questionnaires) but also technical components (usage statistics) will be used to get deeper insights into interdisciplinary knowledge sharing and appropriateness of the used (knowledge base) solutions.

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